Railway Driving Operations and Cognitive Ergonomics Issues in the Norwegian Railway: A Systems Analysis

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Abstract

In this study, an initial systems-based analysis was performed within the Norwegian railway. This approach to system safety attempts to provide information regarding the latent, system-related factors leading up to an unwanted event. The primary data includes two semi structured group interviews with safety officials, two individual semi structured interviews with safety officials, one cognitive interview (CI) with a certified train driver, and two ethnographic observations with in-cab interviews. In addition, a total of 542 reports of Signals Passed at Danger (SPAD) were read and analysed. Leaving a station, out on the route, and approaching the station were found to be critical to train driving operations, while switching was suggested as a fourth system critical situation. The results suggest that there are several weaknesses within the Norwegian railway system which are likely contribute to unwanted events.

Key Words

Railway human factors, human performance in complex systems, cognitive ergonomics, joint cognitive systems

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1.0 Introduction

Fatal crashes in the transport sector have a major impact on society, the domain at hand, and the involved stakeholders. The railway is not exempt from the ramifications of fatal accidents, but cognitive ergonomics/human factors[3] research in the rail domain has been somewhat in a state of dereliction. Currently, a renaissance of railway human factors is taking place. Governments call for zero tolerance policies, and while enterprises have managed to stabilize accident rates, there is still no evidence of a downward trend (Lawton, & Ward, 2005). Enterprises express the wish to decrease potentially dangerous incidents and accidents, but actually reducing rates appears to be challenging.

Modern risk analysis methods are based upon accident models that attempts to move away from human error as a central concept. As seen in CREAM (Cognitive Reliability and Error Analysis Methodology; Hollnagel, 1998) and a number of other human factors research publications, human error is regarded to as a misleading, insufficient and incorrect concept (see for example Dekker, 2002; Hollnagel, 1983; Lawton & Ward, 2005; Rasmussen, Nixon, & Warner, 1990; Rasmussen, 1990; Reason, 1990; Vicente, 2004; & Whittingham, 2004 for more detailed discussion of the concept human error). Within this line of research, human performance variation is viewed as a natural, unavoidable, and positive part of any work task which is difficult to predict. It is rather when these valuable adjustments to work go awry that things tend to go wrong.

The railroad industry qualifies to be categorized as a complex socio-technical system (Wilson & Norris, 2006; 2005). A system is considered a complex socio-technical system if rated highly on several of the following dimensions: large problem space, social, heterogeneous perspectives, distributed, dynamic, potentially high hazards, many coupled subsystems, automated, uncertain data, mediated action via computers, and disturbance management (Vicente, 1999). It may even be argued that the railway system is perhaps the most complex industry around (Shepard & Marshall, 2005). The railway industry stretches over a wide and ever changing geographical area and involves a wide range of engineering disciplines. In addition, customer satisfaction and safety concerns are necessarily taken into account. Different actors are located in different places, qualifying the system to be considered as

[3] The terms cognitive ergonomics and human factors are used interchangeably throughout this report and represent the more performance-oriented research tradition within ergonomics (Hollnagel, 1997).

“distributed” (Wilson, Cordiner, Nichols, Norton, Bristol, Clark & Roberts, 2001). To illustrate, the system has drivers out on route, traffic controllers in the control room, company administrations at respective headquarters, and education/training facilities.

A systems analysis based upon models for understanding human behaviour in complex socio-technical systems mentioned above considers the safety of any system as a result of dynamic interactions at various levels of the Man-Technology-Organisation (MTO) triad. System models of man-machine interaction view the persons and technical system as a *functional unit* which work together to sustain control (Hollnagel, 2002; Hollnagel & Woods, 2005). Control here is referred to as a product of the combination of Man and Machine and cannot be considered the product of only one of these in isolation. Control characterises the way in which one applies or uses competencies. To keep control refers to the ability the agent has to handle a dynamic process by reducing the effect of adverse conditions or situations which cannot be foreseen (Hollnagel 2002). Quite often the ability to have control is related to having sufficient time available to act to reduce adverse conditions or situations. It is important to mention that system models do not discern between man and machine, and the term “cognitive” in this context refers to ‘the ability to adapt to disruptions in the systems environment’ rather than relating to thinking per se (Hollnagel & Woods, 2005).

Previous systems-based analysis has been shown to provide insight into vulnerable parts of the rail system, resulting in concrete safety recommendations for the railway (Lawton & Ward, 2005). Instead of finding human error, the goal of a systems-analysis is rather to provide insight as to how the system or situation contribute to conditions leading up to an unwanted event and to give explanations for why barriers failed to improve system safety (Dekker, 2002; Lawton & Ward, 2005; Rasmussen, 1990). By understanding the latent system-related factors leading up to an incident or accident, researchers and practitioners can either improve existing, or design new, safety barriers in the system (Hollnagel, 2004). Latent system-related factors have previously been revealed when adapting the system-based analysis to interpret factors that contributed to incidents and accidents where human related causes, for example inattention, was previously found as a cause (Van der Flier & Schoonan, 1988; Smiley, 1990). There is, therefore, reason to believe that a systems analysis of the Norwegian railway can provide valuable information which can lead to improved system safety

To be able to obtain valuable information for total system safety, it is necessary to understand the work task (Shepard & Marshall, 2005; Woods & Cook, 2002) The way in which drivers use information while doing work tasks is of the essence for designing safe systems. A thorough understanding of the work task is important when considering all human factors related issues. For example, design of the in-cab interface, signal systems, and teaching aims and methods. In addition, task analysis can be referred to when considering issues of a more operational or managerial nature.

The Cognitive Work Analysis (CWA) framework is an approach to task analysis which demonstrates dimensions of the work task that need to be analysed if one wishes to design, implement or maintain the safety of a complex socio-technical system (Rasmussen, 1986; Rasmussen & Vicente, 1989; Rasmussen, Pejtersen, Goodstein.1994: Vicente 1999). What is most important in this context is to understand the behavior-shaping constraints, or performance shaping factors, of the environment *in the actual work setting* (Hollnagel, 1998).

2.0 Scope and Purpose

The main aim of this project is to provide an initial systems analysis of the Norwegian railway which is based upon modern cognitive ergonomics research. A variety of techniques will be used to assess the MTO relationship with respect to the train driving task in the Norwegian railway. In this initial investigation, the perspective of the driver will be emphasised.

It is important to mention that this project does not aim to present a complete (all-inclusive) systems analysis of the Norwegian rail domain. Rather, this investigation represents an initial attempt to look at the Norwegian railway from a systems perspective. This report will have relevance for both practitioners and researchers. Although this is a research-based article, it is important to keep in mind that the practitioner-researcher distinction is potentially harmful when considering system safety (Hollnagel, 1998). Researchers need to use the knowledge of the task and how the system works in practice to be able to develop relevant models for behavior and methodologies. At the same time, practitioners need relevant methods based upon psychological theory to be able to work with safety issues in the best possible way (Hollnagel, 1998; Woods & Cook, 2002).

This study will 1) provide an understanding of the important system critical situations drivers are faced with, and 2) pinpoint some weaknesses observed in the Norwegian rail system. This initial study should provide a solid basis for the evaluation of effective resource allocation in the future.

The first section of this paper will attempt to find system critical driving situations in the Norwegian train driving task. How drivers use information will be discussed. Previously, CWA in the Swedish rail industry resulted in dividing the train driving task into three system critical driving situations. (Jansson, Olsson & Erlandsson, 2006) These are *leaving a station*, *out on the route* and *approaching a station*.

The second section of, this paper will discuss several rail human factors issues in light of the train driving task. The aim is not a complete evaluation of all human factors issues at all levels of organisation in the Norwegian railway, but rather an evaluation with the aim of pinpointing weaknesses in the system which may be ripe for improvement or further investigation. Some weaknesses that are pinpointed in this evaluation will need to be studied further before safe solutions can be secured, while others may be strengthened with rather simple, cheap solutions.

3.0 Methods

In this study, qualitative methods[4] were used. More specifically, interviews, ethnographic observations with video material, critical incident report analysis, and analysis of secondary documents were used (Woods & Cook, 2002) and CWA (Vicente, K., 1999). This data was seen in the light of relevant human factors research and from the perspective of the train driver.

The primary data includes two semi structured group interviews with safety officials from Norwegian State Railway, two individual semi structured interviews with safety officials from Norwegian State Railway, one cognitive interview (CI) with a certified train Norwegian State Railway train driver, and two ethnographic observations with in-cab interviews with Norwegian State Railway personnel. This data was gathered within the time frame September 2005 to September 2006. Several safety officials are also certified train drivers. There exists

[4] Defined as: "a systematic inquiry which must occur in a natural setting, rather than an artificial constructed one such as an experiment" (Marshall and Rossman, 1995 in Andersen, 1997, p.12)

DVD- material of the ethnographic observations with in-cab interviews, and a sound track of the CI. In the first ethnographic observation, a handheld camera was used to record the in-cab environment, Man-Machine-Interaction, and in-cab interviews. In the first ethnographic observation the hand-held camera was also used to observe the outside environment, while in the second ethnographic observation a second stationary camera was used to record the outside environment.

Norwegian State Railway incident reports on Signal Passed at Danger (SPAD) events from 2003, 2004, and January-(May) of 2005 were read and analysed. There were 251 incidents from 2003, 192 incidents from 2004, and 99 events from 2005 making a total of 542 analysed incidents. In addition, secondary data sources were used (such as official laws and regulations, various reports from the Norwegian Accident Investigation Board, Norwegian Railway Inspectorate, Norwegian Railway Authorities, American Federal Railway Association (FRA) and other relevant sources).

Collected information will be used for the most part indirectly to ensure the informants anonymity. The collected data thus provides a background or basis with which to have a research-based discussion about railway system-safety issues.

4.0 Results

4.1 Cognitive Work Analysis: Train Driving on Local Routes

Table 1 lists examples of the three system critical driving situations' observable and non-observable actions. The results of the current CWA in the Norwegian railway are in partial accordance with these findings. The three situations and their respective observable and non-observable actions were also found in the Norwegian rail domain.

Table 1. Observable and Non-observable actions in Train Driving System Critical Situations. (Adapted from Jansson et al., 2006, p.44)

Actions	Leaving a station	Out on the route	Approaching a station
Observable Actions	Controlling the platform and the doors to be shut through the mirror	Weighing speed against comfort depending on late or on time	Watching for signals expected to show that the switches are clear
	Supervising, detecting and controlling signals and signs	Supervising, detecting and controlling signals and signs	Supervising, detecting and controlling signals and signs
	Listening to and watching for messages from the ATC system	Listening to and watching for messages from the ATC System	Listening to and watching for messages from the ATC System
	Watching for people and unexpected objects	Watching for people and unexpected objects	Watching for people and unexpected objects
Non-observable actions	Judging time available and preparing for next section	Judging speed ahead in order to avoid warnings or braking	Calculating braking power and braking distance needed
	Calculating power needed to leave station	Judging time in order to manage to be on time	Preparing the entering of the Station

In addition to the three system-critical situations found earlier, this study also suggests that "Switching" should be included as a system critical driving situation. Switching appears to be a driving situation which is unlike the three driving situations previously described. The ethnographic observations that were made in this study were observations of trains that had a route, and which weren't classified as a switch. The basis for classifying switching as a separate system-critical situation has therefore been based on interviews, secondary documents, and various incident and accident reports which refer to switching. Interviews with safety officials and train drivers support classifying shifting as an independent driving situation which calls for unique use of information and specific actions. Switching is referred to as being a task separate from train driving. However, train drivers are required to master switching which is referred to as being especially dangerous and demanding (Borgersen, 2001). Switching will be discussed in more detail later in this report.

4.1.1 Leaving a station

When leaving the station, the findings are that the driver is mainly focused on leaving the station as quickly and safely as possible. When the drivers are preparing for leaving, and when they start to leave the station there is a high level of focus and attention. It is important that the conductor has given the 'safe to leave' signal and that the doors are secured. Drivers make themselves aware of how much time is needed to get the passengers aboard safely, and attempt to leave the station as quickly as possible. Keeping the time table is important for the overall flow of the system as well as for the passengers, and drivers attempt to calculate how much power is needed to get the train to accelerate quickly and smoothly. On local routes, the time out on the route where there are opportunities for optimising speed are quite limited. Hence leaving and arriving at stations on time is of the essence and drivers are aware of this when considering safety/efficiency. Drivers are especially aware of passengers that arrive late, as they pose an extra danger as they approach the train. In addition, late passengers may delay the train's departure.

4.1.2 Out on the route

While on the route, drivers are in a more relaxed cognitive state. Drivers are concerned with keeping the time tables and calculate the speed needed to reach the next station on time. Drivers are aware of the speed limits and wish to keep these as to avoid automatic braking by the Automatic Train Control (ATC)[5] system. Drivers experience driving out on the route often as "driving on green." In other words, it is expected that they will most likely be able to drive without interruption to the next station. They are, however, aware that they may occasionally encounter signals that require them to either reduce speed or stop. Drivers take the specifications of the specific train and its load into account to calculate the distance it would take to stop with the specific train set when approaching signals. Brake tests are also often carried out once while out on a route. Usually, this is performed early in the route.

4.1.3 Approaching a station

When nearing a station, drivers shift to a more focused, attentive state. They are looking out of the cab window for signals telling them whether or not it is safe to continue into the station area. Drivers prepare themselves for a potential stop. They calculate speed in relationship the

[5] Automatic Train Cotnrol (ATC) is "the system for automatically controlling train movements and directing train operations" (Railway Technical Web Pages, 2007). The Norwegian infrastructure has some track sections with complete ATC, some track sections with partial ATC, and some sections without ATC coverage.

braking capacity of the train set and calculate the effects that weather conditions, local track conditions, and distance to the signals may have on the ability to stop. At certain local stations, there are many lines and many signals that are in the line of view. Drivers are concerned with locating and reading the signals that apply for their specific line, and ignoring irrelevant signals and signs. In addition, drivers are concerned with approaching the station and making a smooth stop and making themselves aware of the conditions of the platform and what is happening on the platform. Also, drivers estimate the best stop position along the platform in relationship to where passengers are standing/usually stood.

4.1.4 Switching

Switching is the task which may perhaps be the most complex and demanding for drivers. Switching has traditionally been associated with danger and calls for careful attention (Borgersen, 2001). In Norway, switching may be defined as "movements of rolling material with the intention of moving material within a station or a side-track area" which occurs without specific orders (Borgersen, 2001). Switching is therefore not classified as a "train." Train, on the other hand, is defined as "rolling material which is driven out on the line" and which always is carried out with a specific order. A train may be driven with or without a route. Often, the task of switching has been handled separately from train driving due to the technical differences related to their definitions. In other words, "switching" is not "train – driving," but is a locomotive driver task. However, when considering the tasks a train driver is required to carry out, this is certainly one of them. Drivers use the locomotive to move rolling material, and from a user perspective be considered "driving." Perhaps the term "Driver Operator Tasks" would be better suiting in the literature. The term "Driver Operating Tasks" would thus include the tasks drivers are required to operate in the rail domain. Train-driving and switching would be covered under the term Driver Operating Tasks.

When drivers are 'a switch' there are many conditions to be considered. The task is often dependant upon the specific context. While switching, it is especially important to be aware of the state of the switching-signals. More specifically, the dwarf signals. These are the signals that apply specifically to a switch on the Norwegian Railway. These signals show whether switching is permitted, denied, or permitted with caution. Drivers often use hand-brakes in this task and the airbrakes are disabled. The demands and actions of the driver are often dependant upon the kind of switching-task which is to be performed, and the context with which it occurs. In general drivers are in a high state of attention and awareness. Drivers need to be especially aware of how braking affects the material – something which requires special calculations with regard to the specific material which is to be moved. If drivers are to hook up to new material they need to be aware of the speed in relationship to safe and smooth contact with the new material and be aware of persons in the immediate physical vicinity.

In some instances, it may be that a train which is en-route may act as a switch. With that it is meant that in certain situations a train may have to comply with the dwarf signals which normally apply for a switch. So, although technically defined as a train, the rolling material in actuality acts as a switch. For example, if a dwarf signal belonging to the driver's track shows "cautious switching allowed," in practice it means there is an upcoming dwarf signal that shows "switching not allowed." If a train meets a "switching not allowed signal" they are required in most cases to stop (even though it's a *switching* signal). In effect, the signal shows the train driver that entry to the station is not granted at the moment. Drivers must be aware of the meaning of the different dwarf signals theoretically and at the same time evaluate which driver in practice the "cautious shifting allowed" signal actually refers to.

4.1.5 Conclusions

In this study, four system-critical situations were found. Switching was suggested as unique driving situation which is quite complex and demanding. In future studies, a more detailed task analysis of switching as a work task for drivers (including ethnographic observations) should be considered. It is suggested that special attention should be made to how dwarf signals function in theory (for a shift) and how they function in practice (relevance for a switch *and* trains en route).

Local train driving was found to be characterised by more or less systematic variation of concentration and attention intensity. High demand situations (approaching a station, leaving a station and switching) are broken up by less demanding periods (out on route). Local train routes, especially inner city routes, have relatively short routes with many stops. The cognitive demand thus changes quite often, and quite dramatically, throughout the route. In the future, the effects of high-demand and low-demand situations in local, inner-city, rural, and inter-city routes should be looked at. It appears that the train driving task would be somewhat, if not fundamentally, different for various kinds of routes, due to the difference in time intervals between high- and low-demand situations. For example, inter-city routes have a much longer *out on route* period. This could, perhaps, have important implications for the Driver Operating Task in itself and also the support system required for each type of task.

Jansson, et al., concludes that "drivers' work can be divided into three rather different time intervals: a long-range interval with an interaction between the train and a rather distant environment; a short-term interval, with an interaction between the train cab and the visible surroundings; and finally, an immediate sense interval with an interaction mainly in terms of braking and feed-back from the stopping train." (2006, p.45). Our findings are in accordance with this. However, it is important to note that in actual driving situations, the interaction described within the different time intervals appears to occur more or less simultaneously. On the one hand, drivers are aware of the immediate sense interval ("feel" the train sets reaction to braking or slowing down) while at the same time considering the visible surroundings (looking for moose trackside) while at the same time attempting to plan for the future (thinking about where to await upcoming signals). So, while it may be helpful to consider the different time intervals as separate in some situations, it is important to keep in mind that in actual driving situations the driver is simultaneously interacting with the system at the other time intervals.

4.2 Safety Evaluations

The following section is an attempt to evaluate human factors issues relevant to the train driving task with the aim of finding some areas which may be improved in the future. In modern human factors research it has been important to monitor and evaluate safety issues continuously. It is worth mentioning that modern rules and regulations call for continuous auditing and evaluation of system safety control. These regulations have been put into effect January 1, 2007 (FOR 2006-12-06 nr 1356). In addition, a new law for work environment was put into effect during the course of this project (January 1, 2006) which has ramifications for diverse railway safety procedures (LOV 2005-06-17)

The second part of this paper is organised more or less by order of importance with continual discussion. The human factors-related aspects which are to be presented and discussed are: Infrastructure; Incident and Accident Reporting and Follow-up; In-Cab Man-Machine-Interaction (MMI); Situational Awareness; and Training and Experience.

4.2.1 Infrastructure

The Norwegian environment offers a number of challenges for the rail system. This is especially prevalent when the immediate track environment is considered. In Norway there are dense forests, high and steep mountains and fjords, a large number of lakes, and moist areas. In addition, weather conditions such as heavy snow, strong winds and heavy rainfall create challenges for the infrastructure and train driving task. The Norwegian environmental and weather-related conditions are demanding for those who are responsible for designing the infrastructure, those who keep the infrastructure maintained, and those who are users. Many routes have foliage and curves which create a 'tunnel-like' driving experience. Track crossings occur in a variety of settings and are handled in a number of different ways. All of these things contribute to making the driver's ability to plan ahead difficult and highly dependant on experience.

It is well-known in the research literature that aspects related to infrastructure have important implications for the train driving task. Safe train driving presupposes a safe, well-functioning, and supportive infrastructure. The infrastructure is a major contributor to the behaviour shaping constraints related to train driving. If the conditions of the track make it nearly impossible to brake, for example due to ice on the track, the driver will have to take that into consideration when assessing how to approach his or her task. To be able to take track conditions into consideration, a driver must be able to have access to information regarding the tracks condition in any given location.

4.2.1.1 Driver-Infrastructure Interaction

A driver can only stop at required points along the track if the signal system is functioning, relays information in a way in which drivers can understand, and relays important information timely. This has been made clear in recent accidents where trains have collided with rock slides and snow avalanches (Accident Investigation Board Norway), and also in SPAD incidents (Norwegian State Railway). If drivers are unable to detect slides which have occurred on the track ahead quickly (perhaps simultaneously as they occur), accidents will be unavoidable.

There are several concerning aspects of the Norwegian infrastructure from a human factors point of view. The current investigations revealed great variation in the carrying out of train driving procedures – something that was quite often the result of local infrastructure conditions. This is concerning, as the more context dependant the situation, the more dependant safety is on individual actors and single actions. A situation which is highly context-dependant will result in a greater degree of performance variation, which often is difficult to predict. In highly context-dependent situations, agents will have a rather low degree of control (Hollnagel, 1998). Their actions will be more dependent upon “here and now” decisions and the total system safety will be more reliant upon individual’s ability to make appropriate decisions/actions. If one considers the time intervals drivers interact with the system mentioned earlier (immediate, short term, and long-range), the ability to work long-range will be considerably more difficult when the system is highly context dependant.

4.2.1.2 Placement and condition of signals and signs

Signals and signs were often placed in areas which were either hard to see (for example around a bend) or in positions which are exceptions to the rule. Regulations call for placement of signals *as a rule* to be in areas to the right of, or above, the relevant line (FOR 2001-4-12 nr. 1336) . There are instructions referring to how the placement of signals should be handled in special cases. However, there are a vast number of cases where signals are placed in positions which are exceptions to the rule.

In addition, the conditions of signals and signs were often such that they were experienced as difficult or impossible to read. Some signals were dirty or snow covered, while others were dysfunctional or out of order.

Some of the infrastructural conditions which are less than optimal remain so over time, and some are daily (if not hourly) exceptions. Variation in the long-term placement and condition of signals create a situation which demands a high degree of local knowledge for users (drivers). In addition, there are frequently daily announcements and notifications regarding the placement and condition of the infrastructure in any given route which drivers must be familiar with before starting his/her shift. Due to variations in the infrastructure (such as dysfunctional signals, work on platform, and the state of ATC) it is quite often necessary for drivers to make minor or major exceptions to the rules when carrying out procedures. Performance is thus highly dependant upon the ability individual drivers have to integrate new information into their actions while out driving.

Our investigations suggest that there may be problems tied to the frequency and numbers of announcements and notifications drivers are presented with, and also to the time available to become acquainted with and integrate the information in these. To our knowledge, there have been no studies regarding this in Norway. It is therefore uncertain as to how much time is actually necessary to read, be acquainted with, and integrate new information presented in announcements and notifications. Likely, the time needed varies greatly according to the number and type of changes that are being announced, and according to the language used in the documents. In addition, the amount of time needed to integrate new information will likely vary from individual to individual.

4.2.1.3 Light signal system

Several aspects of the light signal system were concerning from a user point of view. Light signals were found to have different purposes and relevance according to the specific location and context. More specifically, the Norwegian "dwarf" signals were found to be especially context dependant.

In addition, it is not unproblematic from a user point of view that signs and signals are physically placed at different trackside locations. Although the placement of signs and signals follow a general pattern determined by regulations, it appears that there are a concerning number of exceptions to the rule. Most signals are placed on the right side of the track, but sometimes signals are found on the left side and also above the track. It may be that drivers' reaction times may vary according to whether signals are shown at different trackside locations.

General concerns with being able to see relevant signs and signals were voiced in interviews. "Dwarf" signals were often voiced as being difficult to read. Drivers have claimed to experience signal failure or malfunction as a large stressor. Drivers also have expressed that they at times experience inconsistencies and incoherence in the infrastructure as a stressor. Changes and deviations from the general rule in the infrastructure put a greater demand on the operator (the train driver) and are experienced by drivers as a stressor.

4.2.1.4 Conclusions

Infrastructure shapes the working constraints of train drivers. The more complex and unpredictable the infrastructure, the less control the user (driver) will have (Hollnagel, 1998).

Complexity and unpredictability contribute to creating a less stable control situation. Actors' (here drivers) ability to plan ahead and act rationally are reduced, and more dependant upon the immediate conditions and situations which are experienced. Something regarded to as context dependency.

To conclude, there were several aspects regarding the Norwegian rail infrastructure which were concerning, and which represent weaknesses in the rail system as a whole. In particular, a high degree of context dependency was found. While context independent signing is independent of the operator, context dependant signing is operator dependant (Flach, 1995). Context dependant signs and signals increase the amount cognitive work needed to complete the task safely and smoothly, demands route experience from drivers, and restricts optimal situational awareness (SA). Context independent signs, signals, and other aspects of the infrastructure should be emphasised and developed in the future.

4.2.2 Incident and Accident Reporting and Follow-up

Often, investigations of accidents or potentially dangerous incidents are used to uncover weaknesses in complex socio-technical systems, and is something required by law. Studying incidents of a potentially dangerous character is an economical methodology that can enlighten researchers and practitioners as to the vulnerable parts of the train system (Kirwan & Ainsworth, 1992). The nuclear and aero industries have long experience with reporting and analysis of incidents and accidents with positive results. Fruitful analysis is dependant upon a high quality reporting system. Reports of near-misses and incidents of lesser degrees of severity can often be used to guide safety prevention work. Such cases are usually closer to normal work-task activities and in that respect should they should be paid attention. Incidents and accident types (rather than specific cases or episodes) indicate weaknesses in the socio-technical system and can thus pinpoint which areas need to be focused upon (Rasmussen, et al, 1990). However, to be able to learn from reporting, it is necessary that investigation has a stop rule which goes beyond the "human error" and which aims to find the latent causes leading up to the unwanted event (Rasmussen, 1990). To maintain or improve system safety, the aim of reporting and report analysis should be to identify and understand missing and/or insufficient barriers rather than finding human error (Hollnagel 2004; 2005c; 2005d; Rasmussen, 1990).

4.2.2.1 Reporting

Procedures related to the reporting of SPAD incidents in Norwegian State Railway were examined and were found to vary. The reporting quality and practice was seen to be somewhat dependant upon the person doing the investigation, with no established practice of anonymous reporting internally within the company. Drivers are required, however, to report sub-optimal conditions and unwanted events. It is the drivers' closest leader who has the main responsibility to evaluate the incident, decide how it should be reported. A guide (checklist) for report writing has been developed in the past, but this checklist is in actuality used very seldom (if at all). The enterprise logs reported incidents and accidents by help of SYNERGI-brand risk management software, but lack formal guidelines for report writing and useful tools with which to analyse this data from a systems perspective.

Recently, the Norwegian State Railway has established that a SPAD event is one of the most potentially hazardous situations in the Norwegian railway system. This type of event has been evaluated as occurring at an uncomfortably high rate, and is regarded as an unwanted incident. The reporting of serious incidents and accidents is controlled by governmental laws and regulations, whilst the reporting practices and investigation of less serious incidents or potential incidents/near-misses are left up to the enterprises themselves.

To date, there is little international research using the systemic approach, and even less national research, concerning the reporting practices and analysis methods used by safety managers to understand SPAD events. There have, however, been several international publications regarding human factors and reporting systems in general, as well as understanding violations and safety cultures in the rail domain (see Wilson, & Norris, 2006; Wilson, Norris, Clark & Mills, 2005; Wilson, J. & Norris, B., 2005; and Kecklund, 2001)

CREAM is a standardised tool which can be used to guide report writing and analysis. It may be applied both retrospectively, using existing incident/accident reports, and prospectively as a form for second generation human reliability assessment (HRA) (Hollnagel, 1998). It is designed to be used in analysis of complex social-technical systems, making it a potential methodology to be used in the rail domain (Hollnagel, 1983; Hollnagel, 2005a). CREAM is perhaps the latest complete analysis methodology which acknowledges the important role the context plays in human performance variability. In CREAM, contextual information is important when considering the specific actions of individual operators in specific incidents.

Since it is important to consider reporting together with report analysis methodology to ensure compatibility and usability, Norwegian State Railway SPAD reports were seen in light of CREAM, and the domain specific DREAM (Driver Reliability and Error analysis method) (Hollnagel, 1998; Ljung, Furberg & Hollnagel, 2004)

SPAD reports have been found to lack important information needed for a modern human factors system analysis. Table 2 presents the human factors-related issues that were often left blank in Synergi reports, while Table 3 presents human factors issues that are important to consider in modern accident investigation methodologies that were not addressed in Synergi.

Table 2. Human Factors information left blank in Norwegian State Railway Synergi Reports

Who	External client involved Comments, suggested cause, suggested initiatives Shift Weekday Experience in position (moths)
Classification	Guiding documentation - rules Involved Equipment/system Equipment/System description Involved Infrastructure Internal Time
Initiative	Another initiative responsible person E-mail - another initiative responsible person

Table 3. Human Factors Issues not addressed in Norwegian State Railway Synergi reports.

Organisational Factors	The quality of the roles and responsibilities of team members Additional Support Communication Systems Safety Management System Instructions and guidelines for externally oriented activities Role of External agencies, etc. Quality of driver- train traffic manager communications Crew collaboration
Working Conditions	Ambient lighting Glare on screens Noise from alarms Interruptions from the task Quality of interaction with in cab interface Weather conditions as experienced by driver

Training and Experience	Familiarity with particular train set Experience with task Experience with route (months) General experience as driver (months) Experience with new technology Age of driver Driver's involvement with previous incidents

SPAD reports were often found to refer to specific problems with the infrastructure as causes. Reports which find infrastructural problems are often constructively sent to those persons who are responsible for infrastructure. Often, problems were related to signal malfunction and tied to certain “problem locations.”

Person-related causes (lack of attention, lack of following procedure) were also found quite often, a cause which is more difficult to work with constructively. As a rule, it is more constructive to dig deeper to understand the latent causes. What happened before the driver “missed” a stop signal? Was the individual exhausted due to lack of sleep? Did the driver loose out on sleep because of the psycho-social environment at work? Were there a great number of signal malfunctions or trackside work going on? Was the air conditioner making so much noise that it led to fatigue? Also, is it the case that “lack of following procedures” is used as a ‘cause’ in situations where normal work adaptation goes wrong (thus being unacceptable) while adjustments to procedures in other situations is regular practice (and accepted or even encouraged)?

The behaviour of users in unfamiliar or unexpected events is often conditioned in everyday, normal work (Rasmussen et al., 1990). As mentioned earlier, the normal train driving task in Norway is characterised by a high degree of context dependency and often reliant upon drivers’ ability to cope with variation. Often, exceptions to the rules are necessary to keep the system up and running. Future research may indicate whether it could be that the referrals to “lack of attention” or “lack of following procedures” in incident reports indicate an area of problematic interaction between driver and infrastructure.

4.2.2.2 .Follow-up

The following up of incidents, like reporting practice and quality, seems to vary. Some incidents are followed up by a talk/interview with the involved driver; some are followed up with in-cab coaching/evaluation, while others are followed up by time in the train simulator.

While certainly many of the decisions related to follow-up of drivers are sufficient and of a good quality, this investigation has uncovered incidents where the treatment of drivers is quite alarming.

To illustrate, an example will be presented. One driver, who had been involved in several concerning incidents involving person-related factors, had received orders to go through a special training course and simulator training. There were a number of aspects related to how this individual was treated that are concerning. The situation involving simulator training was perhaps the most alarming. The individual describes the situation as being a "test" where he was evaluated by several of his superiors simultaneously. He describes the experience as "traumatising" and says that he was "scared and nervous." He reports that the simulation he was made to drive included an abnormal number of critical situations which required special attention. The driving situation which was simulated would most likely never occur in actual train driving, and the individual reports going into a kind of "stand-still" or "mind blackout" due to the stress and abnormality of the whole situation. Physical symptoms of stress related to the autonomic nervous system such as sweating and heart racing were reported. After the simulated driving was finished, the individual was called into an interview with the results of his simulated driving as the main topic of discussion. There, all of his superiors had the opportunity to both ask questions and comment on his simulated driving task. The individual felt like the interview was an "interrogation", and that it was unfair. He reports feeling this due to the abnormality of the scene he was asked to simulate driving, and the stressed state of mind he was physically and mentally in at the time of the simulated driving due to the character of the situation. This particular individual appeared to be aware of his general special need to have "actual driving experience" to understand how to drive appropriately in certain situations – something his driving teacher also had mentioned already during his initial training to be a train driver. His training coach (the driver who had responsibility to accompany him while still being trained to be a train driver) quit being a coach. This has been reported as being due to the fact that issues the training coach pointed out to safety officials (about this individual and other individuals) repeatedly were either ignored or not taken seriously.

Although this is a description of one individual, it indicates the need for a deeper understanding or investigation of the techniques used to follow up drivers involved in unwanted incidents. It is undoubtedly the enterprises' responsibility to find those persons which are incapable of being train drivers. It may or may not be the case that the individual mentioned above did not have the abilities needed to be a train driver. It is not our intention to evaluate that decision. However, the process of evaluation and follow-up should not be carried out in a manor which is detrimental to individuals' physical or mental health/well-being – which appears to be the case in the example described above.

4.2.2.3 Conclusions

The analysis of SPAD incident reports and systems-analysis revealed several weaknesses involved with the reporting practice, report quality, and follow-up routines.

There should be clear instructions as to when and how reporting should be done, and the stop-rule should reflect the wish to get at latent causes in addition to direct causes. Inattention/lack of concentration and lack of following procedures should not be regarded as sufficient latent causes. We suggest a stop-rule which attempts to find factors contributing to inattention and lack of following procedures. In addition, a system which allows for and encourages anonymous reporting of near-accidents and problematic system-interaction concerns should be developed and implemented. This system should be user-friendly to encourage its use.

It is recommended that a guide or checklist is used actively when incidents investigations are initially engaged, and that a high-quality semi structured interview is performed with the train driver to ensure that the details needed to perform modern human factors incident/accident analysis are obtained shortly after the incident happens.

The Cognitive Interview (CI) is a specific interview technique which may be used in incident/accident investigation (Memon, 1999). The CI has previously been used in forensic settings to increase the effectiveness of communication and to better witness performance by drawing upon cognitive and social psychology to better interviewer-interviewee relations and improve memory retrieval. A person conducting a CI will attempt to establish a trusting relationship with the interviewee and assist the interviewee back to the physical scene and mental state at the time of the incident. The interviewer will encourage the interviewee to report everything that comes to mind no matter how important the interviewee regards the information. Allowing the interviewee time to respond and think is important. Questions should be limited and asked timely. Also, the interviewee should be asked to describe the situation or event in reverse order and/or from another perspective.

To the author's knowledge, the CI has not been used in human factors or rail investigation earlier. It is, however, a very relevant method to use. The CI technique was used in the course of this project, and preliminary results suggest that the CI may prove to be a very valuable technique. It is designed to increase contextual and experiential information in witness reports, and is a methodology that can be used by practitioners or non-psychologists/cognitive agronomists. Many of the persons who would likely conduct such an interview are the managers closest to the drivers. It is unlikely that these managers any special training in cognitive ergonomics or psychology-based interview techniques. A specific interview technique may prove to increase the quality and amount of information currently collected from incident/accident interviews. The CI has been shown to exhibit more correct information than the standardized police interviews without increasing incorrect or confabulated information (Geiselman, Fisher, MacKinnon, Holland, 1985; Fisher, Geiselman, Amador, 1989 in Memon, 1999). Also, the CI has been seen as superior to other "good" interview techniques such as the structured interview when it comes to obtaining more information without increasing the amount of incorrect/confabulated information - especially when it is possible to corroborate with other information sources (Memon, 1999). Further research with the use of CI in system safety work may provide practitioners with information about the use of the CI technique in the rail industry. The goal should be, at any rate, for practitioners to find a useable, high quality, psychologically based interview technique to be used in accident investigation.

Follow-up of initial training and of individuals who are involved in incidents and accidents should be handled supportively and with the intention of reducing the risk of repetition. Investigations may reveal system interaction problems and/or special needs of individual drivers. It is important to keep in mind that most incidents are the products of problems with system interaction, and should be looked upon as opportunities with which to find insufficient or missing barriers in the system.

During the course of this project, a guide has been developed for train incident and accident reporting based upon modern cognitive ergonomics human risk analysis methods. The guide has primarily been based upon CREAM and DREAM (Driver Reliability Error Analysis

Methodology (Hollnagel, 1998; Ljung, Furberg, & Hollnagel, 2004).However, the guide has also based upon other relevant modern rail (and other) human factors research in addition to the knowledge gained throughout the course of this project (see for example, Lawton & Ward, 2005; Shepherd & Marshall, 2005; Wilson & Norris, 2006, 2005; Wilson et al., 2005). This guide includes parameters and descriptions of the common performance conditions related to the scene, the driver, and the organisation. The guide is designed to be used by persons with or without a background in human factors. Persons may use the guide when interviewing persons involved with the incident/accident in addition to report writing. Table 4 provides an explanation of the *Common Performance Conditions* (Hollnagel, 1998), and their parameters. Table 5 provides a form which can be used to assist the data collection process and following analysis.

Table 4. Common Performance Conditions in the Railway: CPC explanations

CPC EXPLANATIONS		
Common Performance Conditions - The Scene		
CPC	**PARAMETER**	**EXPLANATION/DESCRIPTION**
Traffic Environment's shaping factors/ frame	Type of Traffic environment	Describe the traffic environment Urban or rural routes? What kind of foilage?
	Complexity	How complex was the traffic environment? How many tracks? Single track or double; main track or side track Single track? Approaching stopping station? Meeting a train? Road Crossings? Were there any tunnels or bends in the track in the area? Were there many signals/signs?
	Information	Were the signals clear and easy to see and be understood? Were the track signs clear? Is information given with sufficient time so that the driver can prevent an accident? Is any important information missing?

Driving Conditions	Traffic Density	How many other trains were in the area? Low volume or rush traffic? Is there any statistics for when there is rush traffic in this specific area/route?
	Track conditions/friction	Where there any factors, such as weather-related factors Dry and above freezing = optimal Dry and below freezing = good Wet track and above freezing = good Wet track and below freezing = tolerable Snow on track = Tolerable/Bad Ice on Track = Bad
	Visibility - Weather and Lighting	How was the weather influencing the visibility? Was the visual field clear? Or was it influenced of the dark, snow or rain, reflecting sun, etc.? If applicable, was artificial lighting/lamps working and sufficient?
	Visibility - Obstructing Objects	Was the visibility clear, or obstructed by poles, bushes, or other physical objects? Were there any blind spots?
	Infrastructure	Railway signalling installation " Track conditions, lighting, signals, signs, platform. Section with remote control, with or without line block? Main track, side track, single or double track section? Station with porter, remote controlled station, or boarder station Section with Full Automatic Train Control (FATC) or Part Automatic Train Control (PATC) Was the track in optimal conditions? Was there any track-side work being performed in the area of the incident/accident? When applicable, was the lighting as it should be? Was it optimal for the weather conditions? Were signals in working condition and easy to be seen/read? Were they placed around a bend, for example? Were signs placed where they should be and easy to be seen/read? If a signal was lit, did the driver have sufficient time to react? Any sudden changes in the signaling? Were there any items on the platform that could be distracting (items that normally aren't there)? Was there anything out of the ordinary happening on the platform?

Common Performance Conditions - The Driver

CPC	PARAMETER	EXPLANATION/DESCRIPTION
Driver's working environment/ conditions for work	MMI - Interface Only	Are the instruments and in optimal working order? MMI- How are the diverse interfaces designed? Are they user friendly? Is the interaction designed with safety in mind?
	MMI - Combination of interface	MMI - Is the combination of interfaces beneficial for the driver, og could it cause a problem?

		Is the interaction designed with safety in mind?
	In cab working environment	Was there anything in the cab environment that could be experienced as uncomfortable or stressful? For example, was the seat in working order and easy to adjust? Were there any disturbing or Distracting noises or sounds such as a loud air conditioner or window washing fluid?
Drivers presuppositions	Time of Day/Day of Week	A well known psychological phenomenon is that one acts outside of the normal daytime rhythm, in other words outside of the time when one normally sleeps, one has a reduced performance Stability. This is known as effects of circadian rhythm. Did the incident/accident take place within the driver's normal sleep-wake rythm or not? State preferably normal sleep-wake rhythm, if the person has worked at night, been up late, etc. How did the driver or others involved sleep the night(s) before the incident/accident? Regarding shift work, how has the individual worked lately?
	Number of Simultaneous Activities/Goals	How many activities did the driver have at the same time? For example checking watch to regulate against time table, braking, and checking platform. Was he/she talking in a mobile phone, looking/listening for some kind of information (-give examples), adjusting seat or heating/air-conditioning, distracting noise from cabin area? Here, time, or lack there of, is important. Did the driver have enough time to see the signals and react? For example, was the allowed time sufficient to both see the stop signal and also brake in time? Or does the signal "sneak up" on the driver?
	Drivers physical and psychological health	How was the driver feeling? Feeling well, or reduced in any way? Was the driver uncomfortably warm/cold? Flu or cold symptoms? Were there any social factor's that could influence the individual? For example, work's social environment, conflict with co-workers, or family situation? Which aspects to be reported may vary from case to case. For example,, low blood sugar levels due to a long period since the last meal.
	Speed in relation to speed limits	Did the driver keep to the speed limits or did he/she drive too fast/slow? If so, how much?
Drivers Experience and Training/Education	Driving Habits	Where was the driver used to driving? Number of years as train driver? Total km per year? Does the driver drive in all kinds of environments, or is his/her driving restricted or reduced to specific areas? An specific reasoning for this
	Driver's acquaintance with the traffic environment	Was this the first time the driver was at this location? If not, how often does the driver usually drive the area of the incident/accident?
	Driver's acquaintance with the train set	Is this a new train set? If not, how often does the driver drive this specific train set? Have there been any recent changes in the cabin or driving area which the driver is unacquainted with?

		How does the driver subjectively feel that this particular train set is to drive? Is it comfortable and easy to drive?
	Driver's training/education	There may be special regulations or procedures for a variety of situations (ex..) If so, is the driver educated i these, and are they applicable in the traffic situation in which the driver found him-/herself? Are the plans, regulations and/or procedures easy to access? If a special train set is involved, is the driver educated in the use of such, and how extensive is his/her level of experience?

Common Performance Conditions - The Orgianisation

CPC	PARAMETER	EXPLANATION/DESCRIPTION
Adequacy of Organization	Roles and Responsibilities of team members	Are the roles and responsibilities of team members clearly defined and non-conflicting? Are there any time/efficiency/safety conflicts? If so, elaborate. For example, have drivers had sufficient time to read through the daily notices about route modifications, changes; notices regarding special circumstances for the route?
	Communication	Were messages/orders given/received when and how and where they should be? Were there any misunderstandings?
	Role of external agencies	Were there any external agencies involved? For example. outsourcing of snow clearing etc. If so, were their roles and responsibilities clearly defined? Were they educated in the rules/regulations that apply? What kind of experience does the agency have?

Table 5. Common Performance Conditions in the Railway: CPC form

Common Performance Conditions Form

Common Performance Conditions - The Scene

CPC	PARAMETER	EVALUATION	COMMENTS	INFO-SOURSE	INFO-QUALITY
Traffic Environment's shaping factors/ frame	Type of Traffic environment	Rural Urban			

	Complexity	Little complexity Moderately complex			
	Information	Supporting Approved Tolerable Inadequate			
Driving Conditions	Traffic Density	Little traffic volume Steady flow Rush traffic			
	Track conditions/friction	Optimal Good Tolerable Bad			
	Visibility - Weather and Lighting	Optimal Good Tolerable Bad			
	Visibility - Obstructing Objects	Optimal Good Tolerable Bad			
	Infrastructure	Supporting Approved Tolerable Inadequate			

Common Performance Conditions - The Driver

CPC	PARAMETER	EVALUATION	COMMENTS	INFO-SOURSE	INFO-QUALITY
Driver's working environment/ conditions for work	MMI - Interface Only	Supporting Approved Tolerable Inadequate			
	MMI - Combination of interface	Supporting Approved Tolerable Inadequate			
	In cab working environment	Supporting Approved Tolerable Inadequate			
	Time of Day/Day of Week	In Daytime rhythm? In between/both Outside of daytime rhythm			
Drivers presuppositions	Number of Simultaneous Activities/Goals	Less than capacity Matching capacity more than capacity			
	Drivers physical and psychological health	Good Reduced			
	Speed in relation to speed limits	Over Same Under			

		Much Under			
	Driving Habits	Sufficient, comprehensive/ extensive Sufficient, but limited Insufficient			
	Driver's acquaintance with the traffic environment	Passes daily Driver there many times before Driven there sometimes before Never driver there before			
	Driver's acquaintance with the train set	Sufficient, comprehensive/ extensive Sufficient, but limited Insufficient			
	Driver's training/education	Supporting Approved Tolerable Inadequate			
Common Performance Conditions - The Organisation					
CPC	PARAMETER	EVALUATION	COMMENTS	INFO-SOURCE	INFO-QUALITY
Adequacy of Organization	Roles and responsibilities of team members	Clear and precise Some discrepancies Many discrepancies			
	Communication	Supporting Approved Tolerable Inadequate			
	Role of external agencies	Supporting Approved Tolerable Inadequate			

The guide presented in Table 4 and Table 5 is designed to be used in all incident and accident investigation. By investigating incidents of a lesser degree more thoroughly, it may be possible to uncover weaknesses in the system that most likely could contribute to serious incidents or accidents in the future. Likely, there will be a much higher number of less serious incidents to investigate, making it easier to detect problematic system interaction and incident "types." But, to get at the latent causes of minor or "non serious" incidents, it is necessary to have the same high quality information as is required for serious incidents and accidents.

4.2.3 In-Cab Man-Machine-Interaction (MMI)

Distractions and task interruptions, together with, for example, technical failure and unexpected events may be a fatal combination (Reason, 1990). This referred to as an *interaction effect*. It is generally important to minimize aspects which may contribute to such an effect. When the task is in normal conditions moderately to highly demanding/difficult, the likelihood that an interaction-effect will produce an unwanted outcome rises. Train driving situations such as approaching a station, leaving a station, and shifting are examples of normal activity which are cognitively demanding. Technical failures or local abnormalities or deviations from the norm also contribute to enhancing the cognitive demand of the train driving situation. Since the train driving task in local routes is often cognitively demanding, it is important that the in-cab environment is as supportive as possible.

Several things that were observed in the in-cab area represent safety hazards..These things could be hazardous by themselves and could potentially contribute to an interaction effect. These should be eliminated or minimised. For example, very noisy window wipers, knobs on the interface that fell off during use, noisy ventilation systems, dysfunctional seats, strong smells in the cab, annoyingly bright screens on the interface, and dirty rear view mirrors.

The observations mentioned above which possesses the most danger, but which have the easiest and cheapest fixes, are dirty mirrors and loose knobs on the interface. Mirrors and knobs are very important artefacts in the in-cab environment. Dirty mirrors and/or windows obstruct drivers' ability to see. One of the most obvious aspects of the train driving task was the importance of visual cues. Drivers use visual keys continuously in their work to drive safely, and it is absolutely vital that they can see clearly out of all windows and mirrors.

Regarding loose knobs, the danger is, for the most part, tied to the function the knob represents. According to Petersen, "it is important to consider how changes in the controlled system and its environment influence the *control situation*: the possibility of bringing about system state changes by performing control actions on the controlled system (*the control possibilities*), and the requirements for bringing about appropriate state changes in the controlled system (*the control requirements*)" (2004, p. 266, original italics). Each knob represents potential change that may be brought about in the controlled system (rail system). Lack of knob (the input device) hinders the actuation of the effector mechanisms. If the knob falls off, the ability to bring about the specific change represented by that knob will be hindered or eliminated. The control situation is instantly changed, by limiting the changes in the system that can be brought about by turning the knob (control possibilities).The direct danger depends, of course, upon the function represented by the knob and the vitality of that function for safe travel. The indirect danger is tied to the reaction of the driver. While one driver may lean down to search for the knob while driving out on route, another may decide to wait until they have stopped at the next station, while yet another may decide to make an exceptional stop to find and fix the knob. What the driver decides to do with the dysfunctional knob (control action) changes the system state further, creating a control situation with other possibilities and restrictions.

4.2.3.1 Conclusions

Distracting noises, dysfunctional seats and strong smells in the immediate in cab environment will likely result in a trial and error method to minimize or eliminate adverse consequences. Well documented aspects related to train driving is the tendency to do what is referred to as 'system tailoring' and 'task tailoring'. System tailoring refers to the fact that operators have a tendency to set up a system in their own way, which in a way which has not been considered standard use. If, for example, the noise of the ventilation system is experienced as unpleasant and annoying, drivers will try to minimize this by perhaps turning on and off the ventilation system to get blocks of time without noise. This behaviour, in turn, results in temperature swings in the in-cab environment which may lead to fatigue, affecting the driver's ability to concentrate and be attentive. In addition, the behaviour itself (turning the switch which regulates the "off" or "on" function) presents a danger in that it takes the drivers attention and actions away from the main task at hand (train driving) and averts it to the task of temperature maintaining.

A more complex issue which should be looked at in the future is related to the different interfaces drivers are required to use. Drivers are to be able to switch between several train sets, all of which have their (more or less) unique interface. Our experience is that the interfaces are somewhat similar, but that each train set has its own distinctive characteristics which require a certain degree of orientation and/or experience.

Human factors research suggests that there may be some adverse effects related to switching between different interfaces. It is widely accepted that the technical system has a tendency to structure the task at hand as such, something regarded to in the literature as 'task tailoring'(Cook & Woods, 1996). The implication is that one has a tendency to relate to the task *as it is represented through the technical interface*. This is also known as the intention-function problem. It is assumed that the more experience one has with the interface, the less one is vulnerable for the problem of task tailoring. It would therefore follow that train drivers will relate to the train driving task in one way while driving one train set, and in another way when driving another train set.

Future studies should explore the effects of changing between train sets. Newer train sets often have more advanced technology and different ways of relating to the ATC. It may be that the differences in the interface change the work task in ways that create problems for the drivers (for example takes longer time to find relevant knobs or to brake smoothly). On the other hand, individuals who have work tasks that are both highly demanding and presented through an interface may benefit from having more hands-on, manual experience (Charlton, 1996). At this point, it is difficult to predict the effect of varying train sets on system safety.

4.2.4 Situational Awareness

Situational awareness (SA) is important for all users of a technical system (Endsley & Garland, 2000; Endsley, Bolte & Jones, 2003).[6] SA is knowledge that operators build up over time, which is used to predict future situations or events. Often that knowledge provides the basis for decision-making processes. The train driving task, especially the local train routes, is similar to the task of manoeuvring an airplane or fast-speed patrol boat in that the task is highly dynamic. In such situations, the drivers' ability to act upon assumptions of the future is necessary to achieve a good result. In scientific terms these are called proactive actions. Proactive actions are considered to be dependant upon a high degree of situational awareness.

4.2.4.1 System coherence and correspondence

To be able to predict future events, it is necessary for the system to have a high degree of coherence and correspondence (Vicente, 1999). Lack of coherence and correspondence in a system can be a source for human performance variance. A number of inconsistencies were observed in this particular system.

There appear to be, at times, quite large discrepancies between procedures and practice. Due to the fact that the actual infrastructure varied quite often, carrying out procedures smoothly

[6] "Situational awareness is the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future" (Endsley, 1988)

and correctly was often seen as being linked to driver's local knowledge and experience (experience as such will follow later in this report). Much of the train-driving task was found to be highly context dependant. It is likely that the inconsistencies in the carrying out of procedures vary due to inconsistencies and lack of correspondence in the infrastructure. There appear to be many exceptions to the rule regarding placement and meaning of signals and signs – something which demands a great deal of local knowledge. Understanding how incoherencies and lack of correspondence in infrastructure affect the task procedures should be considered in the future.

At present, the system conditions put a great cognitive demand on drivers. The more context dependant the situation is, the more the safety of the system is dependant upon the operator. It is important for complex technical systems to work to *reduce* the context dependency of the system as to ensure reliable safety barriers (Flach, 1995). The more the system is dependent upon the operators understanding and interpretation of the immediate environment, a kind of right here right now situation, the more difficult it becomes to think and act proactively. Drivers will experience a lesser degree of control. There is less room (often related to time) for misjudgements, lack of attention, and interruptions. As a consequence, individual differences (performance variation) will have a larger effect on the total systems safety.

4.2.4.2 Conclusions

This project reveals that the current rail system is such that drivers have a relatively low degree of situational awareness. There appears to be many conditions and situations which reduce the drivers' ability to plan ahead. There may be several ways to improve situational awareness by making the rail system less context dependent. Most likely, a variety of initiatives at different levels of the M-T-O triad will be the most successful. A more complete systems analysis of the domain could provide a basis for the design of new technology and other initiatives.

Some ways to make the infrastructure less context dependent were discussed earlier. There may also be technical means of representing upcoming information (state of signal) in the cab, making proactive thinking and actions easier and more accessible. Jansson et al. attempted to improve existing train driver interfaces using modern human factors techniques (2006). The resulting interface presented the most important information of the current status of the train set, while at the same time presented various aspects of the upcoming environment (including special conditions, future speed profile). In addition, the interface included information which would be useful in case of an unwanted event or accident which function as a barrier to reduce the ramifications of such events should they first occur.

It may also be possible to increase situational awareness through specific training initiatives and through hands-on experience. Training and Experience will be discussed in the next section.

4.2.5 Training and Experience

When it comes to education and training of actors working in domains where safety is an issue, it is important to have continual evaluations of both education and the types of experience that are necessary. It has not been the aim of this project to come with any concrete evaluations of the education train drivers receive. We have chosen here to focus on drivers who have gone through the required training and discuss training and experience from a more general understanding of the cognitive work analysis presented earlier.

This is done because education and training, as other areas which must consider human factors, it is first necessary to have an understanding of the operator's task and the domain at hand. An analysis of train drivers' operating tasks should have direct implications for the type of education and training needed. They need to be prepared to meet the driving task *as it is represented out in the real situation*. Different training and experience would be needed from what is required today, if, for example, the signal system were presented only through the in cab interface rather than through signals placed trackside.

It is well-known that length and quality of training and experience for safe driving is important. Training and experience, however, cannot be the easy fix for all problems in a complex socio-technical system (Cook & Woods, 1996). Often, persons are related to as the least constrained cause of accidents, which often lead to the disillusioned belief that they are the most avoidable (Hollnagel, 2005b). Traditionally, many industries and enterprises have assumed that it is possible to "fix" or prevent accidents by training the individuals enough, or by initiating new rules and regulations. More training and detailed regulations has been proven to be an insufficient solution to safety problems, and are not solid long-lasting barriers (Hollnagel, 2005b; Health and Safety Executive, 2002). Individuals have a limited capacity when it comes to what they can be "trained" to do, and what they can remember and use of new regulations or instructions. The specific amount of information that can be dealt with is quite often tied to individuals, but in general, we can say that system safety is compromised when barriers such as training, education, and rules and instructions are relied on too heavily in any system.

The current systems analysis suggests that at the current time there are many safety barriers which are dependant upon drivers' skills, rules, knowledge and experience. The high degree of context dependency we have observed in the Norwegian rail system demands a high degree of education (f. ex. Learning the signal and signing system, rules and regulations related to individual enterprises procedures, how to determine how long it takes to stop the train, etc.) in addition to a great deal of actual hands-on driving experience in specific contexts (hands on experience with the interface, location of signals, weather conditions, what to do when passengers run towards the train and are late, etc.).

4.2.5.1 Conclusion

At the time being, it is difficult to conclude with whether or not the training and experience drivers have today is sufficient. It may be possible to acquaint drivers to specific situations through, for example, situation-based simulator training to increase safety. It may be that drivers, especially inner city drivers, should only drive one specific line due to the high degree of context dependency in the system. However, it may also be that drivers *need* to have variation of routes to avoid burn out due to the intensity and demand connected with certain routes – something which may be a sign that drivers' capacity to "learn more" is being exceeded.

Specific scenario-based simulator training should be considered in the future to help cope with the context dependant rail system which exists today. However, it is quite important to take careful consideration as to *how* simulation should be used. It is suggested that scenario training should be used as a supplement to today's training, and not as a replacement for real-life experience. Nor should simulator training be a kind of "punishment" for drivers who experience difficulties. If simulation is to be used as a testing situation, the design of the test and evaluation methods should be carefully considered before implementation as there are several challenges related to using simulation in testing or evaluation. It is important that simulators are not used haphazardly. Human factors research on simulator training should be referred to during the design and planning processes. The task to be simulated, who is to be trained, and how the training should be carried out are important aspects that should be clear before implementation to be fruitful (Shepherd & Marshall, 2005).In addition, the effects of the use of simulators on other aspects of the MTO system should be considered prospectively - *before* implementing on a large scale.

5.0 Concluding Remarks

This study has provided an initial systems analysis of the Norwegian railway. In Part 1, three system critical situations have been identified in the rail driving tasks, namely *leaving a station, out on route, approaching a station.* In addition *switching was suggested as a fourth driver operation task*. Information regarding how drivers use information in these system critical situations may be useful when the human factors related to various aspects of the MTO system. Future studies may validate considering shifting as a system critical situation in train operation. It may be useful, in the future, to consider train operation in situations other than rural driving routes.

Several system weaknesses and areas for improvement have been discussed, and suggestions for improvement have been suggested. Several suggestions for future research have been pinpointed. The systemic view of man-machine interaction in complex socio-technical systems sees the possibility of failure as an attribute to the context. Hollnagel finds it useful to think of the relationship between common performance conditions (the system's context) and human error probability as one thinks of radio waves (2005b) First generation human reliability analysis methodologies and traditional human factors research based upon human information processing would see human error probability as the "signal" and the performance shaping factors (the system's context) as "noise" affecting the "signal". However, in second generation human reliability analysis such as a systems analysis, the relationship is reversed. Here, the "signal" is the common performance conditions, while the "noise" is human error probability. If the system "signal" is strong and reliable, demands and resources are compatible, and working conditions fall within normal limits, human performance variation should fall within safety boundaries and be more reliable. However, if the system "signal" is chaotic and unreliable, demands vary, resources may be inadequate, and working conditions may at times be sub-optimal the result will be less reliable safety performance. At the current time, it appears that the Norwegian railway system "signal" or performance shaping factors creates quite an irregular and context dependant working situation for drivers. To maintain system safety and reduce unwanted events, the current Norwegian railway system is sub-optimal. In such a situation or context, it is not unlikely that human performance variation could result in unwanted events. Drivers make attempts to relieve the efficiency-thoroughness trade-off's they are presented with in the current situation and safe performance will vary considerably according to the actions individual drivers make.

As this initial system analysis revealed several weaknesses within the Norwegian rail system which should be improved, there is reason to believe that a more comprehensive systems analysis study would be quite useful in the future. This study has shown that a systemic model of human behaviour can be useful in the Norwegian rail domain, and the use and validation of such models in this industry should be considered in the future. More specifically, modelling train driver performance within the terminology of specific models of human behaviour may be able to explain how the joint cognitive systems in the railway act to achieve their goals while at the same time responding to events in the environment (see for example the Contextual Control Model (COCOM) Hollnagel, 1983, 1997, 1998, 2002; and Extended Control Model (ECOM) Hollnagel & Woods, 2005) In addition, several methodologies to assist accident prevention have been presented. More specifically, an incident report guide and form for train driving common performance conditions was developed and presented. Also, the CI was suggested as a practical and helpful tool to use when collecting information relevant to accident and incident investigation. Further research may work to further develop and validate the applicability of these methods

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