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TØI report 1066/2010

Institute of Transport Economics
Norwegian Centre for Transport Research

Helping train drivers pass signals safely: Lessons from ten case studies

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Summary:

Ten incidents in which a train driver overlooks a signal are analysed in order to identify limitations in the organisational and technical systems surrounding signal approach by drivers. Systematic aggregation of case study findings reveals that hazardous signal approach is characterised by (i) deviance from the situation norm; (ii) high demand placed on the driver; (iii) driver reliance on expectations based on the situation norm. According to an accompanying survey, 83 per cent of drivers think that the development of assumptions based on routine norms is an important safety issue. Based on these findings we recommend ways to prevent drivers developing cognitive shortcuts on being exposed repeatedly to unchanging stretches of track. We report on the incidence of different signal approach incidents, according to drivers, and discuss methodological aspects of CREAM, the tool used to analyse and classify error causation in the case studies.

Sammendrag:

Ti hendelser der en lokfører har oversett et signal, er analysert for å identifisere risikofaktorer i organisatoriske og teknologiske omgivelser som påvirker lokføreres håndtering av signaler. Systematisk aggregering av de ti casestudiene avslører at kjøring i strid med anvisninger fra signal er karakterisert av (i) signalet avviker fra det normale; (ii) situasjonen stiller ekstraordinære kognitive krav til føreren; (iii) forventninger basert på vaner. Disse funnene støttes av resultatene fra en spørreundersøkelse blant lokførerne, hvor 83 prosent svarer at det er et sikkerhetsproblem at oppfatninger blir formet av vaner. Vi foreslår metoder for å justere/endre etableringen av kognitive tankeskjemaer basert på vaner. Rapporten omhandler også hyppigheten av ulike signalhendelser rapportert av førerne, samt metodologiske aspekter ved CREAM – metoden som er brukt for å analysere og klassifisere årsakssammenhenger i våre casestudier.

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Preface

This report is part of the project “Investigation of accidents and incidents in transport: Method development and analysis of prerequisites for learning”, carried out under the RISIT (“Risk and Safety in the Transport Sector”) programme financed by the Norwegian Research Council. The aim of the project is to find ways to improve (i) the way accidents and incidents are investigated; and (ii) the way lessons learned from those investigations are applied.

To help achieve (i) we attempted to develop the Cognitive Reliability Error and Analysis Method (CREAM) developed by Erik Hollnagel. This method offered the chance to improve validity of investigations by accounting for the whole system of human, technical, environmental and organisational factors that interact and lead to hazardous incidents. It also allowed findings across different incidents to be aggregated, and in doing so offered a way to combine the systematic properties of quantitative methods with the data-rich benefits of qualitative methods.

In TØI report 915/2007, we report on the use of CREAM to investigate six signal-passed-at-danger incidents involving train drivers. The current report builds on those findings by aggregating the results from ten additional hazardous incidents occurring on signal approach.

We wish to express our warm thanks to NSB for their openness and friendly help and advice offered throughout this project. While we cannot name individuals for reasons of confidentiality, this in no way detracts from the gratitude we owe them.

At TØI, Fridulv Sagberg has been project manager, and Ross Owen Phillips has managed the railway part of the project and written the report. Susanne Nordbakke has offered useful comments and advice, and helped conduct the first of the interviews with the train drivers. Torkel Bjørnskau has been responsible for quality assurance. Trude Rømming has edited and prepared the report for printing.

Oslo, April 2010
Institute of Transport Economics (TØI)

Lasse Fridstrøm
Managing Director

Torkel Bjørnskau
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Summary:

Helping train drivers pass signals safely: Lessons from ten case studies

Train drivers depend on surrounding systems of supporting organisational and technical factors to help them pass signals safely. We identify gaps in these systems by analysing ten hazardous signal approach incidents using a method for the selection and classification of error antecedents. Systematic aggregation of antecedent chains shows that hazardous approach situations are characterised by unusual conditions (excessive task demands or poorly salient signals) which increase the chance that drivers will employ inappropriate routine expectations about signal aspects. In a separate survey we find that 83% of the drivers themselves rate the 'danger of developing assumptions based on routine' as worthy of investigation. We recommend that the organisation finds ways to challenge the establishment of cognitive schemas by drivers exposed repeatedly to unchanging signal aspects. Technical and other organisational recommendations are also given. Further development of the analytical method used is discussed.

In-depth analysis of ten railway incidents is carried out to identify limitations in the way surrounding systems of organizational and technical factors support train drivers on their approach to signals. A secondary aim of the project is to further assess and develop CREAM (Cognitive Reliability and Error Analysis Method) for in-depth railway incident analysis.

To identify suitable signal incidents for case analysis, 115 train drivers were surveyed on three occasions over an 18-month period about their involvement in signal approach incidents. The average survey response rate was 26 per cent.

The share of drivers reporting that they had passed a main signal at danger in the past year was very low. However, in the same period over one in four drivers reported that they had missed an approach signal with the result that the train's computer system (ATC) had had to intervene with automatic braking to prevent the train passing a main signal at danger. Over a two-month period, over one in four drivers reported triggering a "permission to drive" indicator button when waiting at a station, even though the station exit signal did not show green. Also over a two-month period, one in three drivers reported receiving the all-clear signal from a conductor at a station when the exit signal did not show green.

Thus, although signal-passed-at-danger (SPAD) incidents themselves are rare, a substantial share of drivers report involvement in potentially hazardous "pre-SPAD" incidents.

To learn more about influential factors in the build up to these incidents, twelve drivers were questioned in-depth about a single main signal approach incident in which they had been involved. The questions were based on a framework designed to provide data for incident analysis by CREAM.

Two out of the twelve interviews were incomplete, and the analyses were therefore based on ten cases. A systematic aggregated analysis of the case study findings suggests that three event chains are commonly implicated in the run up to a missed observation by a driver, which in turn results in the hazardous approach of a main signal. These chains are as follows:

1. The driver appears to have an inadequate plan or faulty schema for signal approach, which often fails to include the possibility of deviant events such as a non-routine signal aspect. Absent or forgotten knowledge about occurrence of deviances is often implied as an antecedent to a faulty schema.
2. Inattention by the driver is also a common antecedent of a missed observation. Inattention, which may be more accurately described as inappropriate attention, is linked to an expectation about a stretch of track formed after experiencing it repeatedly in an unchanging state.
3. A lack of signal salience (information failure) in the driver’s environment ’forces’ the driver to employ a faulty schema about signal aspects, and increases the chance of a missed observation.

Systematic aggregation did not capture all implications highlighted by several of the individual CREAM analyses. In particular, informal analysis of six incidents also showed that:

4. Extraneous demands increase the likelihood that the driver will rely on a schema they have formed about routine signal aspects on a stretch of track.

In summary, the dangerous signal approaches examined here are characterised by the following elements:

- **Unusual deviance from the situation norm**
- **Several demands placed on driver**
- **Driver employs a schema based on the situation norm**

Because of the problem of schema development, we claim that routine exposure to systems in an unchanging state is a pervasive and dormant potential hazard for drivers. This finding is echoed by the drivers themselves in their responses to a survey about important safety issues by which they were affected. The dangers of routine assumptions was the most highly rated issue, with 83 per cent of drivers saying that it was worthy of investigation. Other issues rated as important by most drivers were fatigue / shiftwork (rated by 75 per cent of drivers) and signage and visibility (rated by 52 per cent of drivers). Although few drivers saw driver-to-driver communication as an issue, almost one in three thought that communication between drivers and conductors is an issue, while a slightly greater share believed driver-manager communications are worth investigating.

Recommendations for the prevention of hazardous signal incidents involving drivers are summarized as follows:

- Find ways to challenge the formation of inappropriate or unsafe schemas by drivers exposed routinely to unchanging signal aspects.
- Design a signal environment that better accounts for human factors, making deviant signal aspects easier for drivers to perceive.
- Design through driver consultation better systems to brief drivers about deviant situations they can expect as they journey on the day's route.
- Promote open communication among drivers of strategies used to deal with the dangers of routine *e.g.* group discussions
- Use refresher training to prime driver's minds about the possibility of deviances and dangers of routine assumptions, and to challenge any inappropriate schemas.
- Consider whether the way ATC is used by drivers is optimal in terms of safety. (We do not consider improvement of the ATC system itself.)
- Investigate factors influencing conductor involvement in incidents occurring on station exit.

Our findings support claims that CREAM is a useful method for the analysis of signal incidents on the railway. We find that the systematic aggregation of ten analyses leads to new information about commonly occurring antecedent events.

Finally, ideas are outlined on how the CREAM method can be evolved. In particular we recommend that CREAM be evolved to better account for feelings and mood in driving.

Sammendrag:

Faktorer som hjelper lokførere til å passere signaler trygt: Lærdom fra 10 casestudier

Lokførere er avhengig av organisatoriske og teknologiske støttesystemer for å passere lyssignaler trygt. Vi har identifisert svakheter i disse systemene gjennom å analysere ti potensielt farlige hendelser der lokførere har handlet i strid med informasjon fra signaler. Analysen er basert på en metode som identifiserer og klassifiserer de faktorene som kommer forut for feilhandlingen. Systematisk aggregering av disse faktorene, viser at risikofylt passering av et signal er forbundet med uvanlige situasjoner (ekstraordinære krav stilt til føreren; signaler som ikke er fremtredende nok osv.) Lokførere handler i stort grad ut fra forventninger og vaner, og dermed blir uventede signaler en potensiell risiko for feilhandlinger. Lokførerne deler denne problemforståelsen; 83 prosent av lokførere anser "faren ved rutinemessige antakelser" som et viktig tema for videre gransking. For å hjelpe lokførere til å passere signaler trygt, anbefaler vi at organisasjonen utvikler metoder for justere dannelsen av kognitive skjemaer hos lokførere som følge av gjentatt eksponering av uendrete signaler. Både tekniske og organisatoriske anbefalinger er gitt. Videreutvikling av selve analysemetoden er også drøftet.

Dybdeanalyse av ti hendelser på jernbane er gjennomført for å identifisere menneskelige faktorer som kan forklare at lokførere av og til overser signaler. Hensikten er å foreslå organisatoriske og tekniske tiltak for å hjelpe lokføreren til å kjøre trygt forbi signaler. En sekundær hensikt med prosjektet er å evaluere og videreutvikle CREAM (*Cognitive Reliability and Error Analysis Method*) for analyse av hendelser på jernbane.

For å identifisere relevante hendelser fikk 115 lokførere tilsendt et spørreskjema om sine erfaringer med feil passering av signaler den siste tiden. Skjemaet ble sendt til de samme lokførerne ved tre ulike anledninger over en periode på 18 måneder. Svarprosenten var 26 prosent i gjennomsnitt.

Andelen som oppga at de hadde kjørt forbi et signal i stopp var svært lav. Men én av fire lokførere oppga at de i løpet av det siste året hadde oversett et forsignal hvorpå togets automatiske kontrollsystem (ATC) måtte gripe inn. Over en periode på to måneder oppga også én av fire at de hadde tent lampen for å vise at kjøretillatelse var mottatt, selv om de ikke hadde fått kjøretillatelse i signal. I tillegg sa én av tre lokførere at de hadde mottatt avgangssignal fra ombordsansvarlig når de ikke hadde fått kjøretillatelse i signal, dette også over en to måneders periode.

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Vi kan dermed slutte at selv om svært få lokførere kjører forbi et signal i stopp, er en betydelig andel innblandet i hendelser som øker risikoen for feilaktig passering av signaler. For å finne ut mer om de faktorene som spiller inn ved forekomsten av disse hendelsene, ble det gjennomført dybdeintervjuer med 12 lokførere. Spørsmålene var utformet for å gi supplerende data til analyse av hendelsene ved hjelp av CREAM-metoden.

To av intervjuene var ufullstendige, slik at analysene er basert på ti av de tolv intervjuene. Systematisk aggregering av funnene fra disse ti casestudiene identifiserer tre kjeder av faktorer som har ført til manglende observasjon av forsignaler, noe som i sin tur førte til for høy fart inn mot et hovedsignal i stopp – og dermed risiko for passering av dette. Disse kjedene er som følger:

1. Lokføreren har en utilstrekkelig plan eller kognitivt skjema for kjøringen inn mot et signal. Planen tar ikke hensyn til avvikssituasjoner, for eksempel et uvanlig signal. Fraværende eller glemt kunnskap om forekomsten av avvikssituasjoner kan føre til at man har en slik utilstrekkelig plan.
2. Uoppmerksomhet hos lokføreren kan føre til manglende observasjon av et signal. Analyser av flere tilfeller viser at denne uoppmerksomheten har utgangspunkt i visse forventninger som lokføreren har dannet om en enkelt strekning over tid. Flere lokførere som hadde vært innblandet i farlige hendelser, hadde oversett et signal i avvik fordi de var svært vant til å se signalet i grønt.
3. Signaler er ofte ikke fremtredende nok i lokførernes siktfelt, noe som både fører til feil oppfatninger av hva signalet viser og som øker risikoen for at signalet overses.

Systematisk aggregering av bakenforliggende faktorer ved hjelp av CREAM fanget imidlertid ikke opp alle implikasjoner som analysene påpekte som viktige. Især viste analyse av seks hendelser at:

4. Ved avvik og uvanlige situasjoner er det stor sannsynlighet for at lokføreren feilaktig handler ut fra et kognitivt skjema basert på et signals vanlige tilstand. I tillegg ser det ut til at avvikssituasjoner med høy kognitiv belastning på lokføreren er spesielt farlige situasjoner.

Farlige situasjoner kjennetegnes dermed av tre hovedelementer:

- **Uvanlig avvik fra normaltilstand**
- **Krevende kognitiv informasjonsbearbeidning for lokføreren**
- **Kognitive skjema basert på normaltilstand benyttes av lokføreren**

Vi vil hevde at gjentatt eksponering for systemer som ikke forandrer seg er en latent og betydelig fare for lokførere. Dette funnet reflekteres også mer konkret av lokførerne selv. I spørreundersøkelsen oppga 83 prosent at rutinebaserte antagelser var det viktigste sikkerhetstemaet. Andre saker som ble vurdert som viktige var trøtthet / skiftmønster (et viktig sikkerhetstema ifølge 75 prosent av lokførerne), og skilting og synlighet (et viktig sikkerhetstema ifølge 52 prosent av lokførerne). Selv om få lokførere betraktet kommunikasjon mellom lokførerne som viktig, mente nesten én av tre at kommunikasjon mellom lokfører og ledere var verdt å studere nærmere.

Våre anbefalinger om hva som kan gjøres for å forebygge farlige signalhendelser som involverer lokførere, kan oppsummeres som følger:

- Finne måter for å forhindre at det dannes utilstrekkelige, uhensiktsmessige og utrygge kognitive skjemaer (tankeskjemaer) når lokførere gang på gang blir utsatt for uforandrete signaler.
- Utforme signalmiljøet slik at det tar bedre hensyn til menneskelige begrensninger, og dermed gjør det lettere å oppfatte avvikssignaler.
- Gjennom konsultasjon med lokførerne kan man utforme informasjons-systemene slik at lokførere på et tidlig tidspunkt får informasjon om avvikssituasjoner som kan påtreffes på den aktuelle ruten.
- Trene lokførere regelmessig for å friske opp kunnskap om mulige avvikssituasjoner, om farene med antagelser, og for å endre uhensiktsmessige kognitive skjemaer.
- Kartlegge om lokføreres bruk av ATC er optimalt i forhold til sikkerhet. (Vi tar ikke opp mulige forbedringer av selve systemet her.)
- Undersøke eventuelle andre forhold som påvirker rollen som ombordsansvarlig har i forbindelse med hendelser knyttet til avgang fra stasjoner.

Vi finner at CREAM er en nyttig metode for analyse av hendelser som lokførere er innblandet i. Systematisk aggregering av ti hendelser ved hjelp av CREAM har gitt ny kunnskap om viktige forhold som fører til risiko for passering av jernbanesignaler i stopp. Vi mener likevel at CREAM kan videreutvikles. Vi anbefaler spesielt at CREAM tar mer hensyn til betydningen av følelser og emosjoner i kartleggingen av feilhandlinger og farlige hendelser under kjøring.

1 Introduction

1.1 Project Background

The improvement of safety on transport networks requires a better understanding of the causes of accidents. Attempts are thus often made to identify factors or event chains commonly present in the build-up to accidents. Until now there have been two contrasting approaches: the statistical analysis of large accident databases and the in-depth analysis of individual accidents.

Quantitative database analyses are all too often limited by the amount and quality of available data. The individual items described by the databases are often not designed for analysis of accident causation (e.g. some of the items in police or insurance company databases), and what data there are can often be missing. Perhaps more importantly, the data and the methods used to analyze databases can never fully consider the complex and dynamic systems of factors and events in which most accidents occur, and even though it may be possible to identify factors and events *associated* with different accident types, little can be said about what actually *causes* accidents.

To understand more about causation the researcher often turns to in-depth investigation of single cases. An attempt is made to reconstruct the chain of events leading up to the accident by analysis of rich data from interviews of witnesses and victims, from bespoke technical analyses or from police or organizational reports. The main criticism of in-depth analysis methods is that it is difficult to generalize from a few case studies about accidents occurring in the population.

One in-depth analysis method has the potential to address this criticism by allowing the systematic aggregation of results of several in-depth analyses of the same accident type. The further development of this method has the potential to improve what we know about accident causation by basing systematic knowledge on an in-depth understanding of the whole system of human, technical and organizational events responsible for accidents. This method is the Cognitive Reliability and Error Analysis Method, or CREAM for short (Hollnagel, 1998).

1.1.1 CREAM for the study of train driver incidents

CREAM has particular potential to inform the design of measures to help prevent accidents involving trains in service. There are several reasons for this:

- Train crashes occur infrequently, making generalizations from large-scale quantitative analysis difficult, and systematic learning from in-depth analyses more appealing.
- CREAM was designed for the analysis of events involving a human operator at the hub of a complex sociotechnical system, of which the train driver is a prime example (Brotnov, 2007).

- Systematic generalization from the aggregated in-depth analysis of one-off events is probably more viable for accidents or incidents for which the circumstances are similar e.g. signal approach incidents involving train drivers.

Using CREAM it is possible to learn not just from accidents but also from hazardous incidents, which invariably occur more often. Hazardous incidents are seen as indicative of gaps in a system's safety defences, and therefore of potential accidents lying dormant in the system. So-called 'undesirable incidents'[1] have been on the increase in Norway recently, according to recent data from the Norwegian railway inspectorate (Jernbanetilsynet). In 2009 there were 7700 incidents compared with 6500 in 2007. If CREAM could be used to identify common events occurring in the run up to a number of similar hazardous incidents involving train drivers, useful recommendations for preventative measures could be made.

The question is then which hazardous incidents should be studied. Previous reports on human factors problems for train driving identify *switching*, *leaving a station, out on the route* and *approaching a station* as situations requiring different cognitive styles or driving approaches (Brotnov, 2007; Jansson, Olsson, & Kecklund, 2006). A frequent and potentially hazardous situation that occurs across these situations is signal approach. An interesting question is whether those system events contributing to the occurrence of hazardous incidents on signal approach tend to be similar, regardless of the situation type, or whether they vary depending on the type of driving situation.

1.1.2 Previous CREAM analysis of train driver incidents

CREAM has been used previously to analyze six signal-pass-at-danger (SPAD) incidents involving train drivers in Norway (Nordbakke & Sagberg, 2007). An incident database, which is filled in by drivers and their leaders following hazardous incidents, was used to identify drivers involved in SPAD incidents. These drivers were then invited to interview. A problem identified by this study was that SPAD incidents were themselves rare, and those that did occur were often caused by signal faults completely beyond the driver's control. Because a main strength of CREAM is its ability to highlight problems occurring in the interface between human operators and the technical, environmental and organizational systems in which they exist, Nordbakke & Sagberg (2007) recommended that future uses of CREAM should focus on more frequently occurring hazardous incidents in which drivers play a significant role. They also echoed the conclusions of the similar Swedish TRAIN project, in finding that data from existing railway company logs were insufficient and inappropriate for use in CREAM analyses (Hollnagel, 1999; Hollnagel, Sverrbo, & Green, 1999)

[1] An undesirable incident is defined as an incident that is not an accident, but which has implications for safety.

The previous studies imply CREAM analysis would be improved in two ways. First, by asking train drivers to recall relevant incidents in which they have been involved in order to capture those incidents not recorded in official databases. Second, by using a driver interview guide structured using the CREAM framework to give a rich source of bespoke information for subsequent analysis by CREAM.

Before the aims of the current study are presented, we describe (1.) signal operations and systems designed to help the train driver on the approach to signals; and (2.) the CREAM method used to analyze the signal incidents.

1.2 Approaching a signal and what can go wrong

All the hazardous incidents analysed in this report occur as the driver approaches a signal. This section gives a basic understanding of the different signal aspects a driver must consider, and outlines the automatic train control (ATC) system, which is used to help the driver monitor signal aspects. A basic insight into the driver's context and general mindset on approaching a signal is also given.

1.2.1 Signals and signal aspects

There are several different signals in use on Norwegian railways. Those we are concerned with are main signals and approach signals.

A **main signal** can be placed at the start of a stretch of track between stations (a block), at the entrance or exit to a station, or within a station. Main signals control the way the train progresses through the subsequent stretch of track.

Approach signals indicate the state of a subsequent corresponding main signal. They are placed several hundreds of meters before the main signal.

Approach and main signals can have a number of different signal aspects. Signal aspect refers to the state of the signal. For instance, a main signal can show flashing red lamp, in which case the driver should stop the train short of the signal; flashing green and yellow lamps, in which case the train must slow to diverge at one or more sets of points; or flashing green, in which case the train can continue on the same stretch of track at operational speed.

For more detail, the reader is referred to Nordbakke and Sagberg (2007), the relevant chapter of which is given here in Appendix 8.

1.2.2 Automatic Train Control (ATC)

In Norway, most railway and rolling stock is equipped with ATC. This is a system comprising of:

- A series of transponders set at periodic distances between the railway tracks, where each transponder is often associated with signal;
- an onboard train computer;
- a display panel in the driver's cabin.

As a train passes over one of the track transponders, data is transmitted and received by the train computer. The data contain information about the signal status for the subsequent block. Once updated with signal information, the computer updates the display panel in the driver cabin. In addition, the computer continuously compares the train's speed against a standard braking curve or algorithm. If the train is at any time going too fast to be able to stop or slow down sufficiently before reaching the main signal, the computer triggers the following stepwise process:

i. A visual warning (flashing yellow button on driver's ATC panel);
ii. Audible warning (if the driver fails to respond to the visual warning);
iii. Automatic braking (if the driver fails to respond to the audible warning).

The strength of brakes applied depends on the excess of speed in relation to the braking curve. The volume of the alarm can be adjusted by the driver.

A stretch of railway in Norway can have no, partial or full ATC installed. Full ATC controls train speed between each signal in addition to the signal approach speed. Partial ATC controls only the signal approach speed.

Below 40 km/h the ATC is temporarily deactivated. If the driver does not brake sufficiently at this speed, it is possible for the train to pass the main signal even where ATC is installed. However, after passing a stop signal, even at low speed, ATC will intervene with full brakes.

Mainline signals whose approach is monitored by ATC are controlled remotely by operators in a traffic control centre.

The approach to dwarf signals (name given to small signals in station shunting areas) is not controlled by ATC. SPADs involving dwarf signals are therefore more common than mainline SPADs, but because they occur at low speeds their consequences are usually – though not always – less serious.

1.2.3 Exit signal approach

A special form of signal approach concerns exit signals viewed by a driver waiting in a stationary train at a platform. ATC is not used in station departures. To ensure safe departure the following procedure is used:

1. The train driver, having stopped and released the passenger doors, waits for a green exit signal.
2. Upon only having checked that he has received this signal does he then press a button in the cabin to trigger several flashing orange indicators placed along the top or side of the train.
3. Once these indicators are seen by the conductor on the platform, the conductor checks that passenger boarding procedures are complete and then double checks that the exit signal is green.
4. Only then does the conductor wave to the driver that he is clear to depart.

1.2.4 Driver context on signal approach

In considering the mindset of the driver as he or she approaches a signal, we refer to Brotnov (2007) and some representative comments by drivers interviewed for the case analyses (Appendix 1).

The railway tracks are lined with a complex array of signs and signals. With experience, the driver learns to attend mainly to those signals he knows are relevant. If a driver is out on route he may often expect signals to allow him to proceed, but will in any case check for any deviant signal aspects.

If he is able to proceed, he needs to do so at the correct speed. The time between stations in relation to the timetable is often in his mind as he does this, and, because a driver becomes so accustomed to driving a certain stretch of track at a particular speed, the speed becomes "felt" rather than consciously chosen. It is often possible, however, that the driver will have been informed about deviations from the norm, such as a signal fault or an unusual diversion at a certain point on the route. Drivers are not unused to departures from normal procedures.

Despite this, the driver is subject to large amounts of routine driving. It is not uncommon that a driver will have driven the same block in the same direction three times a week throughout most of the year, for several years. This means it is possible for the average driver to have driven past an individual signal thousands of times, and most if not all of the time, that signal will have been in the same state. When one considers how many signals must be attended to on the average route, it is only reasonable to expect train drivers to make signal perception errors, especially where there are rare signal deviances.

The problem of routine is exacerbated by standardisation. For example, there is a standard speed for diverging at points (40 km/h) but now and then this can be 20 or 30 km/h. The standard placement for signals is to the right of the track, but again there are exceptions. Such general rules with infrequent exceptions means the driver must continuously concentrate on his environment, and fight a natural tendency to make assumptions based on routine experience, in order not to get "caught out".

1.2.5 Hazardous incidents on approach to signals

In the present study we were interested in quantifying the occurrence of signal approach occurrences that could represent weak points in the system's defence against accidents. The system we refer to is centered on the train driver's feelings, thoughts and actions, and is made up of interacting human, technical, environmental and organizational factors. The system is responsible for the safe running of trains on the railways.

The following categories of incident were of potential interest:

- *Missed approach signal + ATC alarm*
  The driver fails to see an approach signal causing the ATC alarm to be triggered.
- *Missed approach signal + ATC intervention*
  The driver fails to see an approach signal causing ATC to intervene with automatic braking.
- *Dwarf SPAD*
  The driver fails to see and consequently drives past a dwarf signal in stop.
- *Main SPAD*
  The driver fails to see an approach signal and consequently passes a main signal in stop.
- *Driver missed exit signal*
  The driver presses a button in the cabin (triggering a "permission to drive" indicator on the outside of the train) without checking the station exit

signal when waiting to depart from a platform. (The driver can subsequently have cancelled the indicator before driving on noticing that he had made a mistake).

- *Conductor missed exit signal*
  The driver gets a ”ready to drive” signal from the conductor without having confirmed that he has “permission to drive” from exit signal.
- *Driver and conductor missed exit signal*
  The driver presses ”permission to drive” button without checking the exit signal *and* gets a ”ready to drive” signal from the conductor.

1.3 Incident analysis using CREAM

The Cognitive Reliability and Error Analysis Method (CREAM) method has shown itself to be a promising method for accident analysis in various sectors, including the nuclear industry (Hollnagel, 1998) and road and rail networks (Nordbakke & Sagberg, 2007; Sagberg, 2007a; Sandin, 2008).

The method is based on a model of human cognitive control in the context of complex sociotechnical systems. As such it gives particular consideration to how critical cognitive operations of human operators are helped or hindered by the system of technical, environmental and organizational factors in which they take place.

In a CREAM analysis the analyst must select from a set of pre-categorised antecedents or possible contributing factors. While the researcher’s choice is flexible and the resulting network of antecedents is specific for a given incident, the pre-categorisation means that contributing factors and event pathways can be compared and aggregated across different incidents. Thus, as mentioned earlier, CREAM has the potential to allow lessons to be learned from a collection of case analyses in a systematic way.

Another advantage with CREAM is that it is a progressive tool; it contains rules by which it can be adapted for the analysis of certain types of incident or accident in particular sectors.

The main drawback of CREAM is its resource intensiveness. It takes time to learn and time to apply. Some analysts also observe that it neither defines a timeline for the build-up to an incident nor considers post-incident events, although there is no reason why it cannot be combined with other methods where these aspects are important (Sagberg, 2007b).

Some attempts have been made to assess the inter-rater reliability of the CREAM-derived method DREAM. The results suggested that, while reasonable reliability is achievable, it is important that analysts develop a common understanding beforehand (Sandin, 2008).

1.3.1 How does CREAM work?

At the heart of the method is a large table listing operationally defined factors. Each factor is grouped together with related factors in a category denoted with a letter. For example, fatigue is the first factor belonging to group E, *temporary personal factors*. The different categories are listed in Figure 1.

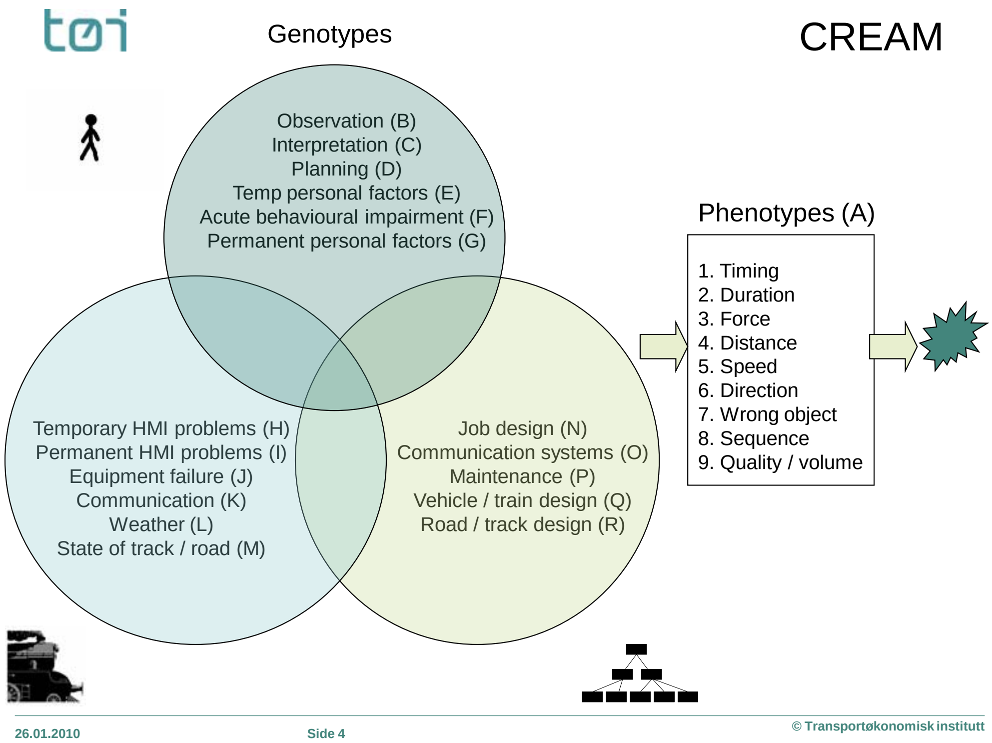

Figure 1. An overview of CREAM. Any one of 17 categories of "genotypes" in the system of human, technical and organizational factors can be expressed as one of nine different "phenotypes". Phenotypes are the observable human action precipitating a hazardous incident, and the genotypes are the less visible antecedents leading up to those human actions. Human; technical/environmental; and organizational genotypes are indicated by symbols of a person; a train; and an organizational hierarchy, respectively. HMI = human machine interface.

As can be seen, categories are pooled into one of four different pools: three "genotype" pools and one "phenotype" pool. In the same way that phenotypes are the visible result of "invisible" genotypes in biology, the visible trigger of an incident, usually an action by a human operator, often has several antecedents that can be hidden in the system. The genotype pools represent human, technical/environmental and organizational factors.

To begin an analysis, the analyst must identify which of nine pre-classified actions or phenotypes precipitated the incident. This process is exemplified here using the excerpt from the CREAM tables shown in Figure 2.

PHENOTYPES (A)			
ANTECEDENTS	**CONSEQUENTS**		
GENERAL Genotypes	**Definition of GENERAL Phenotypes (Critical events)**	**Definitions of SPECIFIC Phenotypes (critical events)**	**Examples for SPECIFIC Phenotypes**
Observation missed (B1) False observation (B2) (added in this version) Faulty diagnosis (C1) Decision error (C3) Inadequate plan (D1) Inattention (EX5) Communication failure (DREAM: between drivers) (J1) Information failure (DREAM: between driver and traffic environment or driver and vehicle) (J2) Inadequate procedure (P1) (CREAM)	**Timing (A1)** The regulation of time for actions to occur.	**Premature action (A1.1)** An action started too early, before a signal was given or the required conditions had been established.	Performing an overtake before there is good visibility. Starting/stopping too early at traffic lights. Dip the lights too early when driving in the dark.
		Late action (A1.2) An action started too late.	Not changing lanes in time.
		No action (A1.3) An action that was not done at all (within the time interval allowed).	Starting an overtaking too late. Dip the lights too late when driving in the dark.
Observation missed (B1) False observation (B2) (added in this version) Faulty diagnosis (C1) Decision error (C3) Inadequate plan (D1) Inattention (EX5) Equipment failure (I1) Communication failure (DREAM: between drivers) (J1) Information failure (DREAM: between driver and traffic environment or driver and vehicle) (J2) Inadequate procedure (P1) (CREAM)	**Duration (A2)** Continuance or persistence in time, of an action.	**Prolonged action/movement (A2.1)** An action that continued beyond the point when it should have been terminated.	Staying in the left lane too long after having performed an overtake.
		Shortened action/movement (A2.2) An action that was stopped before it should have been.	Squeezing in just in front of a vehicle which one has just been overtaking. Not completing braking at stop signs.

Figure 2. Excerpt from a CREAM table (Sagberg, 2007b)

For an incident in which the driver braked too late before reaching a signal, we would choose *Timing* (phenotype A1) as the point of departure for our analysis. We must then work backwards from this phenotype by choosing from a list of corresponding genotype factors, which according to CREAM are reasonable antecedents to a timing problem. If we thought that the driver braked too late because he did not see a signal, we would choose the first factor in the list *i.e. B1 observation missed*.

On choosing *observation missed*, we turn to that part of the table listing category B factors (not shown). We are again faced with a list of possible antecedents, and this time we choose the most suitable antecedent to *observation missed*. We continue choosing antecedents in this way until we build up a chain of genotypes (antecedents) leading to the phenotype.

Because each particular genotype can lead to several other genotypes, and we can choose more than one genotype as an antecedent to a particular genotype or phenotype, our antecedent chain is often linked to other chains. The result is a non-hierarchical network of antecedent chains, which hopefully gives fresh insight into the systemic causes of the analysed incident.

1.3.2 Is CREAM useful in practice?

We consider that CREAM has important potential in that it allows analysts to aggregate findings from case study analysis of similar incidents. Indeed, attempts at aggregating analyses from car accidents have already been demonstrated (Sandin, 2008). However, there have been no attempts at aggregating findings from railway incidents.

Ironically, our ability to compare analyses across domains using CREAM is compromised by one the method's strengths, namely that it can be tailored for use in specific fields by adding or altering factors and categories. Sagberg (Sagberg, 2007b) attempted to collect and revise the different available taxonomies in order to conserve the method's potential for aggregating analyses from different domains. Sagberg's revised taxonomies are employed in this report.

Since it is still in early stages of development as an incident analysis tool, there are undoubtedly methodological issues to be addressed when using CREAM in practice. We also attend to these in our analyses.

Important questions here include the following.

- Is the method valid for analysis of signal approach incidents i.e. do the factor selections we are faced with make sense in relation to the course of the incidents analysed?
- Are there important factors missing from the CREAM tables which nevertheless seem to play a role in the build-up to a signal approach incident?
- If we structure the collection of data from drivers involved in incidents using CREAM, are these data sufficient or are there still important missing data?
- Does the method give useful insight into possible hidden causes of signal approach incidents?
- Can this insight be used to give useful recommendations to the railway organization?

1.4 Aim of this study

The present report attempts to build on the findings of Nordbakke & Sagberg (2007) in the following way:

1. Classify and quantify the occurrence of different signal approach incidents using the self-reports of train drivers.
2. Analyze common signal approach incidents using CREAM.
3. Aggregate the findings from those incidents in order to identify any common antecedent chains.

Particular questions we try to answer in this report are:

- What is the occurrence of different hazardous incidents in which drivers are involved?
- What are the advantages and disadvantages of using CREAM for the analysis of hazardous incidents involving train drivers?
- Can CREAM be used to derive a meaningful aggregated analysis of hazardous signal incidents?
- Do hazardous signal incidents have common antecedents?
- What recommendations can be made about preventing hazardous signal incidents as a result of the CREAM analyses?

2 Method

The research was carried out in four stages.

1. Background research
2. Train driver surveys
3. Train driver interviews
4. Data analysis

The first three stages were coordinated in conjunction with the relevant train driver leader, who acted as sponsor at NSB.

2.1 Background research

The following background material was used to gain insight into the requirements placed on the driver on approach to a signal:

- *NSB Skolen. Trafikkregler ved jernbanen.* An introductory handbook to train driving.
- NSB train driver's traffic safety handbook
- Excerpts from NSB incident database (Synergi)
- A copy of law number 1336 concerning signals and signs on the state railway network and associated private tracks.
- Regional monthly report on traffic safety and punctuality (September 2008)
- Edition of *Til ettertanke* ("On reflection") newsletter concerning signal safety; issued by regional train driver units.
- Copy of *ATC braking curves* pamphlet from NSB

Considerable background information was collected during the case study interviews, particularly concerning culture (representative statements have been collected and are presented in Appendix 1).

Finally, the analyst spent half a day in a NSB driver simulator to experience ATC interventions and the driver processes involved in signal approaches.

In addition to reading the original CREAM book (Hollnagel, 1998), the analyst had attended a training course in the use of a related method, DREAM, and subsequently carried out several analyses using that method.

2.2 Train driver surveys

A survey was sent out to 115 drivers in order to quantify the occurrence of different types of hazardous incidents on approach to signals. The survey was accompanied by a cover letter (Appendix 2) and a sheet giving background information about the project (Appendix 3).

The survey (Appendix 4) asked the driver if they could recall being involved in any of five different types of incident (a) within the last month or (b) within the last 1 to 3 months.

The same survey was sent out to the same drivers at three time points: in December, 2008; March 2009; and September, 2009. Only the first survey also asked drivers about incident involvement in the previous 3 to 12 months.

At the end of each survey, each driver was asked to indicate whether they would participate in a research interview.

2.3 Interviews

After each survey round, responses were collected and analysed. All consenting drivers indicating recent involvement in "*Missed approach signal + ATC intervention*", "*SPAD*" or "*driver missed exit signal*" incidents were invited to interview (Appendix 5). The interview took place at their work base just before or just after each driver's shift. Drivers were paid overtime for the time used during the interview.

The interview questions were guided using a template based on the CREAM method (Appendix 6). The researcher recorded the driver's responses by taking notes. Most interviews were also recorded digitally. The CREAM tables were consulted as necessary during the interview. Each interview lasted between 60 and 90 minutes.

2.4 Research evaluation

A research evaluation survey was sent along with the final survey sent to each driver. The aim was to improve future research communications, and as such the results from this evaluation are not included in the main body of this report (they are, however, given in Appendix 7). Responses to one question, about work-related issues that drivers believe are important, are included as a separate section in the results (3.4) because it is relevant to the current research.

2.5 Data analysis

Descriptive statistics were calculated to summarise data from each survey round. A CREAM analysis was performed on each set of interview notes using the CREAM tables described by Sagberg (2007b). The method was used inflexibly *i.e.* no attempts were made to change category links where they were not described by the method. We consider this to be important if a meaningful assessment of the method is to be presented.

Once an antecedent description had been obtained for each incident, antecedents were aggregated by taking all factors suggested as a possible cause in at least four different incident analyses.

3 Results

3.1 Frequency of signal approach incidents

Out of 115 drivers, 31 per cent responded in December 2008, 30 per cent in March 2009 and 18 per cent in September 2009.

Tables 1 to 5 give data on the percentage of drivers that could recall involvement in different signal approach incidents. There is some support that the self-reports were valid in that there is an increase in the percentage of drivers saying they were involved in an incident in line with an increase in the length of period concerned. For instance, Table 2 shows that the percentage of drivers involved in a *missed approach + ATC intervention* was 3 per cent over a one month period, 8 per cent over a two month period, and 22 per cent over a nine month period. Despite this trend, Table 1 to 5 also suggest that driver recall of incident involvement 3 to 12 months ago is on the whole weaker than recall for the more recent periods.

The different incidents described were evenly distributed among different drivers. There is in other words little to suggest that a minority of “bad drivers” are responsible for a majority of incidents in this sample.

A considerable proportion of drivers reported involvement in *missed approach signal + ATC alarm* incidents. In a nine month period prior to September 2008, 36 per cent of drivers had experienced at least one such incident (Table 1).

Table 1. Missed approach signal + ATC alarm. Percentage of drivers in period failing to see an approach signal with the result that the ATC alarm was triggered. The drivers were told that they need not have driven past the main signal as a consequence.

	Dec 08 (n = 36)
Last month	3
1-3 months ago	17
3-12 months ago	36

According to answers we received in the first round of interviews, an ATC alarm is not at all an uncommon event. Many drivers use ATC to tell them when they are driving too fast, and in this way ATC helps them “feel” how to drive (see Appendix 1). It is important to note, however, that those drivers answering “yes” had been asked whether they had *missed a signal* when the ATC alarm is sounded. This question was dropped from subsequent surveys because it became clear from the first interviews that, because of the frequent occurrence of an ATC alarm, drivers would not be able to recall this type of incident very well.

A substantial proportion of drivers also reported involvement in a *missed approach signal + ATC intervention* incident (Table 2).

Table 2. Missed approach signal + ATC intervention. Percentage of drivers failing to see an approach signal with the result that ATC intervened with automatic braking. The drivers were told that they need not have driven past the main signal as a consequence.

	Dec 08 (n = 36)	Mar 09 (n = 35)	Sep 09 (n = 21)	average
Last month	3	9	5	5
1-3 months ago	8	17	14	13
3-12 months ago	22	--	--	--

An average of five per cent reported experiencing such an event in the month prior to each survey, presumably when recall was easier. 22 per cent of drivers reported experiencing this event over a nine month period. Given these figures, it seems reasonable to conclude that over the course of a year at least one in four drivers miss an approach signal with the consequence that ATC system intervenes.

It is striking that the share of drivers reporting ATC interventions following a missed signal was not substantially lower than that share reporting an ATC alarm following a missed signal. This observation is important because it could mean that drivers might often fail to attend to ATC alarms following a missed signal, with the result that the ATC system intervenes. However, our initial interviews with drivers suggested that they were more likely to remember *missed approach signal + ATC intervention* incidents than *missed approach signal + ATC alarm* incidents, largely because the former occur less often and are considered more serious. It is therefore possible that the latter incident was underreported.

As expected, SPAD incidents did not occur very often. None of the drivers reported that they missed and drove past main signals showing stop.

On average, only one per cent of drivers failed to see and consequently drove past a dwarf signal showing stop, both for the month leading up to the survey and for the two months before that.

The proportion of drivers reporting pressing a button in the cabin to trigger the external "permission to drive" indicator when the exit signal in fact showed stop is given in Table 3.

Table 3. Driver missed exit signal. Percentage of drivers indicating "permission to drive" without seeing the exit signal (even if the driver then cancelled the indicator before driving).

	Dec 08 (n = 36)	Mar 09 (n = 35)	Sep 09 (n = 21)	average
Last month	6	6	10	7
1-3 months ago	22	29	33	27
3-12 months ago	28	--	--	--

An average of seven per cent said they had done this in the month leading up to the survey. Over one in four (27 per cent) said they had done it in the two months before that. The normal system in which drivers operate thus seems to be such that a substantial proportion of drivers could over time be expected to trigger the "permission to drive" indicator erroneously, a fact which is all the more concerning when one considers that an average of 17 per cent of drivers report that within the last month a conductor has given them a clear signal with the exit signal still showing stop (Table 4).

Table 4. Conductor missed exit signal. Percentage of drivers getting a "ready to drive" signal from the conductor without having confirmed "permission to drive" from exit signal.

	Dec 08 (n = 36)	Mar 09 (n = 35)	Sep 09 (n = 21)	average
Last month	--	14	19	17
1-3 months ago	--	23	43	33

Given that the conductors should check both that the driver's indicator has been triggered and that the exit signal is green, this statistic is concerning and merits further investigation.

Reports from drivers of incidents in which both the driver and conductor have failed to act in accordance with the exit signal are given in Table 5.

Table 5. Driver and conductor missed exit signal. Percentage of drivers both indicating "permission to drive" without getting an exit signal and getting a "ready to drive" signal from the conductor

	Dec 08 (n = 36)	Mar 09 (n = 35)	Sep 09 (n = 21)	average
Last month	6	0	19	7
1-3 months ago	6	0	0	2
3-12 months ago	0	--	--	--

It is difficult to draw conclusions about the general occurrence of these incidents because there is no consistent pattern over time, and the numbers responding are low.

3.2 CREAM analysis of signal approach incidents

Across the first two surveys[2], 47 per cent of drivers returning a survey consented to an interview. Analysis showed that the responses of these drivers were not significantly different from those drivers not consenting to an interview.

Drivers were invited for interview as described in section 2.3.

Twelve interviews were carried out. Of these, only ten were subsequently analysed. One of the drivers decided to withdraw during the course of one of the interviews; the data collected from one of the other interviews were regarded as insufficient for in-depth analysis.

[2] Drivers were not interviewed after the third survey.

Of the analyses that follow, seven are of *missed signal + ATC intervention* incidents (cases 1,2,4,5,8, 9 and 10), two are of *dwarf SPAD* incidents (cases 3 and 7), and one is of a *driver missed exit signal* incident (case 6). However, all are signal approach incidents and therefore suitable for the aggregated analysis which follows the individual case analyses.

In all analyses, place names are not given and drivers are referred to as male for the purposes of identity protection. Unless stated otherwise, all incidents occurred in the three months prior to the interview.

3.2.1 Case 1

On the approach to a station area, the driver reported that he failed to observe an approach signal showing “expect to proceed on a different track” (two flashing lights: one green and one yellow). This meant that he did not apply the brakes in order to slow down to 40 km/h so that he could change tracks safely at the set of points following the subsequent main signal. Instead, he continued on towards the main signal and subsequent points at what he called “normal operational speed”, although he could not recall what this was.

Before the train reached the main signal the ATC system detected that the train was going too fast and intervened, applying operational brakes (*driftsbremser*) to slow the train down before it changed tracks. The train changed tracks without further incident.

The driver said he remembered thinking that the approach signal would show “expect to proceed on the same track” (a single flashing green light). He had driven past it many times and had nearly always been allowed to proceed through the station in question without diverging. He said that what had “tricked” him was that his was the last train, and was therefore diverted at the station. He was not used to driving the last train through this station.

The driver had between ten and 20 years of experience with NSB, and was very familiar with the route in question. He said he had not being tired when the incident happened. The incident happened ten months before the interview. He could not therefore remember whether he had been on duty long before the incident happened. The driver reported that he did not think too much about the incident afterwards, since ATC interventions with operational brakes were not uncommon and not necessarily viewed as dangerous. Commenting on this type of incident, he said,

“Nothing could be done to prevent these (types of) incidents, either we see the signals or we don’t”.

Interestingly, he also commented that since he was one of the older train drivers, he had learnt how to drive without ATC. He did not therefore rely on ATC as much as some of the more recently trained drivers. The lower dependence on ATC might have partly explained why he did not respond to the audible and visual warnings that ATC should have emitted before intervening with operational brakes. However, he also said that it was normal to drive as fast as ATC *allowed you to go*, which does indicate reliance on ATC.

3.2.1.1 Results of the CREAM analysis

The output from the CREAM analysis of case 1 is given in Figure 3.

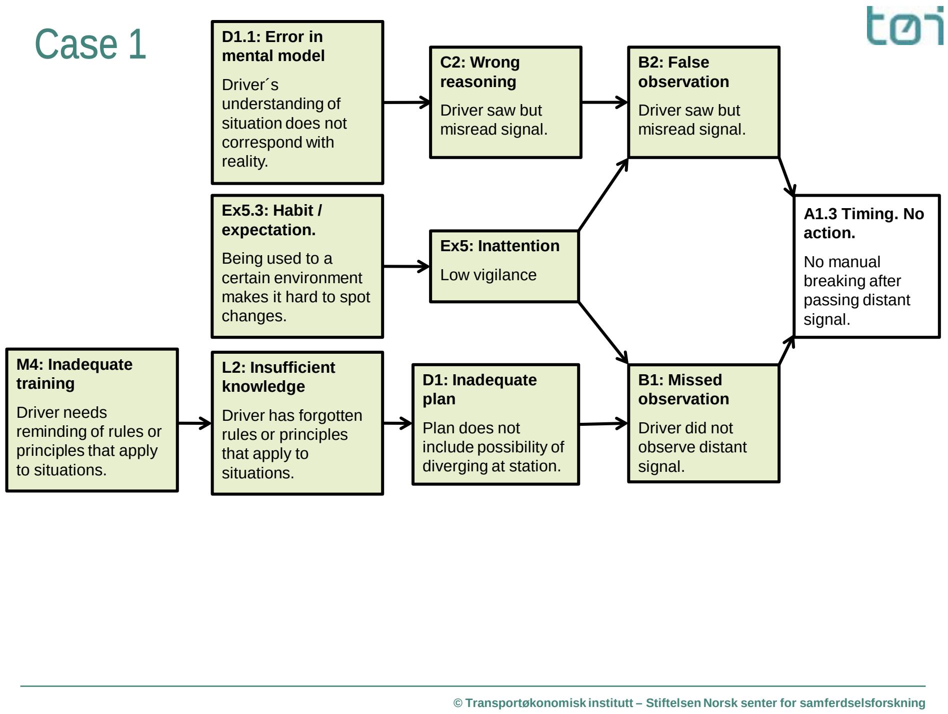

Figure 3. Output from CREAM analysis of Case 1. The clear box shows the visible or precipitating behaviour ("phenotype") resulting in the ATC intervention incident. According to the analysis, this behaviour in turn resulted from the antecedent events or conditions proposed in the shaded boxes. These antecedents are possible contributing factors rather than definite causes.

The "phenotype" chosen for the analysis was **Timing: no action**, since the driver did not brake after passing an approach signal showing "proceed on a different track". The driver's lack of action was almost certainly because he failed to consciously observe that the green and yellow lamps were flashing on the approach signal. There are in turn two possible explanations for this: either he did not see the signal (**missed observation**) or saw the signal but misinterpreted it (**false observation**).

A **missed observation** would have been more likely to occur if the driver had an **inadequate plan** for this part of the journey. In other words, before approaching the station the driver was minded to proceed through the station on the same track, thus lessening the need to attend to the approach signal. That the driver did not know or had forgotten the last train was usually diverted at the station suggests there was **insufficient knowledge** about the situation, and this may have contributed to the formation of an inadequate plan. This implies that refresher **training** by the organization, to remind drivers about uncommon but dangerous deviances from routine situations, may have possibly helped this driver to "re-set" his plan for driving through the station.

It is likely that **inattention**, due to routine exposure to this signal in an unchanging state (**habit and expectation**), would also have been a contributor to any **missed observation** of the signal by the driver. **Inattention** is evidenced by the lack of response to the ATC alarm, while **habit and expectation** is evidenced by the driver's experience in this area and his claim that he expected to go straight on.

As noted, it is also possible that the driver *saw* the signal, albeit briefly, and then misread it (**false observation**). This would have been possible if he had subconsciously excluded the possibility that the approach signal would show "proceed on a different track" at this station, again because of his routine exposure to the signal in a certain state. Indeed, there is research evidence that such "top-down"-directed processing of perceptions, which is built up to allow more efficient processing of information in unchanging environments, can lead to quite fundamental observational errors when the environment eventually changes (Hollnagel, 1998). In this case the mental model built up over time was inappropriate (**error in mental model**) because it did not apply in a deviant signal situation. This led to **wrong reasoning** about the state of the signal. **Inattention** causing lower than normal vigilance would have increased the likelihood of the driver's reliance on top-down processing, and thus his probability of making a false observation.

3.2.1.2 Implications

Two threads of factors are suggested by the analysis, depending on whether the driver did or did not see the signal. Both threads suggest that the driver formed an incorrect picture of the upcoming situation. The driver seemed to make a subconscious assumption that the signal would allow him proceed straight on, as it normally did, and based all subsequent cognitions on this assumption. It is instructive therefore to ask why this assumption was made.

There is a high chance that a driver exposed to a signal in an unchanging condition hundreds or even thousands of times will begin making assumptions about the state of the signal. The checks made about the state of the signal will tend to become more cursory with each successive exposure if the signal is always in the same state. Even if we can say that the driver then has an error in his mental model with respect to the signal in a deviant state, the fault does not necessarily originate in the driver's mind, but rather in the system that allows incorrect mental models to be reinforced through routine driving without challenge or correction.

Some sort of continuous training to prime the driver's mind is implied that would challenge and help reset any faulty models or plans that may build up in the driver's mind through routine. In this case, such training could have served to remind the driver that last train tended to be diverged at this station. Procedures could have been put in place to remind the driver before he started his duty. Some way to draw extra attention to more non-routine signals would also have helped the driver.

The broader implication is that ways should be found to make drivers vigilant about unexpected changes in signals.

Earlier attention by the driver to the warnings emitted by the ATC system would clearly have lessened the risk in this incident. In addition to the missed signal, this was an additional barrier that failed. However, comments from this and other drivers lead us to believe that it is not al all unusual for ATC to intervene with operational brakes in everyday train driving. Indeed, some drivers seem to use the alarm to help them "feel" the speed limit. This may be a completely correct and normal way to drive, but it lessens the psychological impact of the ATC alarm when it is triggered in potentially dangerous situations.

This analysis is not definitive and should be regarded as suggestive. Based solely on driver recall we can not be certain about the results of the analysis i.e. the driver says he cannot remember ever hearing or seeing the ATC alarm, but one might question whether it would be possible to remember whether or not he had seen it after several months had passed.

3.2.2 Case 2

This incident occurred between 18.15 and 18.30 in a tunnel through which the train passed at too high speed past a signal showing "proceed on a different track". The driver had been driving for six or seven minutes through the tunnel at the speed limit of 160 km/t. The speed limit at the approaching set of points was 80 km/t and so the driver began to slow the train. As he passed a set of transponders situated between the signal and the points, the ATC system intervened in order to slow the train down before it reached the points. The driver felt the intervention "was sudden and severe". The driver said that he could not remember how fast he had been driving, and reported feeling very surprised that ATC had needed to intervene. The train proceeded without further incident.

The driver had five to six years of experience, and drove this route several times a week. The driver said he knew he had to drive at 69-79 km/t along this stretch, and could not understand why he had been driving too fast on this occasion. He said that he had had a good understanding of the situation:

"The signals were easy to see, I knew that I would divert onto a different track (on reaching the points), and I knew the (speed) limit at the points."

Despite acknowledging that he must have had surplus speed, the driver maintained that he was in control of the situation. He thought that the ATC system had been over zealous.

"I have driven that stretch a thousand times. ATC is a little fussy, it can intervene too fast sometimes."

The driver was relatively recently educated, and therefore had learned to drive using ATC. He explained how he relied on ATC to help judge his speed and drive efficiently.

"I calculate how far I can drive at a certain speed before ATC takes me. But ATC can often take you before (you change speed). You use ATC to drive against the (speed) limit."

In explaining what had happened, the driver said that the distance between the signal and point of speed measurement by ATC was unusually short on this stretch. He said he must have assumed that the distance between the signal and point of measurement would be longer, as it is normally.

Despite being familiar with this stretch of track, the driver claimed it was not always possible to remember every specific local deviation, because it was often necessary to drive using instinct.

"It has to do with routine. You don´t always look at the speed. That´s more important when you´re going though a station area."

"This had a lot to do with local knowledge. There ought to be standardization of the distance between the triangular sign that says how fast you should go and the actual point of measurement."

The driver was coming to the end of his duty, having begun at 11.30 that morning. He remembered feeling tired at the time of the incident, but did not think this played a large role because he had felt alert. He rather emphasized how much he had been looking forward to the upcoming break.

"It was just before my break. Maybe I began too early, maybe I hurried towards my break, I'm not sure."

There was nobody with him in the cabin at the time of the incident.

3.2.2.1 Results of the CREAM analysis

The output from the CREAM analysis of case 2 is given in Figure 4.

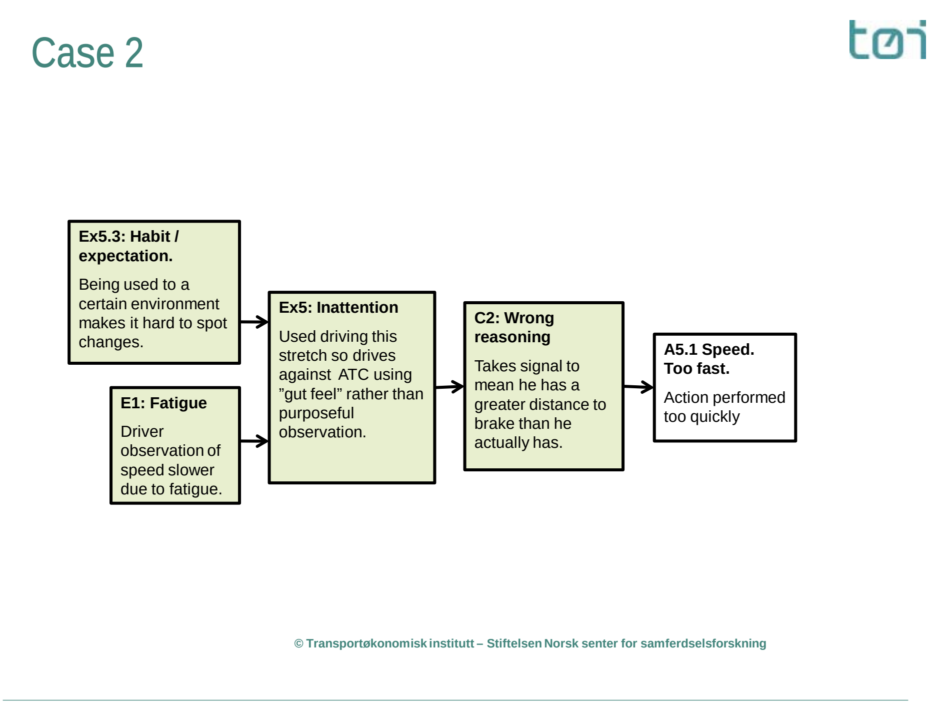

Figure 4. Output from CREAM analysis of Case 2. The clear box shows the visible or precipitating behaviour ("phenotype") resulting in the ATC intervention incident. According to the analysis, this behaviour in turn resulted from the antecedent events or conditions proposed in the shaded boxes. These antecedents are possible contributing factors rather than definite causes.

The phenotype **speed** was chosen as the phenotype rather than timing: too late action, because the driver started to brake after observing the signal. Clearly aware of the speed limit and approaching track change, the driver did not appear to miss any observations or make any false observations that could explain his surplus speed. Rather, the driver used **wrong reasoning**, assuming, albeit subconsciously, that the signal meant he had longer time to break before ATC "took him" than he actually did. This meant that he had surplus speed on reaching the point of measurement.

Although the driver claimed that the incident was about having local knowledge, he had driven through the same junction without incident hundreds of times before. When looking for possible causes of his faulty diagnosis we can see, however, that he had several possible reasons to be inattentive (**inattention**). Although he said he was alert, we include the possibility that his being **fatigued** may have led to this inattention. This is because he admitted being tired and he had been approaching the end of his shift. Indeed, the driver emphasised being distracted by the thought of ending his shift. Both **fatigue** and **distraction** could have led to inattention, increasing his tendency to drive using instinct, and making him less likely to deliberately watch his speed. (The method does not allow us to link distraction to inattention.) Using slightly more instinct than normal would have increased his dependence on generalizations made from **habit and** his **expectations** based on how things are normally. In other words, he might have assumed that the distance between the signal and point of measurement was longer, as it usually is in other places.

3.2.2.2 Implications

When we are tired or distracted by other events, we are more likely to rely on schemas of how things are generally, and apply them in order to perform a specific task with less resource. Even though selection and training may serve to reduce the *extent* to which this tendency occurs in train drivers, it will inevitably occur from time to time. The CREAM analysis suggests that in this case a schema about the standard amount of time used to slow down from signal to point of measurement has been applied incorrectly in a deviant situation in which the signal is placed a shorter distance than normal from the point of measurement. The schema may have been invoked because the driver was distracted and fatigued.

But why had the driver never made the same mistake before at this signal? It is unlikely that he had never before been tired and starting to look forward to the end of his shift on at least one occasion out of the hundreds of other times in which he would have passed this signal. One explanation is that it takes time for a schema established through routine braking at other signals to be formed. Thus the driver may only recently have applied it on being distracted or fatigued.

Accepting that the formation of schemas is an inevitable human tendency leads one to consider that the ATC system is a useful corrective mechanism for the driver. The driver himself clearly regarded ATC as useful in this way.

The incident seems to have stayed with the driver because the ATC intervened so suddenly, and we can assume the driver has learned, at least temporarily, to remember the deviant braking distance at this signal. However, if one regards both driving below the speed limit and the ATC system as barriers in the defence against SPAD incidents, then it would be preferable if drivers did not learn in this way. One solution would be to standardize the distance between signal and measurement point, but the downside of this is that it would increase the routine the drivers are exposed to, and may even increase boredom for the driver. A better solution would therefore be to draw the driver's attention to the abnormally short distance between signal and measure point.

Finally, it is notable that the incident was not reported in Synergy. This leads one to question how other drivers learn from the incidents such as this.

3.2.3 Case 3

This was a SPAD incident occurring while the driver pulled away from a station area at 01.30 in the morning. While waiting at the station platform, the driver had received a telephone call in the cabin informing him that due to maintenance work on the line ahead he would be diverted from the normal route. Instead of proceeding on the same track on exiting the station, the driver was to be diverted onto the track normally used by oncoming trains.

The driver waited at the station for an oncoming train to clear the stretch of track before receiving permission to exit the station. On leaving the station the driver´s train was diverted into a relatively complex multi-track environment. It was here that the driver approached a station exit (*utkjørings*-) signal showing red (stop). Unusually, the signal was situated to the left of the driver's track, presumably because spatial limitations prevented it from being placed on the more usual right. Despite searching extensively and driving at a low speed (10 km/h), the driver failed to recognize until too late that the signal applied to his stretch of track. The train drove a short distance (1 m) past the stop signal and so the driver was taken out of service.

The driver said that it had been difficult to identify the relevant signal because an arrow telling the driver which track the signal applied to had been difficult to see. The arrow was small, had been placed at the bottom of the signal stack and was poorly illuminated.

The driver had 24 years of experience. This was his first SPAD incident. The driver said that he knew from a flyer the organization had sent out that there had been some changes made to the track environment in this area, so had been focused and attentive on leaving the station. The driver commented that:

> "*you feel a station rather than memorise it, so if you know that you are not familiar with an area, you make sure you are try and aware of any changes*".

The driver said that it was very difficult to accept what had happened because he felt he had done everything possible to avoid a mistake, but had been let down by insufficient information about the unusual signal. Commenting on the lack of awareness during changes the driver felt that it was not untypical:

> "*In my experience the drivers are very strict and have high safety morals; sometimes it is as if the surrounding environment does not support this.*"

The arrow was changed as result of these and other SPADs at this signal, so that it is now higher up on the signal, larger and better illuminated.

3.2.3.1 Results of CREAM analysis

The output from the CREAM analysis of case 3 is given in Figure 5.

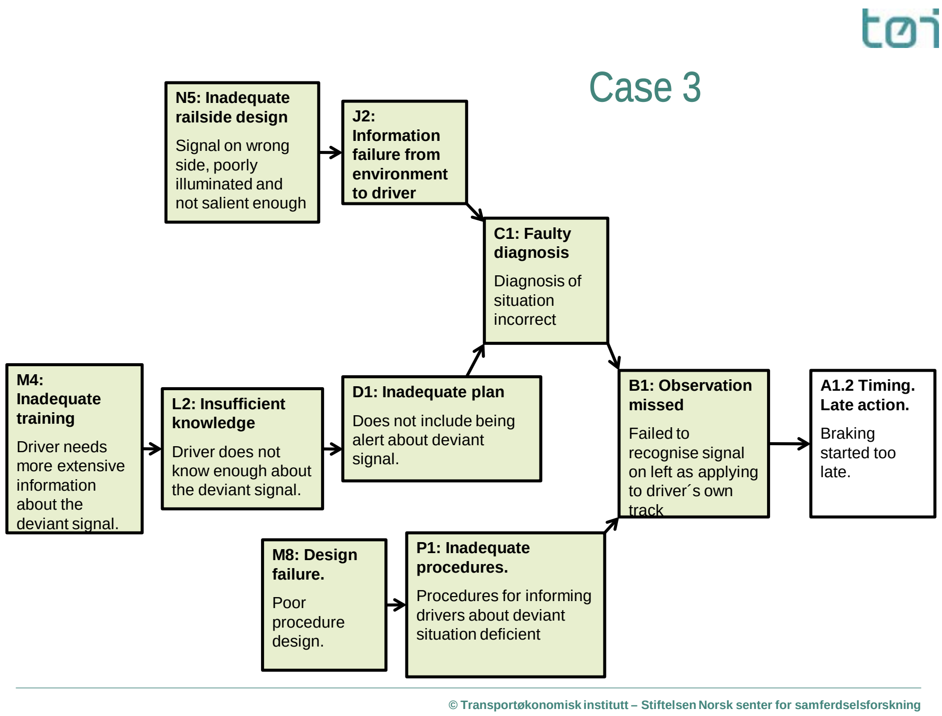

Figure 5. Output from CREAM analysis of Case 3. The clear box shows the visible or precipitating behaviour ("phenotype") resulting in the ATC intervention incident. According to the analysis, this behaviour in turn resulted from the antecedent events or conditions proposed in the shaded boxes. These antecedents are possible contributing factors rather than definite causes.

Timing: too late action is chosen as the phenotype because the driver braked too late to stop before passing the signal. The delay in action was caused by the **missed observation** of the stop signal situated on the left hand side of the track. Two antecedent chains leading up to the **missed observation** are suggested by the CREAM method.

The first chain describes that the driver thought it was ok to proceed because he diagnosed that there was either no signal for his track or one of the signals on the right applied to his track. This **faulty diagnosis** was made because (a) the applicable signal was inadequately labeled and one of several in a confusing multi-track environment taking insufficient account of the limitations of human perception (**information failure from environment**); and (b) the driver was not told enough about the location of the deviant signal (**insufficient knowledge**) and therefore had an **inadequate plan** for driving on this stretch of track.

Organizational antecedents are suggested for both factors leading to the driver's faulty diagnosis: **inadequate rail design** and **inadequate training**.

The second chain of antecedents leading to the missed observation of the stop signal is rooted in **inadequate procedures** for the work going on around the station. The procedures were inadequate because they did not take sufficient account of the effect of the changes to the station area on the driver's ability to perceive signals on being diverted through the station. An adequate procedure would have warned the driver about the possibility of being diverted onto a track with a deviant (left-hand side) stop signal. Here an organizational precedent is suggested in terms of procedure design (**design failure**)

3.2.3.2 Implications

Where an alert driver clearly struggled to understand a deviant situation, the method points to several improvements at organisational level. Perhaps the most effective change would be to change track signals so that all conform. Accepting that this is impractical due to physical constraints, the next possibility is to make deviant signals very salient to be sure they can easily be picked out by the driver in complex environments.

One way to improve design procedure would be to better attend to sociotechnical principles, one of which holds that drivers (end users) should be fully consulted before and after deviant signals are set up. Indeed, procedures which consider carefully how any change to the track environment might impact the driver, with corresponding action to help the driver, would be useful. A representative selection of drivers could be consulted, who could get to “blind test” signals by driving a train through the track environment in a changed state. This would clearly depend on resource availability and possibly closer cooperation between those responsible for the track and those responsible for the running of the trains (Nordbakke & Sagberg, 2007).

On a related point, training is suggested to increase driver identification of deviant signals. Such training could take the form of more detailed briefing at driver meetings or before individual drivers start their shift. Preferably, drivers would also be reminded by the train dispatcher who diverts them into the path of any deviant signal.

3.2.4 Case 4

The incident happened at about 08.00 in October on a stretch at which the train stopped at a platform for staff use in between the approach and main signals. The incident happened four months prior to interview.

The driver estimated that the distance between the approach and main signals was 800 m. The main signal was placed before a set of points at the entrance to a minor passenger station (*innkjøringssignal*). Before reaching the staff stop, the driver had driven a long stretch at 130 km/t. The driver stopped at the staff stop for about 30 s, and on leaving expected to proceed through the upcoming station area as he usually did, without diverging onto another track. However, on this occasion there was maintenance work on the track ahead, and so there was a diversion at the points.

The driver reported that he could not remember recalling what the approach signal before the staff stop had shown, and the ATC panel in the driver cabin did not help as it is reset every time the train stops at a platform. Because of the diversion the main signal in fact showed “proceed on a different track”. A set of transponders, placed some distance before the main signal, did not detect that the train was going too fast because its speed was still relatively low (ca. 30 km/t) while it was accelerating away from the staff stop. However, these transponders would have resulted in the driver's panel being updated, showing the driver that the oncoming signal showed "proceed on a different track". The driver failed to see this on the panel and failed to see the oncoming signal in time. On reaching the next set of transponders, situated next to the main signal, the driver estimated his speed to be 70km/t. At this point the ATC system intervened with emergency brakes because the speed limit at the oncoming set of points was only 20 km/t.

The driver had 12 year's experience. He drove along this stretch two to three times every week. The driver reported that his expectation was important.

"I remember that I had a hundred per cent expectation that I would go straight ahead. It was remarkable because you normally check (the signal) two or three times."

The driver had gotten up that day, between 02.30 and 03.00. He began work at 05.00. He commented that this was the first early shift of several, and that it was always difficult to get enough sleep for the first early shift.

The driver reported that the placing of the stop between the approach and main signal was a key factor:

"The approach signal is before that stop. So you stop and speed is totally out of your head. This is one of the risks that everyone knows about that are not accounted for by the system."

The incident took place in the autumn, when the tracks were very slippery due to wet weather and leaves on the line. The driver reported that leafy trees lined the route between the staff stop and the set of points afterwards, and that this increased the braking distance by two or three times. His thoughts were therefore occupied by the bad conditions throughout his duty that day. In particular, because he knew this area to be particularly bad, he remembers pulling away from the station without wanting to "let the wheels slip and the motor overwork". The driver's train was a "double set" and so heavy. The driver had been trained not to damage the train when the conditions were slippery. The message he remembered was "leave the engine as you find it".

The train was full and the driver remembers feeling that he had no time to spare. He also reported, however, that he liked this feeling, because it kept him focused throughout his duty.

The driver recognizes that he should have noticed the ATC system update on his panel but stressed again that he was focused on the track conditions. Regarding the main signal, the driver said that his focus was possibly too much inside the cabin, on precisely controlling the acceleration using his controls and listening to the sound of the engine, rather than being directed outside the cabin on the signals.

Again, routine and time pressure was highlighted by the driver as a main problem.

"When you get to know a stretch, you drive on the edge (of ATC). It can happen that the system intervenes without you even noticing."

However, the driver was not certain whether routine or focus on the weather was the most important factor in the incident.

The driver was alone in the cabin at the time.

The driver reported feeling uncomfortable afterwards because if it hadn't been for the intervention by ATC there was a risk of derailing. He had thought a lot about the incident, and he thinks he has learned from it.

3.2.4.1 Results of CREAM analysis

The output from the CREAM analysis of case 4 is given in Figure 6.

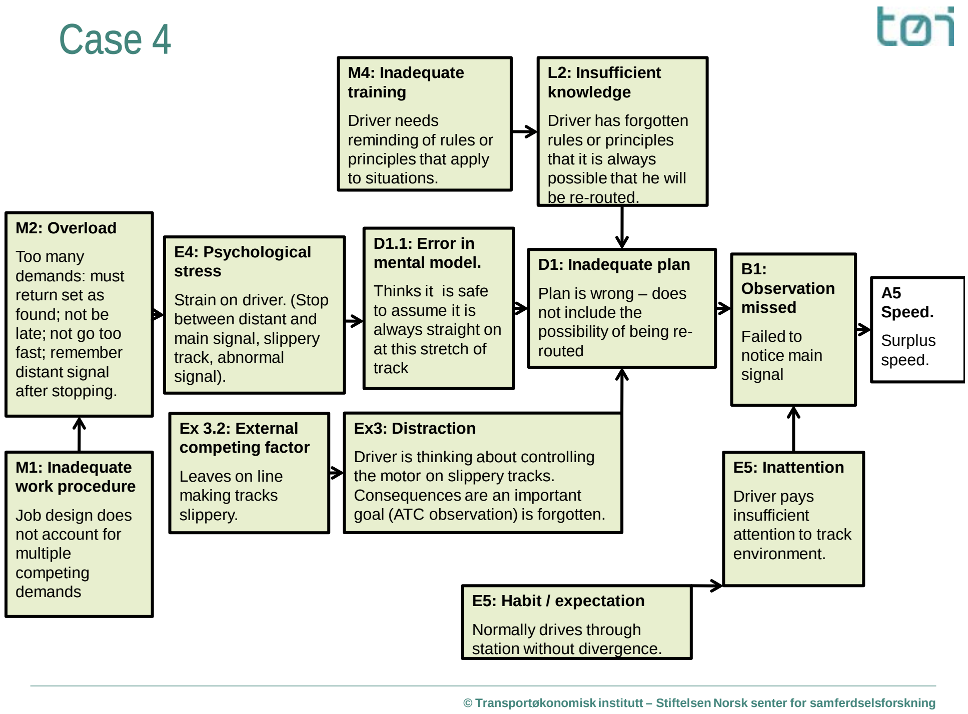

Figure 6. Output from CREAM analysis of Case 4. The clear box shows the visible or precipitating behaviour ("phenotype") resulting in the ATC intervention incident. According to the analysis, this behaviour in turn resulted from the antecedent events or conditions proposed in the shaded boxes. These antecedents are possible contributing factors rather than definite causes.

Surplus speed is selected as a phenotype because the driver drives too fast towards the points and does not take any braking action. The driver drives too fast because he does not observe the main signal (**observation missed**). The analysis suggests two antecedent pathways which could have been responsible for this.

First, the driver's missed observation could have been caused by having an **inadequate plan** for this part of the tour as he approached it. This antecedent chain implies that the driver generally did not plan for the possibility of being re-routed at this station. This was because a focus on effective train operation increased his reliance on a schema of how the signal aspects usually are when he passes through the station. The change in focus was due to the **distraction** of controlling the train in the presence of an **external competing factor** (wet leaves on line). He had forgotten to prioritise safety tasks (signal checking) over other tasks (not slipping; making up for time). In terms of the analysis model this forgotten knowledge might usefully be labeled **insufficient knowledge**, which has an organizational precursor in terms of **inadequate training**. The method alternatively offers that a deficient plan could have developed from an **error in** his **mental model** saying that one always proceeds on the same track through this station. The tendency to self-monitor for this error would have been reduced by **psychological stress**, in turn caused by having too many tasks when passing through the station. At the time of this specific incident there is indeed evidence of **overload:** the driver has too many simultaneous tasks e.g. trying not to slip, making up for time, stopping at the staff stop, remembering the approach signal. The analysis further suggests that the **work procedure** does not account for too many competing demands in this situation.

A second antecedent pathway leading to the missed observation of the main signal is **inattention** concerning the signal environment due to the expectation that he would drive through the station without being re-routed as he normally did (**habit/expectation**).

3.2.4.2 Implications

Two chains of antecedents are suggested by our analysis. The main one suggests that due to the presence and possible prioritizing of several distracting factors, the driver seemed to rely too much on a schema he had formed about how he normally proceeded through the station. This schema had been formed from repeated exposure to the same process i.e. passing through the station without diverting.

One way to prevent similar safety failures occurring is to implement more frequent refresher training, to remind drivers to always prioritise safety over punctuality and slippage and make signal checking more salient in the driver´s mind. Another solution is constructive on-the-job feedback of how the driver drives, something which would probably depend on the presence of favourable cultural conditions. Either forms of training could be based on a needs analysis and driver consultation. A further solution suggested by the method is that a task analysis of the driver's job in this and similar scenarios may reveal that there are too many competing tasks, such that the driver cannot be realistically expected to attend to them all simultaneously. In this case it would be necessary to reduce the number of tasks, either by technical means or by easing the pressure on the driver to attend to slippage or time-keeping.

Finally, it seems that the ATC system does not account for acceleration, but simply measures speed at one point. In this case, although the train was accelerating towards the signal, the corrective measuring point did not see the problem because the speed at measurement was below the threshold required to trigger the ATC alerts.

3.2.5 Case 5

The driver drove in the same direction and stopped at the same staff stop described for Case 4 i.e. the stop was situated between an approach and main signal.

In this incident the approach signal had shown "proceed to stop" (flashing yellow). The driver stopped at the *staff stop* and said that he must have forgotten the approach signal. On stopping, the ATC panel in the driver cabin was set to "stop" by default, so did not help the driver remember the approach signal. On passing a set of corrective transponders between the stop and the upcoming main signal at surplus speed, the ATC system intervened, slowing the train down in order to stop before the main signal. The driver could not say if the brakes applied by the system were full or partial.

The driver was not too perturbed by the incident, and perhaps because of this failed to remember too many details. He did comment that the intervention by the ATC system was not at all unusual, and he mirrored the comments of other drivers in commenting that the ATC system about to "replace the main signal" in the driver's mind in terms of checking speed limits and upcoming diversions and stops.

3.2.5.1 Results of CREAM analysis

The output from the CREAM analysis of case 5 is given in Figure 7.

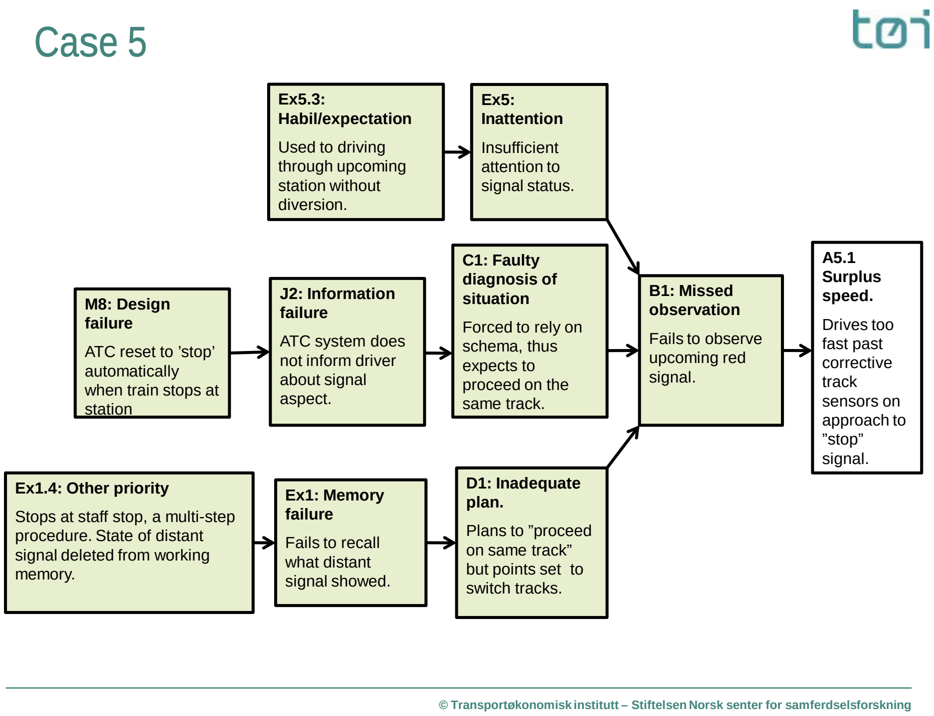

Figure 7. Output from CREAM analysis of Case 5. The clear box shows the visible or precipitating behaviour ("phenotype") resulting in the ATC intervention incident. According to the analysis, this behaviour in turn resulted from the antecedent events or conditions proposed in the shaded boxes. These antecedents are possible contributing factors rather than definite causes.

The driver does not brake towards the stop signal but crosses a preceding corrective track sensor at **surplus speed**. This was because he did not see the main signal (**missed observation**). Three antecedent chains possibly contributed to this missed observation.

First, his failure to observe the signal could have been caused by his having an **inadequate plan** for the upcoming stretch of track, which did not allow for the possibility of either stopping or being diverted at the station. The driver failed to recall the approach signal as the multi-step procedure of stopping and departing from the staff platform (**other priority**) meant that recall was displaced from his working memory (**memory failure**).

Second, the driver made a **faulty diagnosis** as the situation developed, assuming that he would be allowed proceed through the passenger station on the same track and without having to stop. Lack of information about signal aspect on leaving the staff stop resulted in this faulty diagnosis.

Third, the driver was inattentive because of routine exposure to passing through the station in an unchanged stated, meaning that he had formed a **habit** which led to an **expectation**.

3.2.5.2 Implications

This is another case in which the driver seems to have developed a schema over time due to repeated exposure to a system in a fixed condition. In this case the driver usually drove through the passenger station without stopping or being diverted, and this may have lessened the importance of maintaining the high effort required to attend to and recall the approach signal while at the same time stopping, waiting and departing from the preceding staff stop. While leading us to question the placing of the staff stop between the approach and main signals, the analysis also suggests that ways to disrupt the formation of nonadaptive schemas, through constantly challenging driver assumptions, would be helpful.

Again questions are raised about the conflicting purpose of the ATC system. In this case the driver considers the intervention by the system to be part of normal driving procedure, and not broken barrier in the defence against SPAD incidents.

3.2.6 Case 6

Case 6 was an incident in which the train driver incorrectly triggered the train's external "clear to proceed" indicator while the train waited to depart from the station platform. The context of the incorrect trigger is given as follows.

After releasing the doors to let the passengers out of the train, the normal procedure is for the driver to wait for a green signal (*avgangstillatelse*) located at the station exit, and only then press a button on his control panel. The button sets off a flashing indicator on the side of the train. On seeing the indicator is flashing, the conductor is then supposed to check that all passengers are safely on board, before double checking that the exit signal is green. The conductor is then clear to give the driver the final "clear to proceed" signal. The driver's trigger of the indicator is therefore a key step in the safe exit of a station by a train.

The incident happened at about 10.00 am while the train waited at a station. Before entering the station the train had stopped three times on its current route. There were several tracks in operation leading to and from the station where the incident took place, and it was therefore normal for drivers at this station to get a "clear to proceed" (green) exit signal soon after stopping.

At the time of stopping the train was already delayed by between 10 and 12 minutes.

The train was full of passengers. There were other train staff in the driver's cabin at the time of the incident. The driver could hear music and a lot of other background noise from the passengers. Leading up to the incident, the driver had also received several phone calls, some of which he had ignored.

The driver was very experienced, with 40 years service. He drove through this station between one and two times a day, three days a week. At the time of the incident the driver was halfway through his duty and did not feel tired. He said that getting a green exit signal at the station was the routine norm.

"It gets boring because you get a green there so often."

He said that the procedure followed after stopping at a station happened so often that it was almost automatic. It was something that happened without thinking.

The driver recalled being aware of the need to make up time as he had lost so much in such a short time. He said:

"You feel you need to stick to the timetable, that's something you get nagged about".

He added that there was often pressure from passengers who, frustrated by the delays often take it out on the driver, for example by banging or even kicking on the door. He reported that the presence of others in the cabin might have made him lose focus, but placed more emphasis on the role of an irrelevant call he had received while at the station. He said the call had annoyed him and had preoccupied his thoughts, but admitted it should have been his responsibility to deal with such disturbances.

He was annoyed generally by the amount of calls coming into the cabin, and felt that they could often be dealt with by the conductor. He estimated that in general 70 per cent of incoming calls were not necessary.

There was snow on the ground at the time of the incident, but the driver did not think weather played a role in the incident. The driver had a clear view of the exit signal.

3.2.6.1 Results of CREAM analysis

The output from the CREAM analysis of case 6 is given in Figure 8.

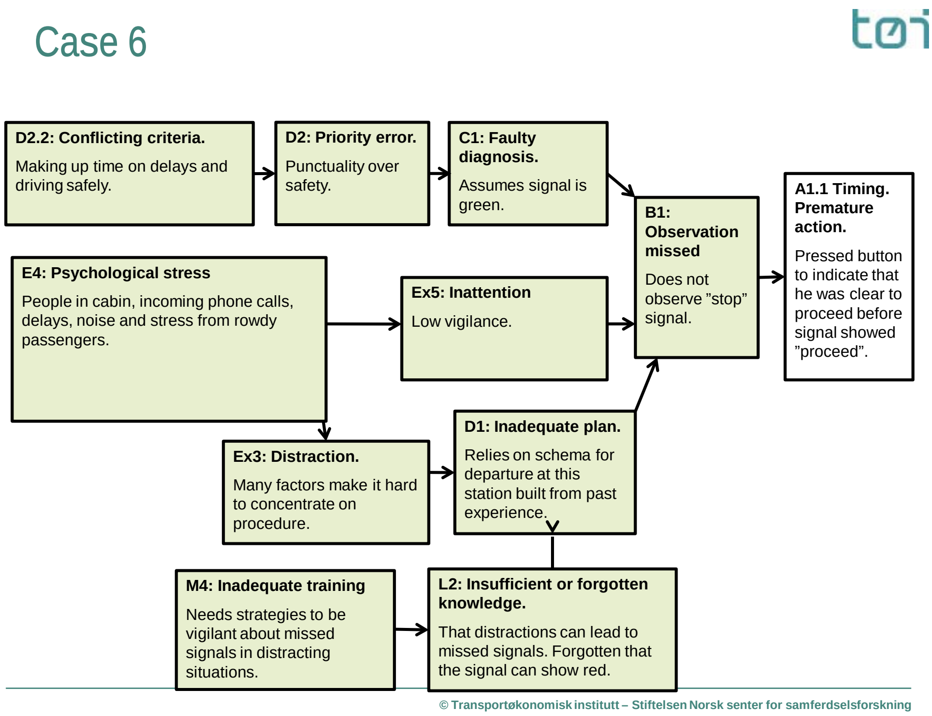

Figure 8. Output from CREAM analysis of Case 6. The clear box shows the visible or precipitating behaviour ("phenotype") resulting in the ATC intervention incident. According to the analysis, this behaviour in turn resulted from the antecedent events or conditions proposed in the shaded boxes. These antecedents are possible contributing factors rather than definite causes.

The driver pressed the “clear for departure” indicator before the station exit signal had turned green. **Timing: premature action** was therefore selected as phenotype for antecedent analysis. The driver said that he did not see the red signal and so **observation missed** was selected as the immediate antecedent to the early action. There are three possible antecedent chains leading to the missed signal.

First, the driver made an automatic **faulty diagnosis** about the signal state. The possibility of the signal being red was not salient in his mind because he was prioritising punctuality over safety (**priority error**).

Second, the driver’s plan did not include the possibility of having to wait for permission to leave the station (**inadequate plan**). This plan was based on a schema developed from past experience of routinely getting immediate permission to leave the station. His reliance on the plan was increased because he did not know, or had forgotten, that distractions can lead to missed signals (**insufficient knowledge**). **Distraction** due to **psychological stress** also increased his reliance on this schema. Psychological stress may also have contributed to **inattention**, which in turn led to the missed signal observation.

3.2.6.2 Implications

The analysis suggests that in the face of several cognitive distractions (the delay, the noise from the passengers, the conversation in the cabin, incoming phone calls) the driver naturally relied on a schema built up from previous routine of leaving this station. Most of the time the driver had checked the exit signal on previous occasions, it had been green. As the driver also commented, the driver’s procedure for leaving the station becomes highly automised with experience, such that it is “felt” rather than consciously thought through. Thus the driver’s error probably occurred subconsciously.

The analysis suggests that two kinds of measure would be useful: those that prevent the build up of schemas through routine; and those that reduce the number of driver distractions building up in station areas.

Training to raise the salience of the dangers that distractions can lead to would be useful. A culture in which both the driver and any extra persons in the cabin could recognize and act on distraction situations, for example by being quiet to help the driver focus, would presumably help.

Procedures which clearly prioritise safety over punctuality are also implied. If these are already in place, one must question how such procedures are interpreted by drivers, or the *culture* in which the drivers (colleague, manager, passenger attitudes etc.) operate affect this interpretation.

A way to encourage more deliberate consideration by the driver of what becomes a highly automised leaving procedure is also implied.

To prevent distractions, procedures that allow the train dispatcher increased visibility and understanding of the driver’s context would be helpful and lead a reduced number of unnecessary phone calls, and phone calls at more convenient times.

Reduction of noise from behind the driver in trains which have the passenger wagons directly connected to the driving cabin is an additional consideration.

3.2.7 Case 7

The incident happened at 13:30 on a weekday early in autumn. On approaching a station area, the driver received a telephone call in the cabin, instructing him to swap trains. As the driver entered a multi-tracked shunting area, he searched to identify the train he was to swap to. To the right of the driver's track was a service track, and to the left three or four shunting tracks. On proceeding towards a parking track, the driver failed to notice a dwarf signal showing "stop" placed at the bottom of a signal stack on the left hand side of his track. The incident happened about three minutes after the phone call.

Most signals are placed on the right of the track. Indeed, the tracks either side of the driver had their corresponding signals on their right hand side. The driver said that he thought that the signal that applied to him was one to the right of the track to his left. This implies that the driver knew he was searching for a deviant dwarf signal i.e. a signal to the left of the track. The dwarf signal the driver took for the correct signal stood alone and was therefore easier to see than the correct dwarf signal, which was placed at the bottom of a stack of signals.

The driver noticed too late that he had made a mistake and there was another signal that applied to his track. Although he braked before the signal, he failed to stop until after he had passed it. The driver was taken out of service and interviewed by a manager.

The driver had started his shift at 5.30 am, and was due to finish soon after the incident happened. The driver was experienced and familiar with both the area and the shunting operation he had been asked to perform. Indeed, he had performed the same operation in the same area several times before. However, he could not remember if he had ever had to stop at the same dwarf signal.

He remembers thinking before the incident that it was nearly time to go home. Moreover, just before the SPAD, he remembers clearly trying looking over to the left in order to identify the train he was to swap with.

He did not feel stressed leading up to the incident, and remembers thinking he had plenty of time to perform the shunting operation.

The weather conditions and visibility were good and there was nothing blocking the driver's view of the signal.

3.2.7.1 Results of CREAM analysis

The output from the CREAM analysis of case 7 is given in Figure 9.

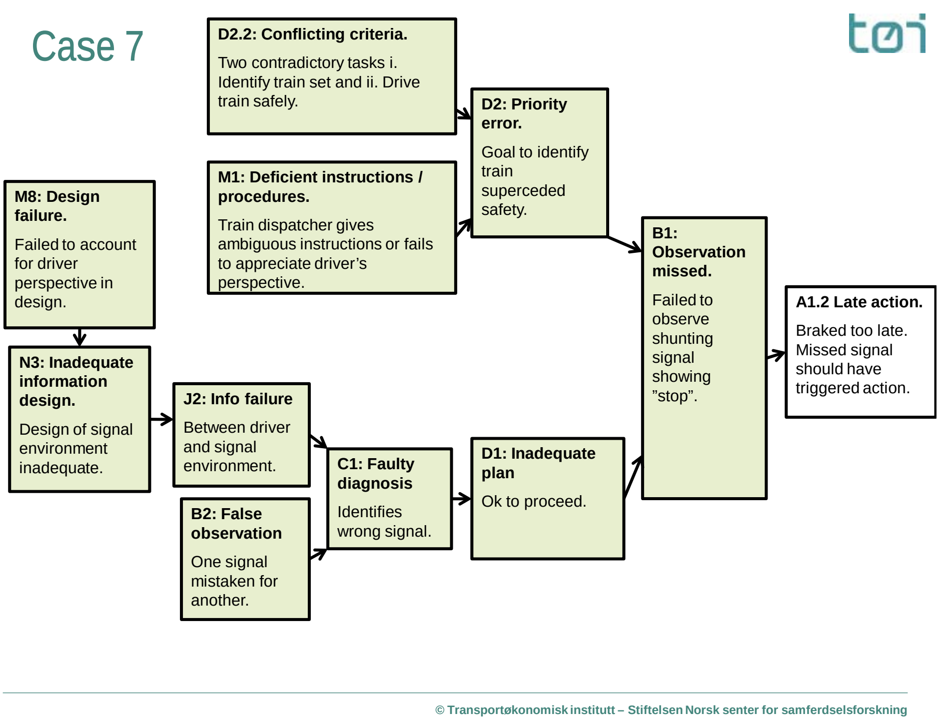

Figure 9. Output from CREAM analysis of Case 7. The clear box shows the visible or precipitating behaviour ("phenotype") resulting in the ATC intervention incident. According to the analysis, this behaviour in turn resulted from the antecedent events or conditions proposed in the shaded boxes. These antecedents are possible contributing factors rather than definite causes.

The phenotype **timing: late action** is chosen because the driver began braking too late. This was because of a **missed observation** of the signal on the left. To chains of antecedent events or conditions are suggested as responsible for the missed signal.

First, the driver made a **priority error** by searching for the train he was to swap to instead of the signal applying to his track. This was because he had **conflicting criteria** (identify train and identify signal), not helped by the incomplete instructions given to him by the train dispatcher (**deficient instructions**).

Second, the driver formed an **inadequate plan** for shunting that did not include the possibility of stopping at the dwarf signal. This developed after he made a **faulty diagnosis**, undoubtedly based on the **false observation** that the wrong one of two signals on the left applied to him. A poorly designed signal environment contributed to the faulty diagnosis (see **info failure**, **inadequate information design** and **design failure**).

3.2.7.2 Implications

The analysis suggests that the driver's focus on the safe identification of the dwarf signal applying to his track was compromised by several factors.

The driver was not sure which train set he needed to swap with. Presumably the instructions given over the phone could have been clearer, although we know little about the content of this call or whether there is a standardized method of giving directions to drivers. If a standard method was used, the analysis implies that ways to make the instructions less ambiguous could be considered and incorporated into procedures. Ways to increase the driver's focus on deviant or hard-to-perceive signals along the way towards any new destination are also implied.

The search for the other train set may thus have compromised the driver's search for the signal. With high cognitive demand in the face of a competing search task and a confusing signal environment, the driver relied on a mental plan that it was ok to proceed after reasoning that the stand-alone dwarf signal applied to him.

A signal environment that takes greater consideration to drivers' perception ability during different shunting tasks would reduce the likelihood of such an incident occurring again. This in turn implies a proper driver consultation as part of the process of design of the signal environment.

3.2.8 Case 8

This incident happened early on an autumn afternoon as the driver drove away from a low sun, towards an approach signal showing "expect to stop". The driver said that although he could see the approach signal from far away as he approached, he could not see which of the lamps were lit until he was right in front of the signal. On noticing that both green and yellow lights were flashing, he began to brake from 130 km/h in order to be able to stop at the main signal in time. However, on passing transponders at the approach signal, the ATC system intervened, braking him down more abruptly.

The driver said that he had not seen the approach signal because of the sun reflecting off the lamps. He also said that the signal had been dirty. Although it was autumn, there were no problems with leaves on the line on this stretch of track at the time.

The driver was not very experienced, having worked as a train driver for only three months. He had, however, driven past the signal several times a week since beginning. This was the first time he had driven past when the sun had been so strong and low. Apart from the low sun the weather conditions were good. The driver had been on duty for less than two hours when the incident happened.

The driver says that he was shocked by the incident, but feels he learned a lot from it. He feels much more confident now when approaching this signal because he knows to be cautious, braking to slow down on approach, and looking longer into the distance sooner. He commented that a stronger light would have been more clearly visible and prevented the incident. He said that there is a need in general to keep signal lamps cleaner.

3.2.8.1 Results of CREAM analysis

The output from the CREAM analysis of case 8 is given in Figure 10.

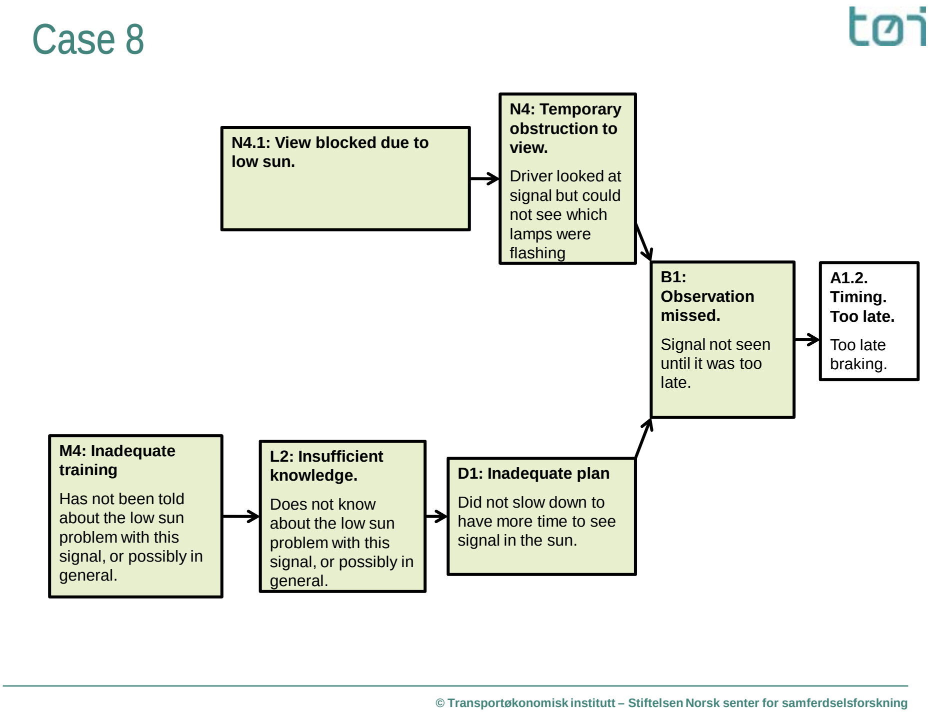

Figure 10. Output from CREAM analysis of Case 8. The clear box shows the visible or precipitating behaviour ("phenotype") resulting in the ATC intervention incident. According to the analysis, this behaviour in turn resulted from the antecedent events or conditions proposed in the shaded boxes. These antecedents are possible contributing factors rather than definite causes.

The phenotype **timing: too late** was chosen because the driver slowed down before the signal, but too late to prevent an intervention by the ATC system. The immediate antecedent to this was the **missed observation** that the approach signal showed "expect to stop". The driver missed the signal primarily because the **low sun** reflecting off the lamps formed a **temporary obstruction to view**.

However, it could be argued that if the driver's plan to approach the signal under conditions of low sun was adequate, he would have had more time to observe the signal and brake. His **inadequate plan**, to approach the signal at normal speed, was due to **insufficient knowledge** about the effect of low sun on this signal, or possibly how low sun affects the visibility of signals in general. According to the method, **inadequate training** is an antecedent for this lack of knowledge.

3.2.8.2 Implications

The driver could not see the signal because the low sun reflected off the lamps. The analysis does not directly imply a solution, but the use of better lamp technology and better placement of signals are two possible improvements that could be made. We might also consider that better maintenance of the existing signal lamps, and possibly use of stronger bulbs or clearer lenses would have improved the driver's ability to perceive the signal in low sun, although this is again not suggested directly by the method (see below).

Likewise, although the method does not suggest that better *practical* experience of approaching the signals under different weather conditions would have helped, this is suggested by the driver's comments. Whether such experience could be gained in the simulator, through on-the-job training, or whether it is best left to chance exposure while alone on the job – which happened in this case – is a matter for debate.

The organization has no formal method for learning from such incidents (it was not reported in Synergi). One therefore has to question how other new drivers can benefit from the experience of this driver. Whether this happens informally, for example through conversations among drivers in break times, presumably depends on how much the prevailing culture encourages drivers to talk openly with each other about incidents on the railway.

3.2.9 Case 9

This incident happened at 09.20 in autumn on the approach to a passenger station. Before reaching the station, the train had passed an approach signal and then briefly stopped at a staff stop before proceeding towards the main signal at a set of points. The passenger station had several tracks in operation to and from the station.

On leaving the works platform, the driver remembered that the approach signal had shown "proceed on a different track", but then failed to notice a sign showing that the speed limit at the upcoming points was for a sharp divergence i.e. 20 km/h instead of the normal 40 km/h. He also failed to notice ATC system updating and subsequent speed alarms as he passed transponders on the way from the works stop towards the points. As he was driving too fast for changing tracks at the points, the ATC system intervened as he reached the main signal, slowing him down with emergency brakes. The train was then able to proceed without further incident.

The driver had ten year's experience and said this was the only one of its type he had experienced during that time. He therefore remembered it clearly. He was very familiar with the area:

"I have driven that route so many times, it is so routine it is shocking that something like that happened."

The driver said that 99 times out of 100 the signal showed "proceed straight on" at that station, and that despite his experience it was possible that he was not familiar with the speed limit for changing tracks there.

The driver had started his shift at 04.15 am, having got up at 03.00 am. He was due to finish around midday. He could not remember if this was the first night duty or whether he had also driven the night before. When asked about factors which may have distracted him, he remembered that he was having a conversation with a conductor beside him, and said that he did find it easier to focus when alone in the cabin.

The train was not full but the driver remembered being distracted by noise from passengers on the train.

The sound on the ATC warning alarm was set at a level which the driver estimated as 3 or 4 out of 10. The driver thought that he could have set the volume higher so that he would have noticed the problem earlier. However, he also said that he did not tend to get concerned when ATC sounded during driving because he regularly used the ATC warning to help him drive:

"You feel the distance and brake accordingly with your body. You are not always so worried when ATC sounds because you use ATC now and then for automatic stopping."

The driver commented that a more conspicuous sign for the unusual speed limit would have possibly prevented the incident. He was not concerned about the lack of standardized speed limits for changing tracks though, since variation was something that kept him alert.

The weather was cloudy and partially wet.

3.2.9.1 Results of CREAM analysis

The output from the CREAM analysis of case 9 is given in Figure 11.

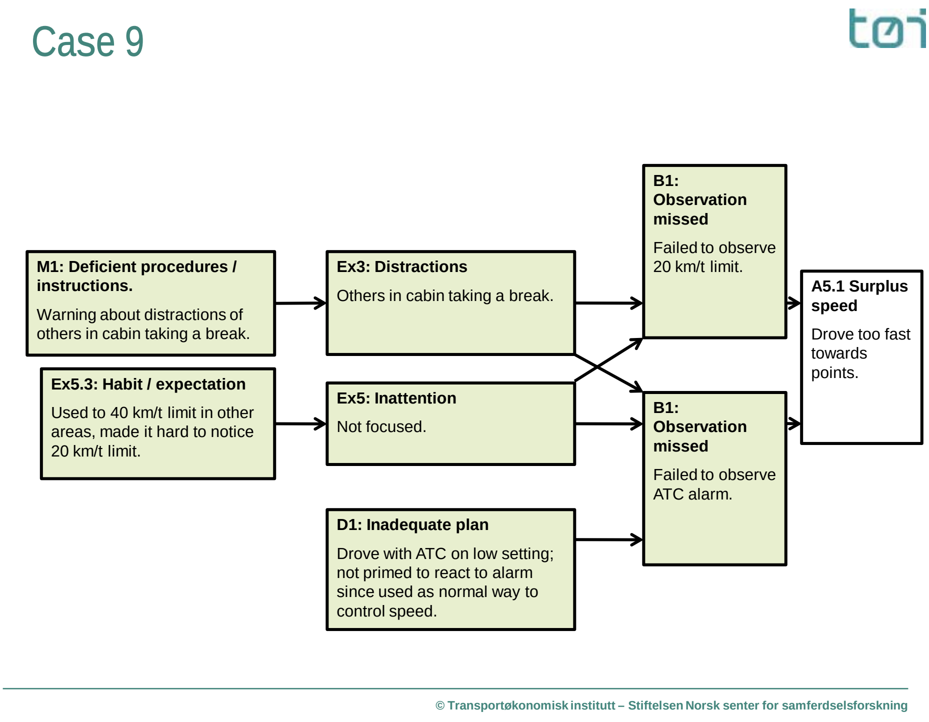

Figure 11. Output from CREAM analysis of Case 9. The clear box shows the visible or precipitating behaviour ("phenotype") resulting in the ATC intervention incident. According to the analysis, this behaviour in turn resulted from the antecedent events or conditions proposed in the shaded boxes. These antecedents are possible contributing factors rather than definite causes.

The phenotype **surplus speed** was chosen as the antecedent in this case because the driver did not attempt to limit his speed before ATC intervened. This was based on two **missed observations**. First, he missed the 20 km/h sign and then missed the ATC alarm on the driver's panel. The method suggests that possible **distractions** from the others in the cabin combined with a reduced level of attention, due to an **expectation** about the speed limit based on previous exposure to signal changes at other locations, increased the likelihood that the driver failed to observe both the 20 km/h sign and the ATC alarm.

The driver may also have missed the ATC alarm because he was not primed to attend to the ATC alarm as soon as he heard it. In other words, by using the system for a purpose other than a safety warning, he had been conditioned to pay little attention to the alarm, its meaning had been lost.

3.2.9.2 Implications

The procedures and/or culture surrounding several people in the driver's cabin could possible better consider the driver's need to focus in complex signal environments.

The driver's expectation that he would change tracks at 40 km/h could also be addressed, possibly by regular training to challenge those assumptions and schemas which can be useful most of the time, but become dangerous in deviant situations. Another way to address this would be increased standardization of speed limits. This might, however, prove impractical and lead to increase routine and decreased focus on the part of the driver.

The analysis was somewhat limited by a limited understanding of what drivers are told to prioritise and how they are taught to use ATC. Specifically, if drivers are trained to drive using ATC to guide them, **lack of knowledge** would not be appropriate as an antecedent for the driver's inadequate plan. On the other hand, if drivers are taught to use the speedometer to control speed and that ATC should not be used as a mere guide to speed, **lack of knowledge** and better **training** is implied.

If there is a need for the ATC system to serve two purposes – both as a speed regulating device and a warning for dangerous situations – then the driver should be able to distinguish clearly in which state the system is operating according to the warning sounds and lights triggered.

3.2.10 Case 10

The incident happened towards the end of February at 15:30 as the driver drove through a tunnel directing a student under training. After passing an approach signal showing "proceed on same track" for a short stretch, the driver turned a corner only to see the subsequent main signal showing stop. The main signal was too near for the driver to be able to brake without passing it. On contacting the train dispatcher, the driver was told there had been a technical fault with the signals.

The driver had 11 years of experience. It was the first time he had trained this particular student, but otherwise he was used to training students. The tour of duty had begun shortly before, at 14:50. According to the driver this was not a complex incident, and there was nothing he or the student could have done to prevent it. There was nothing unusual inside the driver's cabin or out, apart from the faulty signal. The driver saw the incident as positive in that it allowed the student to see ATC's emergency braking in action. The driver had a lot of respect for the ATC system.

The weather outside the tunnel was fine and clear.

3.2.10.1 Results of CREAM analysis

The output from the CREAM analysis of case 10 is given in Figure 12.

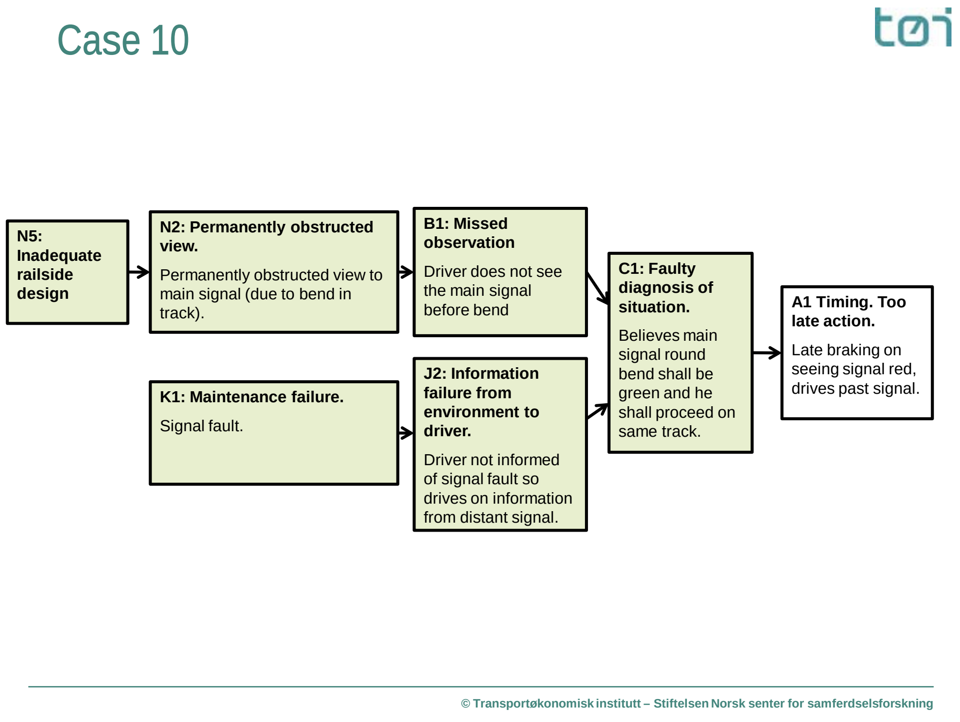

Figure 12. Output from CREAM analysis of Case 10. The clear box shows the visible or precipitating behaviour ("phenotype") resulting in the ATC intervention incident. According to the analysis, this behaviour in turn resulted from the antecedent events or conditions proposed in the shaded boxes. These antecedents are possible contributing factors rather than definite causes.

The phenotype **timing: too late action** was chosen because the driver began to brake too late to be able to stop before the main signal showing red. Although the driver's actions were based on a correct observation and response to the approach signal, the driver's diagnosis of the actual situation was incorrect. The immediate antecedent of the late action is therefore **faulty diagnosis** caused by a) the driver's inability to see the main signal in time to be able to stop (**missed observation**); and b) an **information failure** in terms of the conflicting signals. The former implies **inadequate track design**, while the latter implies a **maintenance** or other technical **failure**.

3.2.10.2 Implications

A signal fault is clearly implicated as the main cause of this incident. The incident is nevertheless interesting from a human factors perspective because its analysis suggests that a track design in which the main signal is visible from a distance that gives drivers sufficient braking time would reduce the likelihood of SPADs occurring. This could be achieved by lowering the speed limit between the approach and main signal for this particular signal.

3.3 Aggregated analysis of signal approach incidents

Many train accidents occur following SPAD events. It is therefore useful to ask whether there are common antecedents for safety failures which increase the likelihood of a SPAD event occurring.

Each of cases 1 to 10 in section 3.2 contains such a safety failure. In order to highlight those antecedents occurring most frequently across the ten cases, the results of each CREAM analysis was summarized in an aggregated analysis (Figure 13).

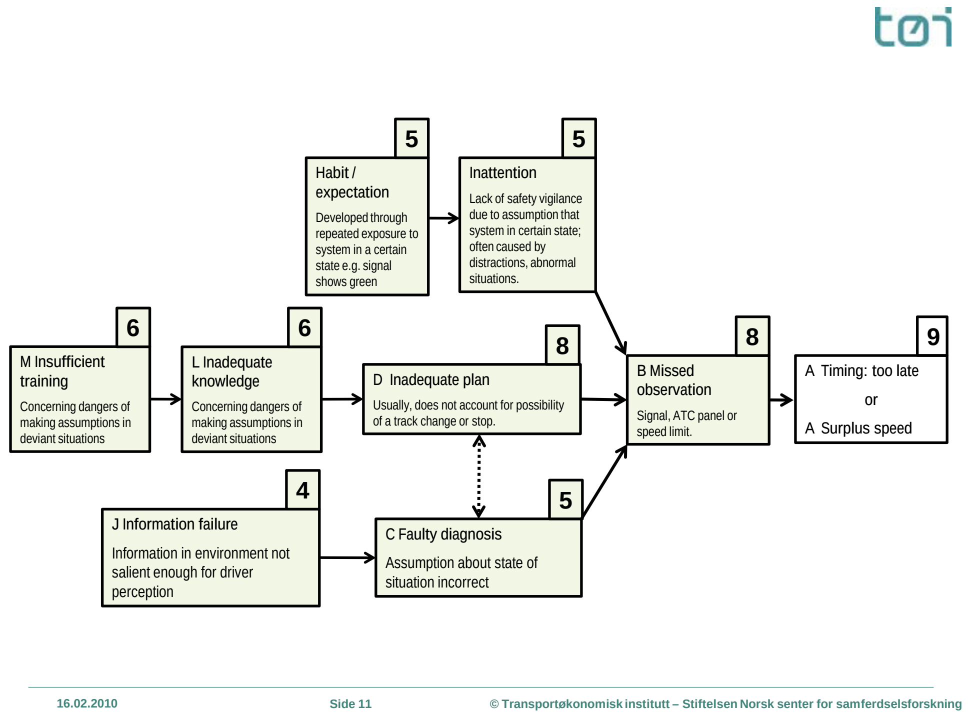

Figure 13. Output from an aggregated analysis of signal approach incidents. The boxed numbers indicate the number of times the subsequent link(s) was found after CREAM analyses of ten signal approach incidents involving train drivers. Only those factors linked at least four times are shown.

This was done by including only those antecedent events found to occur at least four times across all ten cases, where an antecedent event is defined as a link between two antecedents.

The analysis shows that most signal approach incidents are precipitated by too late braking or no braking, and therefore surplus speed. The immediate antecedent for this is most often a missed observation by the driver.

Interestingly, three antecedent chains are commonly implied for this missed observation across the signal approach incidents analysed here. These are:

(1) that partly due to inadequate or forgotten knowledge the driver has an inadequate plan or schema for approaching the signal, which does not account for possible deviances;

(2) that the driver is inattentive because of expectations from habitual exposure to the system in an unchanging state;

(3) that the driver makes a faulty assumption about the state of the signal approach situation (often a deviant signal aspect) because information in the trackside environment lacks appropriate salience.

3.4 Issues train drivers believe are important

Eighteen drivers responded to a question asking them about various safety themes affecting them that they think are worthy of research. Drivers were asked to select from any one or more of ten given themes, or given the chance to name other themes if they wanted. The responses are shown in Figure 14.

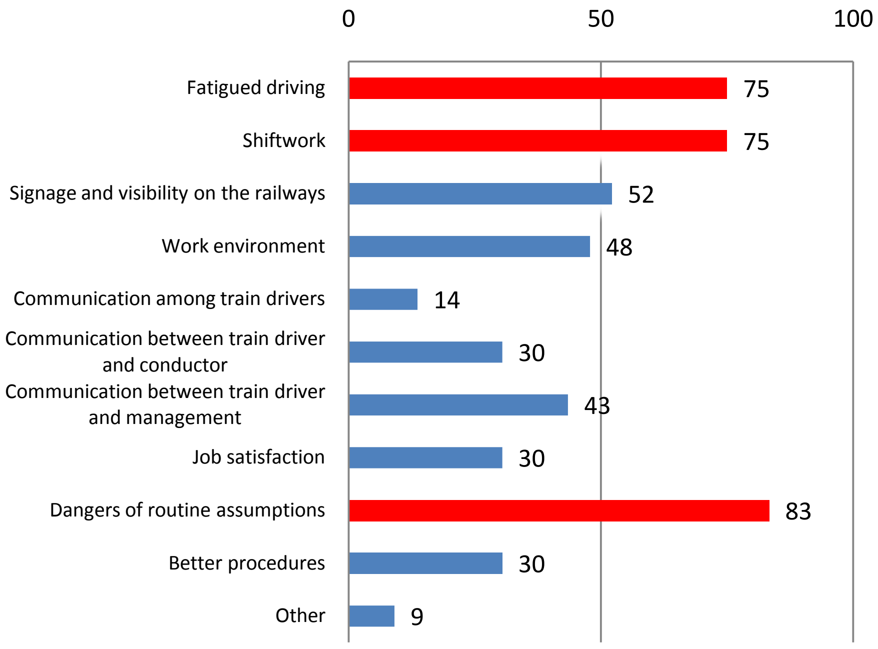

Figure 14. Issues drivers believe are important. The figure shows the percentage of drivers (n=18) regarding theme as worthy of investigation in a safety context.

The theme regarded by drivers as most important was the danger of making routine assumptions on the railway (Figure 14). Over 80 per cent of drivers recognized this as worthy of further research.

The next two most important themes were fatigued driving and shift work, with 75 per cent of drivers indicating that they thought these were important safety themes.

Although only 14 per cent of drivers thought that communication among drivers was important, more than double this amount (30 per cent) thought that communication between drivers and conductors was important. An even greater share (43 per cent) thought communication between train drivers and leaders was worth investigation.

Around half the drivers report that signage and work environment are important themes for them.

4 Summary and discussion of findings

This project aimed to learn about limitations in the system of human, technical and organizational factors that could contribute to hazardous signal incidents; and to develop the in-depth analysis CREAM for use in railway incident analysis.

To identify suitable signal incidents for analysis, 115 train drivers were asked on three separate occasions, spanning an 18-month period, about their involvement in different incidents. The average survey response rate was 26 per cent.

None of the responding drivers reported involvement in SPAD incidents at main signals for any of the surveys. Only two drivers reported involvement in SPAD incidents at dwarf signals. Conversely, over the course of a year at least one in four drivers reported experiencing an automatic braking intervention because they had missed an approach signal. Over a two-month period, over one in four drivers also reported triggering a "permission to drive" indicator button when waiting at a station, even though the station exit signal did not show green. Also over a two-month period, one in three drivers report receiving the all-clear signal from a conductor at a station when the exit signal did not show green.

We derive two main implications from these findings:

First, although SPAD incidents themselves are rare, a substantial share of drivers report involvement in potentially hazardous "pre-SPAD" incidents. Thus it seems that the system of organizational, environmental and technical factors in which all drivers operate could be improved to support their general ability to respond to signal aspects appropriately, and reduce the occurrence of SPADs still further.

Second, potentially hazardous "pre-SPAD" incidents occur frequently enough for several of them to be analysed in depth, and the findings aggregated in order to learn more about what occurs in the build up to SPADs.

Twelve of the drivers responding to our survey were subsequently invited for interview in order to provide material for in-depth analysis of signal approach incidents, using CREAM. The ten resulting analyses were then aggregated in order to learn about common antecedent events occurring in the build up to signal approach incidents.

The systematic aggregated analysis suggests that a missed observation by the driver is a common antecedent to a hazardous driver action such as failing to brake or braking too late. The missed object is usually a signal, but can also be a speed limit sign or a warning alarm in the driver's cabin. That a missed observation is a frequently occurring antecedent is not surprising given that we purposefully invited those drivers involved in "missed signal" incidents for interview. What we really want to know is what events tend to cause drivers to miss signals.

The aggregation shows that three antecedent chains commonly lead to a missed observation by the driver:

1. The driver appears to have an inadequate plan for signal approach, which often fails to include the possibility of deviant events such as an unusual signal aspect. Absent or forgotten knowledge about occurrence of deviances is often implied as an antecedent to an inadequate plan.
2. Inattention by the driver is also implied as an antecedent of a missed observation. Analysis of several cases suggests that this is a result of an expectation the driver has formed about a stretch of track, as a result of experiencing it in an unchanging state. In particular, several of the drivers involved in approach incidents had been faced by a deviant signal after becoming accustomed to seeing green signals.
3. A lack of signal salience (information failure) in the driver's environment leads to a faulty diagnosis about the state of the signal aspects, and increases the chance of a missed observation.

As far as these findings are useful, we have demonstrated that CREAM can be used to derive meaningful aggregated analysis of hazardous signal incidents. However, in our analyses aggregation did not capture all important implications across in-depth analysis of several of the signal approach incidents.

In particular, there were six cases where the presence of extraneous or unusual circumstances appeared to cause the driver to rely on a schema they had formed about the usual state of signal aspects on a certain stretch of track (cases 2, 4, 5, 6, 7, 9). The circumstances in question came in various forms such as high task load, a non-safety priority (punctuality; change trains), or distractions from others in the cabin or from the public.

Given the regularity with which drivers report they are normally allowed to proceed through stretches of track without deviation (usually hundreds or even thousands of times), it is not unreasonable to assume most if not all drivers would develop a schema as a result of routine exposure to systems in an unchanging state. This is only human nature. Normally, drivers would carry out deliberate checking of signals and would not employ their schema, but demanding or deviant situations appear to increase the likelihood that such schemas are employed.

The dangers arising from routine coupled with unusual circumstances appear to be underestimated by the aggregated analysis, which only implicates routine exposure or habit as a specific antecedent of inattention, even though mere inattention is never by itself sufficient to cause a missed observation according to the cases analysed here. A consideration of the individual written analyses suggests that routine exposure to systems in an unchanging state is a pervasive and dormant potential hazard for drivers, which merits greater emphasis than the aggregated analysis suggests.

This point becomes even more pertinent when we consider the driver ratings of ten different safety issues impacting them (Section 3.4). The danger of routine assumptions is the most highly rated issue, with 83 per cent of drivers saying that this issue is worthy of investigation.

Fatigue / shiftwork was the next most rated issue, with 75 per cent of drivers rating it as worthy of investigation. After that, signage and visibility is rated as worthy of investigation, by 52 per cent of drivers. Although drivers do not see driver-driver communication as an issue, almost one in three think that communication between drivers and conductors is an issue, while an even greater share believe driver-manager communications are worth investigating. Around half of the drivers report that signage and work environment are important themes for them.

CREAM as a method for the analysis of signal approach incidents

We support the findings of Nordbakke and Sagberg (2007) that CREAM is a useful method for the analysis of signal incidents on the railway. Furthermore, we find that the systematic aggregation of ten analyses leads to useful findings about commonly occurring antecedent events.

In our analyses it was useful to employ the antecedent **inadequate plan** in a way that is perhaps a little more abstract than the original creators of the CREAM method intended. Rather than meaning that the driver has a specific and definite idea about the how things will be before he sets out on the journey, we used this antecedent to refer to the driver's evolving idea of how the journey will progress *as he continues along the journey*. For us, the driver did not necessarily think consciously about the plan in question. The plan is therefore analogous to a schema. Use of the antecedent in this way was necessary and sensible, in that it allowed us to access what we felt were the most appropriate antecedent chains for these cases.

We found that, even though data was obtained from the drivers themselves, we could rarely be certain about the antecedent events suggested by the analysis. This is understandable given that certainty often requires concrete knowledge about cognitive events occurring often several weeks ago in the driver's mind. The lack of certainty is not a problem if one regards the resulting analyses as suggestive of possible or likely events occurring in the run up to each incident. Such an approach leads to a more open analysis in which several antecedent chains can arise and be considered together. We consider this approach to be the most informative.

Another concern about the method is whether incidents would ever occur as some of the resulting box diagrams suggest. For example, Case 2 describes that the driver reasoned wrongly about the amount of distance he had in which to brake. But do drivers actually think in this way? In an interview, for instance, a driver would never say "I reasoned wrongly about the distance I had to brake", but this is implied by the box diagram because when using the method the analyst is forced to assume about cognitive processes occurring in mind of the driver. There are two problems with this.

First, the drivers themselves say that after experiencing a stretch of track many times, they begin to drive by *feeling*. They are probably reflecting that deliberate cognitive processes become automised to such an extent that drivers eventually respond to changes in the signal environment without thinking. Given that it is hard to describe such proceduralised knowledge, there will inevitably be a gap between the driver's actual experience and the analyst's portrayal of cognitive processes.

A second and related point is that the method appears to be limited in the way it accounts for the role of cognitive biases or heuristics. For instance, where risk is salient, such as the risk of missing a deviant signal when there are several demands in addition to signal observation, the driver may act depending on the *subjective* probability of that risk occurring. This probability can be influenced by his background mood (i.e. *emotions*) or the immediacy with which that risk is perceived. The method does not account for these influences. There may also be social influences arising from organizational culture (e.g. how other drivers tend to do things; what other drivers value), or the mere presence of other staff in the driver's cabin, that affect how key decisions are made. Such factors are not accounted for by the method.

For methodological considerations and further development of CREAM the reader is referred to Appendix 9.

5 Recommendations

Perhaps the biggest challenge for the organization is finding out how to change a system that fails to challenge the natural development by drivers of inappropriate signal aspect schemas. Drivers currently face a high level of routine, letting drivers pass through blocks or stations possibly hundreds of times in an unchanging state. It is perhaps not surprising that drivers fail to notice when deviant situations occur. It is perhaps more surprising that they usually *do* notice them, and that only when deviant situations are accompanied by other circumstances do potentially hazardous incidents arise. While the current politcal climate (increased demands for punctuality) points towards an increase in demands placed on the driver, the need to challenge inappropriate schema development is paramount. How this should be done is not clear, but it undoubtedly requires expert knowledge about driver tasks, which not least should come from the drivers themselves. That more than four out of every five drivers rate the dangers of routine as a safety issue to be investigated underlines the need for increased focus in this area.

The aggregated analysis shows that in several cases drivers were persuaded to make a faulty diagnosis about the state of the situation because they did not perceive the deviant signal. One way to decrease the chance of drivers employing schemas would therefore be to increase the salience of deviant signals or situations. One way to achieve this would be by designing a signal environment that better accounts for human factors.

Insufficient knowledge is implicated by the aggregated analysis as contributing to an inappropriate schema. But what is the knowledge in question? Case analysis shows that it concerns important deviances that the driver faces on that day's route. In case 1, for instance, the driver forgets that the last train tends to be diverted at the approaching station, and a reminder about this, perhaps before the driver started his shift, would have helped. In case 3 the driver does not have sufficient knowledge about a new deviant signal on a stretch of track onto which he is diverted. Improved systems to brief drivers before they set out on the day's route might also have helped here. Another approach would be to find a formal way for drivers returning from the same route to log and inform subsequent drivers about deviances or incidences. Alternatively, refresher training could also help by priming the minds of drivers about the dangers of deviant situations, especially in those situations in which they are faced by other challenges. Any training should be based on a needs analysis and involve a full driver consultation.

Our final recommendation concerns the ATC warning system. In several cases, drivers appear not to have heeded audible and visual warnings emitted by the system prior to an automatic braking intervention. The most likely explanation for this is that the drivers use ATC warnings in normal driving to control their speed, and therefore do not treat those warnings as emergency warnings. The psychological impact of the ATC alarm appears to be compromised by the dual use of the ATC system. It is used not only as a way to flag up dangerous situations such as missed signals, but also as a way to drive at maximum speed without breaking the limit. The organization should consider whether this dual use of the ATC system is acceptable.

In summary, our recommendations on ways to prevent hazardous signal approach incidents are as follows:

- Find ways to challenge the formation of inappropriate or unsafe schemas by drivers exposed to extreme routine.
- Design through driver consultation better systems to brief drivers about deviant situations they can expect as they journey on the day’s route.
- Use refresher training to prime driver’s minds about the possibility of deviances and dangers of routine assumptions, and to challenge any inappropriate schemas.
- Design a signal environment that better accounts for human factors, making deviant signal aspects easier for drivers to perceive.
- Consider whether the way ATC is used by drivers is optimal in terms of safety.
- Investigate factors influencing conductor involvement in incidents occurring on station exit.

These recommendations do not consider any possible technical improvements to the ATC system.

For recommendations on development of CREAM the reader is referred to the end of Appendix 9.

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Appendix 1: Some comments about working culture

The study of Brotnov (2007) is particularly informative with regard to train driver culture in NSB. The importance of keeping to the timetable is clearly paramount for drivers, whether they are in or out of stations. Expectations are described as a normal part of efficient driving, and the complexities of station approach are outlined. Of particular interest is an observation that drivers "have frequent daily announcements regarding the placement and condition of infrastructure on any given route", and that as a result of these announcements "drivers make minor or major exceptions to the rules when carrying out procedures".

To add to this report, a selection of comments from the 12 drivers interviewed in this study is given here to illustrate our impression of the relevant aspects of the driver's day-to-day working environment, and the organizational culture in which the drivers work. We do not claim that the picture drawn by these comments is representative of the working culture across the organization. It should be remembered that the drivers knew that the focus of the interviews was safety, and so interviewees were trying to help by searching to identify problems that they saw as relevant. The comments have been translated from Norwegian.

On ATC

"ATC can be fussy, it can intervene with operational brakes, but it's not dangerous."

"You get used to hearing the alarm, it's not so unusual. It becomes a way to drive"

On current climate of delays and deviant situations

"I feel the last two weeks have seen the worst delays in 12 years. Things begin to happen. There is more chance for mistakes."

"If a train is cancelled you get stress from the customers."

"We get stick from the customers. I feel that my job is customer management. The management don't do this."

"You are not secure in the knowledge that you know everything that is going on. You don´t always get to know about delays. Some things you have to find out for yourself. This is an extra load on the driver."

"In abnormal situation you feel exposed to safety vulnerabilities. You don't always follow procedure. Operation control cannot always manage the situation from where they are. We have to do it under stress."

"The train dispatcher fails to explain fully difficult situations."

"We have old stock, 20, 30 years old, with different problems. Sometimes you have to connect a reflector (?). It's always in the back of your mind: what is going to happen today?"

"Mistakes happen whenever there is deviance from the norm".

On learning from incidents

"Nothing happens when you report in Synergi."

“There was an opportunity to write the incident into Synergi. But the press have access to the system. I think maybe this is modified now, but I am still not as good as I should be at reporting. But the culture is still rather to keep yourself to yourself and learn by yourself.”

“I have written into Synergi several times when others wouldn’t have. But you only report something when you think something will happen (as a result). Sometimes you see that nothing happens.”

Others say you can speak to colleagues openly about incidents, but that you must do it “tactically”.

“I could have reported (a problem with leaves on the line); nothing happens so you give up. It’s the same with dust in the tunnels…”.

“It’s not worth reporting dirty signals, there are so many and nothing would happen. Synergi is for bigger things.”

On the dangers of routine

“Routine and stress are the biggest problems facing drivers.”

“The train was packed. I had no time to spare, but I like that feeling. It keeps me focused.”

On fatigue

“You get tired towards the end of the shift (having been on night duty).”

Several commented on the difficulties of a first early shift.
“If you have a lot of coffee and food it goes ok. But there are times when you think could something happen now? The car journey home especially can be a problem.”

Appendix 2: Letter to train drivers

XXXXXXXX

XXXXXXXX

Invitasjon til trafikksikkerhetsundersøkelse

Hei!

Transportøkonomisk institutt (TØI) gjennomfører nå et forskningsprosjekt om sikkerhet på jernbane og veier. Hensikten er å forstå hvordan systemet av organisasjons- og tekniske faktorer er til hjelp eller hindring når lokfører eller bilfører utfører sikkerhetsrelaterte manøver. For å forstå samspillet av ulike faktorer, vil TØI lytte til de som kjenner systemet best, dvs lokfører og bilfører. Resultatene fra prosjektet vil bli brukt av forskerne til å foreslå endringer i de tekniske systemer og organisasjonsprosesser.

NSB XXXXX betrakter dette som ett viktig bidrag i vårt arbeid med å forebygge og dermed også forhindre at slike hendelser skjer. Som lokfører kan dere ved å bidra til slik informasjon, hjelpe en kollega til å unngå å komme ut for en slik hendelse, eller kanskje selv unngå det. Vi håper at flest mulig av dere ser nytten av å delta i undersøkelsen.

Hvis du vil bidra, så vær vennlig å svar på det vedlagte spørreskjemaet. Alle svar som blir gitt i skjemaet, og i et eventuelt intervju, vil bli anonymisert. Din besvarelse er helt frivillig.

Hvis du har noen spørsmål til undersøkelsen, kan du sende en e-post til forsker Ross Phillips rph@toi.no.

På forhånd tusen takk for hjelpen!

Med vennlig hilsen

XXXXXXX

Lokførerleder

NSB Drift XXXXX

Forsker

Transportøkonomisk institutt

Appendix 3: Information to train drivers

The information below was given out in Round 1 and 2.

Forskningsprosjekt: oversette signaler

Kunnskap om forhold som kan føre til farlige hendelser

Transportøkonomisk institutt gjennomfører et forskningsprosjekt for å få mer kunnskap om forhold som påvirker sannsynligheten for farlige hendelser i transportsektoren. Utgangspunktet for undersøkelsen er at det ikke er tilfredsstillende å forklare en farlig hendelse som et resultat av menneskelig svikt, slik det ofte gjøres. Selv om en farlig hendelse kan sies å være utløst av en handling foretatt av en operatør eller fører, er det sentrale spørsmålet hvorfor denne handlingen skjedde. Kan den føres tilbake til mangelfull utforming av det tekniske systemet som føreren/operatøren betjener? Kan det knyttes til forhold ved arbeidsmiljø og arbeidsorganisering (f.eks., arbeidsbelastning, stress, kommunikasjonsproblemer, uklare regler, etc.).

Lokførere kan sikkerhet

I dette prosjektet ønsker vi å benytte lokomotivførere som informanter når det gjelder risiko for farlige hendelser. Dette gjør vi bl.a. fordi jernbane er en transportform med et høyt sikkerhetsnivå, og lokførere har svært gode forutsetninger for å kunne vurdere hvordan sikkerheten best kan varetas og eventuelt forbedres. Dette er kunnskap som også kan komme til nytte innenfor andre transportformer og virksomheter.

Hvorfor blir signaler oversett?

I det nåværende prosjektet ønsker vi å betrakte to typer hendelser.

i. Et signal er oversett av lokføreren slik at ATC griper inn med enten drifts- eller nødbrems.

ii. Lokføreren tenner lampe ”kjøretillatelse mottatt” uten å ha fått kjørtillatelse i signal, lokfører får ”Avgang” signal fra ombordsansvarlig og kjører mot signal i stopp.

Disse er hendelser som av ulike grunner forekommer av og til, men er interessante fordi de representerer sviktende barrierer i et system av forsvar mot fare. I dette prosjektet ønsker vi å bruke lokførernes kunnskap om og erfaring med denne type hendelser som en av flere innfallsvinkler for å analysere sammenhengen mellom et teknisk system og operatørers handlinger. Informasjonen vil vi innhente gjennom å intervjue 20 lokførere som blir innblandet i slike hendelser.

Hvordan gjøre et sikkert system enda sikrere?

Undersøkelsen av slike hendelser har to formål:

1) Å skaffe kunnskap om forhold som påvirker risikoen for farlige hendelser, både innenfor jernbane og andre områder. (Det er IKKE et formål å finne ut om en lokfører har gjort en feil eller ikke – fokus er på hva det er ved hele systemet som gjør at feil oppstår.)
2) Bruke kunnskapen om farlige hendelser til å finne ut mer om hvordan systemet eventuelt kan forbedres – det kan gjelde både utformingen av de tekniske systemene, organiseringen av arbeidet, opplæring, rutiner osv.

Konfidensiell informasjon

Det kan tenkes at de som intervjues, i enkelte tilfeller vil ha informasjon som de av forskjellige grunner ikke ønsker skal komme videre. Vi ønsker at intervjuingen skal foregå i en tillitsfull og trygg atmosfære, blant annet for at vi skal få et best mulig datamateriale. Vi har derfor som et viktig prinsipp for intervjuingen at all informasjon om enkeltpersoner er fortrolig, slik at ingen andre enn forskerne i dette prosjektet får tilgang til den. I rapportene fra forskningsprosjektet vil det ikke bli henvist til enkelthendelser, og alle data vil bli presentert på en slik måte at ingen opplysninger kan føres tilbake til enkelthendelser eller enkeltpersoner.

Appendix 4: Survey and invitation to interview

Invitasjon til av forskningsintervju (2.omgang)

I sammenheng med forskningen om oversette signaler (vedlegg), ber vi deg om å fylle ut skjemaet på den andre siden.

Skjemaet spør om mulige hendelser på de siste 12 måneder.

Selv om du svarer *Nei* på alle spørsmålene, vennligst returnerer skjemaet ved bruk av den vedlagte frankerte svarkonvolutten.

Dette er 2. av muligens 3 invitasjoner du vil motta.

På forhånd, takk nok en gang for din deltakelse!

Ross Phillips

Forsker

Skjema til lokførere: Vennlig kryss av for det som passer.

Har du i løpet av tidsrommet…		siste måned	siste 3 måneder
1.	Oversett et forsignal hvorpå ATC grep inn og bremset ned? *(det er ikke nødvendig at du har passert et signal i stopp)*	☐	☐
2.	Oversett og passert et dvergsignal i stopp?	☐	☐
3.	Oversett et forsignal og passert et hovedsignal i stopp?	☐	☐
4.	Tent lampe 'kjøretillatelse mottatt' uten å ha fått kjørtillatelse i signal? *(selv om lampe ble slått av etterpå)*	☐	☐
5.	Tent lampe 'kjøretillatelse mottatt' uten å ha fått kjørtillatelse i signal, og fått 'Avgang' signal fra ombordsansvarlig?	☐	☐

	Ja	Nei
Samtykker du til et intervju med en forsker fra TØI? *Intervjuet vil vare i omtrent 90 minutter, og vil gjennomføres utenfor vanlig arbeidstid. Dette godtgjøres med 90 minutter overtid.*	☐	☐

Hvis du samtykker til intervju, vennligst oppgi kontaktdetaljer nedenfor. Dine detaljer vil bli behandlet strengt konfidensielt.

navn:

e-post adresse:

telefonnummer:

foretrukket kontaktmetode:

Vennligst returner det utfylte skjemaet ved bruk av vedlagt svarkonvolutt. Du kan enten sende skjemaet direkte til Transportøkonomisk institutt, eller legge den i en egen postkasse på ordrerom.

Takk!

Appendix 5: Invitation to interview

Kjære XXXXXXXXXXX

Forskning om sikkerhet på jernbane

Tusen takk for at du innleverte skjemaet og samtykket til intervju. Jeg er nå i ferd med å gjennomføre intervjuene og vil gjerne lage en avtale med deg.

Intervjuet skal foregå på undervisningsrommet i 3. etasje, XXXXXXX stasjon, utenfor arbeidstiden. Det kommer ikke til å ta mer enn 90 minutter. Temaet for intervjuet er hva kan påvirke sikkerhet på jernbane. Ditt navn vil ikke bli knyttet til dine svar, og intervjuet vil behandles strengt konfidensielt.

For å kompensere for den tiden du bruker, skal du få 90 minutter overtid utenfor arbeidstiden.

Har du et tidspunkt som passer i løpet av de neste tre ukene? I så fall er det fint om du ringer, sender e-post, eller skriver ved bruk av detaljene nedenfor.

Med vennlig hilsen

Ross Phillips

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Transportøkonomisk institutt
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0349 Oslo

kontor +47 22 57 38 00

mobil +47 47 68 33 81

e-post rph@toi.no

Appendix 6: Interview guide

Intervjuskjema, XXXXXX lokfører (2009)

1. Gi kort beskrivelse av hendelse

2. Beskrive bakgrunnsomstendighetene som følger
    a. Når?
    b. Hva? Tog, rute, osv
    c. Hvor?
        i. Hvilken type av strekning?
        ii. Viktige faktorer i det lokale miljøet?
        iii. Kompleksitet?
        iv. Informasjon / signaler lett å forstå / manglende info?
    d. Hvor (hva var lokførers miljø)?
        i. Sete, kontroll, HMI
        ii. Syn
        iii. HMI fører-maskin; sammenstilte grenseflater
    e. Miljøomstendigheter
        i. Vær, lys, sol, tåke osv
        ii. Syn til viktige objekter / ’blind spots’
        iii. Spor
    f. Lokfører
        i. Helse
        ii. Fart ift fartsgrense
        iii. Biorytme
        iv. Andre oppgaver / mål (enn å føre toget)
        v. Skifte, tid som gjensto
    g. Opplæring / erfaring
        i. I denne situasjonen, området, tid på dag, tog, rute, med utstyr
        ii. Generell erfaring (lengde)
        iii. Vanlig skiftemønster
        iv. Hva synes lokføreren av kabinen / utmiljøet
        v. Opplæring
        vi. Kunnskap av prosedyrer, regler generelt / ift hendelse

3. Detaljert beskrivelse av hendelse basert på tabellen
    a. Hva skjedde?
    b. Menneskelige faktorer
    c. Miljøfaktorer
    d. Organisasjonsfaktorer

Appendix 7: Train driver opinion of research

1. Recall – only 42 per cent correctly remembered how many times they had received the survey.

I have now received a survey about signal incidents...

(n = 24)	
2 times	50 %
3 times	42 %
4 times	4 %

2. Knowledge – only 29 per cent knew exactly what the project was about.

I think that the point of this project is to get a better understanding of the following safety factors (answer one or more). [Subsequently human, technological and organizational factors were listed].

(n = 24)	
1 right	42 %
2 right	29 %
All 3 right	29 %

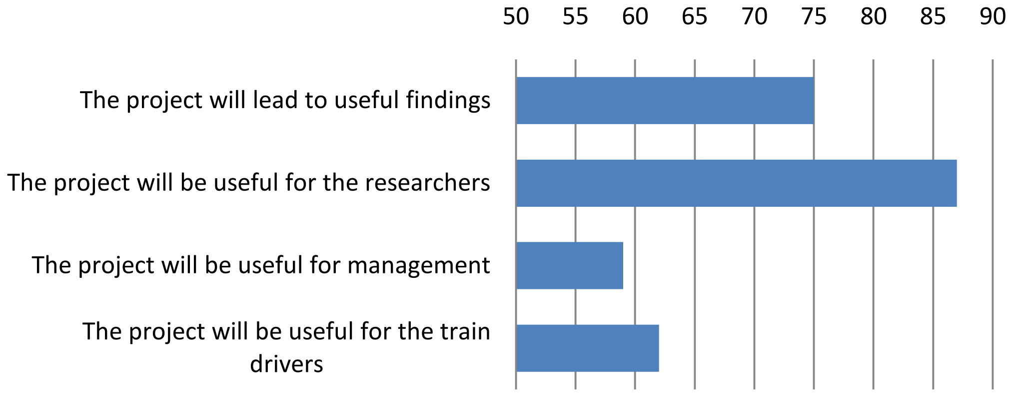
3. Attitude to project – 71 per cent thought the project would increase understanding of their situation.

Which statement best describes your attitude towards the project?

(n = 24)	
The project will lead to an increased understanding of the train driver's situation.	71 %
The project is a waste of time.	0 %
The goal of the project was good but the method was lacking.	25 %
Other (free to state).	4 %

4. Opinion of the project.

Percentage of drivers agreeing with statement…



Appendix 8: Signals and signal aspects

The following section is based largely on Nordbakke & Sagberg (2007).

Main signals

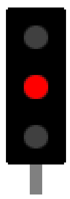
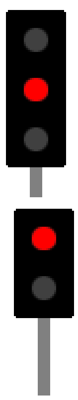
There are four types of main signal on Norwegian railways:

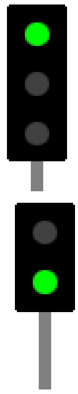
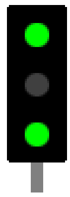
- Home signals ("Innkjørhovedsignaler") – at the station area
- Exit signals ("Utkjørsignaler") – at the station area
- Inner signals ("Indre hovedsignaler") – at the station area
- Block signals ("Blokksignaler") – between stations

In addition, there are approach signals that forewarn about main signal aspect (details in next section).

Permission to proceed at a main signal means that the train route is set and that the points are secured. All stations in Norway are equipped with both home signals and exit signals. Some stations (especially large or long stations) are in addition equipped with inner signals. Home signals mark the station boarder and are normally placed 200 meters before the outermost points and exit signals mark the end of the entry train route.

Main signals. Source: Signalforskriften av 2002 (NSB 2002).

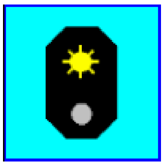
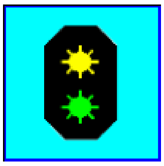
Image	Signal	Meaning	Used in
	Signal 20A - **Stop** (flashing red light)	The train must stop short of the signal.	Home signals, block signals.
	Signal 20B - **Stop**	The train must stop short of the signal.	Exit signals, inner signals.

	Signal 21 - **Proceed on different track**	The train can proceed, by diverging at one or more sets of points.	Home signals, exit signals, inner signals, block signals.
	Signal 22 – **Proceed on same track**	The train can proceed, *not* via deviant switches.	Home signals, exit signals, inner signals, block signals.

Approach signals

Approach signals, also known as distant signals, indicate the state of the subsequent main signal. It can either stand by itself or be situated beneath the preceding main signal, but it is in any case placed to allow sufficient braking distance between it and the corresponding main signal. All home signals and block signals have a corresponding approach signal at least 800 meters before them. Normally, exit signals and inner signals also have corresponding approach signals.

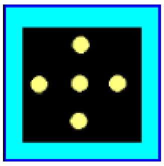
Approach signals. Source: Signalforskriften av 2002 (NSB 2002).

Image	Signal	Meaning
	Signal 23 - **Expect stop** (flashing yellow light)	The subsequent main signal shows signal 20A or 20B.
	Signal 24 - **Expect to proceed on a different track** (flashing green and yellow light)	The subsequent main signal shows signal 21.
	Signal 25 - **Expect to proceed on the same track (**flashing green light)	The subsequent main signal shows signal 22.

Proceed with caution (signal 32)
This signal is used to show that the train is about to enter a shortened track (*avkortet togvei eller buttspor*). The signal appears at the same time as signal 21. The signal might also be used in other situations where it is necessary to drive carefully in to or out from the station. Normally, it is placed on the same post as the main signal or stands alone on its own post.

Source: Signalforskriften av 2002 (NSB 2002).

Signal 32. Proceed with caution.

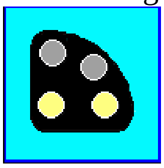


Dwarf signals

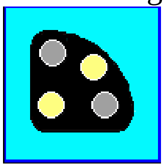
Stations with local signal control are also equipped with signals that regulate shunting operations. There are two kinds of shunting signals: dwarf signals and high-shift signals. In the analyzed incidents, only the dwarf signals were relevant. The three major dwarf signals are given below.

Dwarf signals. Source: Signalforskriften av 2002 (NSB 2002).

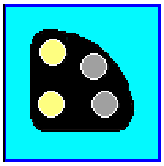
Signal 43. Shunting forbidden.



Signal 44. Careful shunting allowed.



Signal 45. Shunting allowed.



On seeing a "proceed with caution" on signal 32, drivers should attend to the dwarf signals, even when they are passing through a station (i.e. not carrying out shunting movements).

Appendix 9: Evolving CREAM

The following methodological comments pertain to the cases detailed in Chapter 3, as indicated. For elaboration on recommendations about better accounting for driver culture in analysis, the reader is directed to Nordbakke and Sagberg (2007).

Case 1

Arguments could be made for choosing surplus speed as a phenotype rather than timing: no action, but the latter was chosen as it was seen itself as the reason for surplus speed. Confusion concerning choice of phenotype is not uncommon using CREAM-based methods but often, as in this case, the subsequent choice of antecedent events and conditions is not affected.

The genotype "inadequate plan" was intended by the developers of CREAM to describe a formal plan, possibly carried out for the whole journey before exit. Throughout these analyses, however, we use the term "inadequate plan" to refer to a more dynamic and immediate planning, continually updated in the driver's mind as events either confirm or deviate from routine as the journey progresses. Use of the term in this way gives allows the analyst to consider important antecedents which otherwise would be omitted. In this case, for example, the analysis suggests some sort of training could be constructive, and this would not have been considered had "inadequate plan" been used as the original developers suggested. We recommend that future analyses using CREAM-based methods consider this alternative use of the genotype.

The analysis is for the missed signal event, but could also have been performed for the missed or ignored audible and visual ATC alarms. While the outcomes in terms of suggested antecedents may have been similar, we may also have found that the settings on the alarm were not optimal for alerting the driver.

Either missed or false observation but not both are possible as antecedents of the lack of action. Elsewhere all of the preceding antecedents could have occurred together or in isolation. A way to denote which antecedents are mutually exclusive and which are additive would be helpful.

Case 2

As pointed out by Nordbakke & Sagberg (2007), the CREAM method does not allow for potentially important cultural influences to be accounted for in incident analysis. Several drivers pointed out that they "drive against" ATC, estimating distances between transponders and signals in order to brake only when they need to, a tendency which helps them drive efficiently. Presumably there is a belief among the drivers that they need to save time whenever it is safe to do so. While such a culture prevails the driver will always try to judge where the boundaries of safety lie i.e. drive "against" the ATC system designed to keep them and their passengers safe. This factor may have played a role in this incident, but is not accounted for by the method.

An option that could arguably considered as an immediate antecedent to the **surplus speed** phenotype is that the driver had an inadequate plan for driving through the signal. We did not choose this because the driver usually passed the *same signal in the same state* without incident. In any case, such an analysis would have led to a very similar set of genotype chains.

Surprisingly the method does not allow distraction (Ex3) as a phenotype of inattention (Ex5).

Case 3

No comments.

Case 4

The analysis focuses on the missed main signal, but in addition the driver (possibly) forgot the approach signal. By forcing the analyst to focus on one phenotype, the incident is not considered as a whole. An extended analysis might have had extra implications. For example, the placing of a staff stop between approach and main signals is clearly detrimental to the driver's ability to remember the approach signal. The resetting of the ATC panel to default "stop" every time the train pulls away from a stop is also problematic in this sense, and in addition means the driver becomes accustomed to questioning the "stop" display when he sees it.

As mentioned above, the analysis suggests several causal chains of antecedents that appear to say similar things. While the method can be criticized for being repetitive or overly complex, different perspectives are provided about the same state of the MTO system. These are helpful when considering recommendations.

It should also be noted that we have taken an open approach in the selection of antecedents in these analyses, and other analysts may not have selected so many antecedents. We consider that it is necessary to be open while there is uncertainty about cognitive events occurring in the head of the subject of the analysis. It seems better to consider several event chains together in order to build up a picture of the events leading up to an incident, rather than conclude too much from a few selected antecedents.

See 3.2.1 for notes about the use of "inadequate plan" antecedent.

Case 5

We really have no explanation for why the driver did not see the upcoming signal other than that he was relying on a schema formed from past experience. Analysis of the other incidents suggest there is usually some other factor which "forces" the driver to rely on an established schema. A lack of data may explain why the results of this analysis are not entirely satisfying.

The amount of information gathered from an interview depends not only on recall but on varying openness of drivers. The quality of this analysis is probably compromised by the limited amount of information the driver was willing to give. We know little in this case, for instance, about the driver's experience or shift pattern at the time of the incident, factors which may also have played important roles in the incident.

See Case 1 for notes about the use of "inadequate plan" antecedent.

Case 6

Again, cultural factors are implicated in this incident, but the method does not inform about what these issues are or how they play a role. Would all drivers feel comfortable asking for silence in the cabin during periods of distraction? How much responsibility do different drivers feel for punctuality when they encounter passenger reactions every day? Does this mean they pay too much attention to punctuality and therefore become tempted to take shortcuts?

Distraction would appear to be a natural antecedent to inattention, but the method does not allow this.

See case 1 for a discussion of the antecedent "inadequate plan".

Case 7

The analyst could have also chosen **false observation** instead of **missed observation** as the immediate antecedent of the phenotype **timing: too late action**, since the driver falsely interpreted a signal to the right as applying to his track. However, since false observation comes out in the analysis as an antecedent of missed observation, a more complete explanation is given by choosing missed observation as the first immediate antecedent.

We decided to stop the analysis at **false observation**, even though there was not a stop rule in the method. This prevented similar antecedent chains being accounted for in the same analysis.

Case 8

The method does not account for the possibility of dirty lamps suggested by the driver. In other words, the antecedent **K1: maintenance failure** is not available for the list of antecedents linked to **N4: temporary obstruction to view**.

Likewise, **L1: insufficient skills** is not available for the antecedent **D1: inadequate plan.** Although insufficient knowledge is suggested by the method, this does not presumably cover knowledge gained from *practical* experience, since this is detailed as an example under L1. The analysis would have been strengthened had we been able to consider a lack of practical experience as a key antecedent to the driver's inadequate plan and subsequent missed observation.

As with some of the other cases, there are interesting cultural factors that may also play a role in incidents like this. Could the driver have been made more aware about low sun effects by talking with other drivers? Does the driver culture encourage this? The method does not consider such factors.

Case 9

This analysis was simple enough to allow two missed observations to be considered in the same analysis.

Distraction could reasonably be interpreted as a possible antecedent to **inattention** but this is not possible with the method. The method rather appears to treat inattention as general loss of focus or vigilance.

The need for training to address bad habits or incorrect expectations formed by drivers is not implied directly by the method, even though common sense would suggest this as a solution.

The method is clearly influenced by the analyst's interpretation of interviewee responses. In this case the driver began his shift outside normal working hours, something that could have contributed to the driver's lack of attention. Despite this, the driver said he could not remember being tired. Whether fatigue is implicated as an antecedent to inattention is, however, not clear.

Finally, although procedures is suggested as an antecedent to the distraction of having others present in the driving cabin, the method does not offer a cultural antecedent.

Case 10

No comments.

Evolving CREAM: Summary

We highlight the following recommendations for evolving CREAM for analysis of signal approach incidents.

- A more useful definition of the antecedent **D1 inadequate plan** is as an inappropriate evolving plan or schema about the developing journey i.e. not just to a plan for the whole journey formed before it begins.
- It is more instructive to consider antecedent event chains as possible explanations for the course of events leading to a missed signal, rather than definitive causative paths.
- Consider how to close a gap between driver descriptions of how they *felt* and thought during the incident and the analyst's subsequent mapping of cognitive events.

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