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TØI report 915/2007

Institute of Transport Economics
Norwegian Centre for Transport Research

CREAM analysis of “Signal Passed at Danger” (SPAD) events

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915/2007

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ISSN 0808-1190
ISBN 978-82-480-0801-9 Paper version
ISBN 978-82-480-0802-6 Electronic version

Oslo, November 2007

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Date: 11.2007

TØI report: 915/2007

Pages 44

ISBN Paper: 978-82-480-0801-9

ISBN Electronic: 978-82-480-0802-6

ISSN 0808-1190

Financed by: The Research Council of Norway

Project:

Project manager: Fridulv Sagberg

Quality manager: Torkel Bjørnskau

Key words: Accident investigation
Erroneous action
Railway
SPAD (signal passed at danger) events
Traffic safety

Summary:

When a train passes a stop signal, it is potentially a dangerous event. In this project six cases of "Signal Passed at Danger" events have been analysed. The primary purpose was to test the applicability of CREAM, which is a system of classification and method for analysing error causation. The project was also expected to provide knowledge about factors that may influence the risk of SPADs, and thus provide background for countermeasures. The analysis resulted in suggestions in regard to adaption of the CREAM method in the rail domain. Furthermore, specific suggestions to the Norwegian railways were made both in regard to countermeasures and to reporting routines concerning such events.
There is a need for more standardized positioning of signals, and for improved communication between traffic control centre and train drivers.

Language of report: English

Tittel: CREAM analyse av kjøring mot stoppsignal på jernbanen

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Dato: 11.2007

TØI rapport: 915/2007

Sider 44

ISBN Papir: 978-82-480-0801-9

ISBN Elektronisk: 978-82-480-0802-6

ISSN 0808-1190

Finansieringskilde: Norges Forskningsråd

Prosjekt: 2891 - Feilhandlinger og ulykkesrisiko i framføring og overvåkning av transportmidler.

Prosjektleder: Fridulv Sagberg

Kvalitetsansvarlig: Torkel Bjørnskau

Emneord: Feilhandlinger
jernbane
Passhendelser
Trafikksikkerhet
Ulykkesanalyse

Sammendrag:

Når et tog passerer et stoppsignal, er det en potensielt farlig situasjon. I dette prosjektet har det blitt gjennomført seks case studier av slike passhendelser. Det primære formålet med prosjektet var å prøve ut anvendbarheten av CREAM, som er en metode for klassifisering og analyse av årsaksforhold når det gjelder ulykker og farlige hendelser. Et annet formål var å få mer kunnskap om faktorer som påvirker sannsynligheten for passhendelser, noe som igjen gir grunnlag for utforming av tiltak. Analysene resulterte i forslag til tilpasninger av CREAM til jernbanehendelser. Basert på resultatene fra analysene, er det også blitt gitt konkrete forslag til tiltak for å forhindre passhendelser og til hvordan slike hendelser kan rapporteres.
Det er behov for bedre standardisering når det gjelder plassering av signaler, og bedre rutiner for kommunikasjon mellom togledersentral og lokfører.

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Preface

This report is part of the project "Errors, information processing, barriers, and accident risk in the operation and control of different means of transport", which has been carried out within the RISIT programme ("Risk and Safety in the Transport Sector") of the Research Council of Norway. A main objective of the project has been to try out and adapt a methodology for identifying and analysing erroneous actions and their causes, which can be applied across transport modes. In the first phase of the project it was decided, on the basis of a review of previous work, to focus on methods based on the Cognitive Reliability and Error Analysis Method (CREAM). This method, developed by Eric Hollnagel at the Institute for Energy Technology, Halden, Norway, in the mid 1990's, is based on an MTO (Man-Technology-Organisation) approach to analysing incidents and accidents. It was decided to carry out case studies within both rail and road transport. In this report we present the rail case studies, which consisted of analysing "Signal passed at danger" (SPAD) events related to missing observation of a stop signal on the part of the train driver. The road traffic case studies are presented in a separate report.

This project was carried out in cooperation with the University of Oslo, Department of Psychology, (which also resulted in a master thesis). Special thanks to Sarah Brotnov for her contribution in the preparatory phase of the project.

The case studies are based on incidents within the Norwegian State Railways (NSB), and we would like to thank the following person within the NSB for providing us with background information on the railway system, the reporting routines and the internal investigation of SPADs, as well as for providing us with informants to the case studies: Svein Ivar Johannessen, Kåre Bøklepp, Stein Erik Olsen, Sigurdur Petursson, Ulf Glasrud, Jon Anders Orving and Odd Vognild.

At TØI, Susanne Nordbakke has managed the project and written most of the report. Fridulv Sagberg has authored some of the introductory parts of the report and has provided comments on theanalysis. Torkel Bjørnskau has been responsible for the quality assurance, and Trude Rømming has edited and prepared the report for printing.

Oslo, November 2007
Institute of Transport Economics

Lasse Fridstrøm
Managing Director

Torkel Bjørnskau
Chief Research Officer

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Summary:

CREAM Analysis of "Signals Passed at Danger" (SPAD) events

When a train passes a stop signal, it is potentially a dangerous event. In this report six such events are analyzed, primarily in order to assess a generic method for error analysis in man-machine systems, and its applicability to the rail domain. The project resulted in several recommendations for improvements and adaptations of the method, as well as suggestions for measures to prevent SPADs. For example, there is a need for more standardized positioning of signals, and for improved communication between traffic control centre and train driver.

Railway transport safety depends heavily on an effective interaction between signal systems, rolling stock, train drivers and train control centres. When a train passes a stop signal, it is a potentially dangerous event, and it is therefore of utmost importance to get information about the factors that influence the probability of such events. "Signal passed at danger" (SPAD) is the common term used to denote such events (in Norwegian: "PASS-hendelser"), and railroad authorities have reporting systems to monitor SPADs in order to take appropriate countermeasures.

In this project a few cases of SPADs that may be related to train drivers having failed to observe a stop signal, have been investigated. The general purpose of the project was to develop and try out the Cognitive Reliability and Error Analysis Method (CREAM, Hollnagel 1998), which is a system for classification and analysis of error causation in transportation. Although the primary goal was to test the applicability of this classification system, the study was also expected to provide knowledge about factors that may influence the risk of SPADs, and thus provide a background for countermeasures.

The case studies are based on incidents within the NSB (Norwegian State Rail). NSB has procedures to secure that all unwanted incidents during train driving or shunting are reported. Each incident is reported in a database named Synergi (standard form). As the Synergi reports from the SPAD incidents were insufficient, in terms of information, for conducting a CREAM analysis, it was decided to conduct qualitative interviews with train drivers that had been involved in SPAD incidents.

The report can be ordered from:
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The applicability of the CREAM method in the rail domain

In all of the incidents examined here, human error is stated as a direct cause in the Synergi reports. Incidents where technical factors were stated as the direct cause, were not included in this study. In almost all the incidents that were analysed, the CREAM method manages to capture more contributing factors than in the original analysis as documented in the Synergi report. Moreover, it manages to capture the interaction between different contributing factors.

Our analysis shows that technical and especially organisational factors are important contributing factors in most of the cases even though not always mentioned in the Synergi reports.

A general remark to the CREAM classification scheme is that it could be expanded with regard to organisational categories, especially concerning more informal parts of an organisation and the relations/interaction between people within the system of an organisation. The human and technical categories seem to be dominating.

Based on the findings in our case studies, suggestions to new organisational categories have been made in order to adapt the CREAM method to the rail domain.

Furthermore, the case studies reveal that there is extensive communication between the train driver and the train dispatcher/traffic controller. Thus, we suggest to include a category under "communication" that specifically relates to this kind of communication.

In addition, the analysis revealed that the definition of the "Communication" category should be expanded when applying the CREAM method in the rail domain. As in one case, the train driver "reads" the actions by the train dispatcher/traffic controller through the technological system and uses this as information. Even though not considered as an information channel in the CREAM classification scheme, this is an information channel which is actively used by the train drivers. It should be included in the CREAM classification scheme (in the "Communication" category") as it might reveal possible errors on the part of the train dispatcher/traffic controller.

A general point, which summarises many of the remarks and suggestions above, is that the interaction between train driver and train dispatcher, as a representative for the organisation, has to be more fully described in the CREAM classification scheme, if used in the rail domain.

Suggestions to the Norwegian railways

The advantages of case studies are that one is able to get into the depth of complex questions. The application of the CREAM methodology enabled new questions to be asked and thus, new contributing factors to be revealed. Based on the findings in the case studies, the following suggestions can be made to the Norwegian railways:

- *Standardization.* The most common contributing factor in the case studies was the deviant placement of a dwarf signal (that is, placed on the left-hand side of the track instead of the right-hand side, marked with an arrow on the pole of the signal). In most of the cases where this contributing factor was present, the train driver did not have knowledge of this deviant placement of the signal. This indicates that the system, as it is designed today, requires local skills on the part of the train driver. The need for local skills is especially a problem in situations that are new to the train driver. Even though it is impossible for a train driver to be trained for all different situations, it would nevertheless be easier if the system was more standardized.

  Some of the case studies revealed that the train drivers expectations and habits are related to the design of the system.Standardization is also an important factor for avoiding errors by train drives due wrong expectations and different habits.

- *Knowledge about the train drivers' working conditions and practices*. The findings suggest that more knowledge among the train dispatchers/traffic controllers about the train drivers' working conditions and their practices would increase their understanding for the train drivers information needs and how they interpret different kinds of information given by the train dispatcher/traffic controller. This would possibly increase the communication between them, and hence possibly increase the efficacy of the system on the one hand and increase the train drivers feeling of control on the other.

- *Separate follow-up routines - a challenge*. The responsibility for the follow-up of an unwanted incident is today divided between NSB, when the incident is said to be directly caused by the train driver, and Jernbaneverket (the Norwegian rail administration) when the incident is said to be directly caused by factors under their responsibility (the infrastructure such as the track, the signalling system and train dispatchers and traffic controllers). One suggestion is to coordinate, in the case where human error is said to be the direct cause of an event (either by the train driver or the train dispatcher/traffic controller), the investigation and reporting between NSB and Jernbaneverket.

- *The CREAM classification scheme as a basis for reporting a SPAD event.* As the Synergi reports turned out to be insufficient for a CREAM analysis, and our findings show that the CREAM analysis reveals more contributing factors than stated in the synergi reports, we suggest to use the CREAM classification scheme as a basis for the reporting of SPAD events. This will secure necessary information to be reported. Even though CREAM analysis is not used in the investigation of an incident, it would be useful to use the CREAM classification scheme in the reporting of an incident.

TØI rapport 917/2007
Forfatter: Susanne Nordbakke og Fridulv Sagberg
Oslo 2007, 44 sider

Sammendrag:

CREAM analyse av kjøring mot stoppsignal på jernbanen

Passering av stoppsignal er en potensielt farlig situasjon. I denne rapporten gjennomgås seks slike hendelser, primært for å prøve ut en analysemetode for årsaker til ulykker og farlige hendelser i menneske-maskin-systemer generelt. Prosjektet resulterte i flere forslag til forbedringer og tilpasninger av metoden, samt forslag til tiltak for å forhindre kjøring mot stopp. Blant annet er det behov for bedre standardisering når det gjelder plassering av signaler, og for bedre rutiner for kommunikasjon mellom togledersentral og lokfører.

Sikkerheten på jernbanen er avhengig et godt samspill mellom signalsystemet, det rullende materiell, lokomotivførerne og togtrafikksentralene. Når et tog passerer et signal i stopp, er det en potensielt farlig situasjon. Det er dermed viktig å få informasjon om hvilke faktorer som påvirker sannsynligheten for en slik hendelse. Passhendelser er den vanlige måten å betegne slike hendelser på i Norge, og jernbanemyndighetene har rapporteringsrutiner for å overvåke slike hendelser.

I dette prosjektet er det blitt gjennomført noen casestudier av passhendelser som kan være relatert til at lokomotivfører har oversett et signal i stopp. Det generelle formålet med prosjektet har vært å utvikle og prøve ut ”The Cognitive Reliability and Error Analysis Method” (CREAM, Hollnagel 1998), som er en metode for klassifisering av årsaksforhold innen transport. Selv om det overordende målet var å prøve ut denne metoden på jernbanehendelser, var studien også rettet mot å øke kunnskapen om faktorer som kan påvirke sannsynligheten for en passhendelse. Kunnskap om slike faktorer er viktig med tanke på å utforme de riktige tiltakene.

Casestudiene er basert på hendelser innen Norges statsbaner (NSB). NSB har prosedyrer for å sikre at alle uønskede hendelser under togframføring eller under skifteoperasjoner blir rapportert. Hver hendelse blir rapportert i en database ved navn Synergi. Det var imidlertid ikke tilstrekkelig informasjon i Synergirapportene til å kunne gjennomføre CREAM-analyser av de utvalgte hendelsene (casene). Det var derfor nødvendig å benytte intervjuer med lokomotivførere som hadde vært involvert i hendelsene, som det primære datagrunnlag for gjennomføringen av analysene.

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CREAM metoden anvendt på jernbanesektoren

I alle hendelsene som her er studert, er menneskelige feil oppgitt som den direkte årsaken i Synergirapportene. Denne studien viser at ved en CREAM- analyse klarer man å fange opp flere påvirkningsfaktorer enn dem som er dokumentert i Synergirapportene. En annen fordel med CREAM-analysen er at den også klarer å fange opp interaksjonen mellom ulike påvirkningsfaktorer.

Analysene i denne studien viser at tekniske og spesielt organisatoriske faktorer er viktige påvirkningsfaktorer i de fleste casene som er studert, selv om slike faktorer ofte ikke er nevnt i Synergirapportene.

En generell kommentar til CREAMs klassifiseringsskjema er at det bør bli utvidet med henhold til organisatoriske kategorier. Dette gjelder spesielt forhold som går på de mer uformelle delene av en organisasjon og mellom personer i en organisasjon (innen jernbane; mellom lokmotivførere og andre i organisasjonen). De menneskelige og tekniske kategoriene er dominerende i klassifikasjonssystemet i dag.

På grunnlag av resultatene fra casestudiene foreslår vi å innlemme nye organisatoriske kategorier i CREAM-skjemaet når dette anvendes på jernbaneområdet.

Casestudiene avdekker også at det er en utstrakt kommunikasjon mellom lokomotivførerne og toglederne. Et forslag er derfor å inkludere en kategori under ”Kommunikasjon” som spesielt favner denne typen kommunikasjon innen jernbane.

Med utgangspunkt i resultatene fra casestudiene, har vi også blitt foreslått å utvide definisjonen av kategorien ”Kommunikasjon”, når metoden brukes på jernbaneområdet. I et case vises for eksempel at lokomotivfører ”leser” togleders handlinger gjennom det teknologiske systemet og bruke disse handlingene som retningslinjer/informasjon. Dette er ikke blitt betraktet som en informasjonskanal i CREAMs klassifiseringssystem, men det er likevel en informasjonskanal som blir brukt aktivt av lokomotivførerne. En slik utvidelse av kategorien ”kommunikasjon” vil være viktig for å fange opp eventuelle feil fra togleders side.

En generell kommentar, som oppsummerer mye av det som er sagt over, er at samhandlingen mellom lokomotivfører og togleder bør blir mer detaljert beskrevet i CREAMs klassifiseringssystem, hvis det skal brukes for å studere jernbanehendelser.

Forslag til Norges statsbaner/Jernbaneverket

Fordelen med casestudier er at man har mulighet til å gå i dybden på komplekse spørsmål som avdekkes i en hendelse. I tillegg bidrar bruk av CREAM-metoden til at nye spørsmål blir stilt, noe som igjen bidrar til at nye påvirkningsfaktorer blir avdekket. På grunnlag av resultatene fra casestudiene, er følgende forslag til NSB satt opp:

- *Standardisering:* Det mest vanlige påvirkningsfaktoren i passhendelsene som her er studert, er avvikende plassering av dvergsignaler. I de fleste av tilfellene med avvikende dvergsignal har ikke lokomotivfører hatt kunnskap/erfaring med dette i det aktuelle området. Dette indikerer at systemet, slik det er i dag, krever at lokomotivfører har lokalkunnskap for hvert område han/hun kjører i. Behovet for lokalkunnskap er spesielt problematisk i situasjoner som er nye for lokomotivføreren. Et mer standardisert system ville ha minsket dette behovet.

  Forventinger og vaner er gjerne knyttet til utformingen av systemet, slik en del av casestudiene viser. Standardisering er dermed også viktig for å unngå at man begår feil som følge av gale forventninger/vaner.

- *Kunnskap om lokomotivføreres arbeidsforhold og praksis i ulike situasjoner.* Resultatene i denne studien tyder på at økt på kunnskap blant togledere om lokomotivførernes arbeidsforhold og deres praksis ville kunne bidra til bedre forståelse for lokomotivførernes behov for informasjon (og type informasjon), og om hvordan de tolker ulike typer informasjon som blir gitt av togledere. Dette vil kunne bedre kommunikasjonen mellom dem, noe som på den ene siden vil kunne gi lokomotivførerne økt opplevelse av kontroll og på den annen side bidra til økt effektivitet i systemet.

- *To separate oppfølginger - en utfordring*. Oppfølgingen av en uønsket hendelse er i dag fordelt mellom NSB, når menneskelige feil sies være den direkte årsaken, og Jernbaneverket, når hendelsen sies å skyldes en faktor under Jernbaneverkets ansvarsområde (skinnene, signaliseringssystemet eller toglederne). Vi foreslår å samkjøre rapporteringen og oppfølgingen av uønskede hendelser hvor menneskelige feil er involvert (enten den direkte årsaken knyttes til lokomotivføreren eller toglederen).

- *CREAM-metodens klassifiseringssystem som grunnlag for rapportering av passhendelser*. Studien har vist at CREAM-analysene klarer å fange opp flere påvirkningsfaktorer enn om man kun rapporterer overfor Synergi. Vi foreslår dermed å benytte CREAMs klassifiseringssystem i rapporteringen av passhendelser, selv om man ikke har til hensikt å analyse en hendelse på grunnlag av CREAM. Dette vil sikre at nødvendig informasjon blir rapportert.

1. Introduction

1.1 Background and research questions

Railway transport safety depends heavily on an effective interaction between signal systems, rolling stock, train drivers and train control centres. When a train passes a stop signal, it is a potentially dangerous event, and it is therefore of utmost importance to get information about the factors that influence the probability of such events. "Signal passed at danger" (SPAD) is the common term used to denote such events (in Norwegian: "PASS-hendelser"), and railroad authorities have reporting systems to monitor SPADs in order to take appropriate countermeasures.

The purpose of this study is to investigate a few cases of SPADs that may be related to train drivers having failed to observe a stop signal. The study is part of the project "Errors, information processing, barriers, and accident risk in the operation and control of different means of transport", which in turn is part of the Norwegian Research Council programme "Risk and safety in transport". The general purpose of the project is to develop and try out a system for classification and analysis of error causation in transportation, and SPAD events make up one of several cases for trying out the method. Although the primary goal is to test the applicability of the classification system, the study is also expected to provide knowledge about factors that may influence the risk of SPADs, and thus provide a background for countermeasures.

The main research questions in this project are the following:

a) To evaluate whether the CREAM method is applicable for analysing driving on stop signal incidents? What are the strengths and weaknesses of CREAM method in regard to railway incidents? How can CREAM be adapted to railway incidents and accidents?

b) To identify contributing risk factors in SPAD incidents, by the use of the CREAM method,.

1.2 Different types of SPADs

Not all SPADs involve non-observation of stop signals by a train driver. It is therefore necessary for the purpose of this study to differentiate between different types of SPADs, and as a background we will describe the normal course of events for a train approaching a stop signal, and the safety systems involved.

Main signals are positioned at the approach and exit zones of all stations (approach and exit main signals), and at certain intervals (blocks) between stations (block signals). All main signals are preceded by a distant signal, which gives a pre-warning ("expect stop") when the main signal indicates "stop". The distant signal used to be positioned at a standardised distance of about 800 m before the main signal; however, on new railroad sections the positioning of the distant signal is determined on the basis of the allowed speed on the section.

Most railway sections and rolling stock (exceptions will be described below) are equipped with ATC ("automatic train control"), which implies that the driver is warned if a signal is approached with too high speed, and the brakes go on automatically if the driver does not respond appropriately to the warning. A full ATC system (FATC) also controls train speed between signals, but the majority of the Norwegian railway network is equipped with a partial ATC system (DATC), which controls the speed only when the train is approaching a stop signal. A transmitter between the rails sends a signal to a computer in the locomotive when the train passes a distant signal showing "expect stop". The computer compares the train's speed to a braking curve showing the necessary retardation towards zero speed at the main signal. Whenever the actual speed of the train exceeds the speed defined by the braking curve (e.g. because the driver fails to brake or brakes too weakly), a visual signal appears on the ATC display in the driver's cabin. If there is no response, the next step of the ATC is to sound an alarm, and the third step is emergency braking.

When the driver is braking, and the speed has been reduced to 40 km/h, the ATC is temporarily deactivated. This means that if the driver brakes too weakly at this speed, the train may pass the main signal. In that case, the ATC is activated again and brings the train automatically to a stop by applying full braking power.

The signals on sections with ATC are remotely controlled by operators in a traffic control centre. Some sections are, however, not remotely controlled, and those are not equipped with ATC. On those sections all stations are manned with train dispatchers, who set the signals for driving into or out from a station. Before leaving the station the train driver has to receive permission from the train dispatcher, in addition to observing the exit signal and making sure it indicates "go".

Station areas where switching operations take place (i.e., connecting, disconnecting, turning, etc. of trains or carriages) are not equipped with ATC. These areas have special signals called "dwarfs" that drivers have to observe during switching operations. Due to the lack of ATC, switching areas are especially vulnerable to SPADs, and especially safety-critical points are those where passing a dwarf signal may result in movement onto a main track with through traffic. During shifting operations, the speed is usually low, so although the probability of SPADs is lower than on a main track, the consequences are as a rule less serious.

On this background, one can differentiate between the following types of SPAD or SPAD similar events:

1. Passing a dwarf signal at danger during shifting without observing the signal.
2. Passing a dwarf signal at danger during shifting, observing the signal but misjudging the stopping distance of the train or locomotive.
3. A main signal changes to stop after the driver has passed the distant signal (showing 'expect go'), and the distance is too short for stopping in front of the main signal. This may be caused by infrastructure failure or an action by a

traffic controller. Both distant signal and main signal are observed by the driver.

4. The driver brakes in time, but the braking power of the train is not sufficient for the conditions, and the train stops some distance beyond the main signal. Both distant signal and main signal are observed by the driver.
5. Driver brakes in time, keeping the train below braking curve down to a speed of below 40 km/h, but brakes too weakly during the last phase where ATC is not active, and therefore moves past the main signal before stopping. Both distant signal and main signal are observed by the driver.
6. Distant signal showing "expect stop" is not observed by the train driver. The ATC is activated and brings the train to a stop in front of the main signal.
7. Distant signal showing "expect stop" is not observed by the train driver. The ATC is activated, but the braking distance is too long, and the train stops after passing the main signal.

The most safety-critical events, and the ones we are interested in here, are those where the driver fails to observe a signal. In those cases one of the barriers (the human operator) has failed, and the safety depends on the adequate functioning of the remaining barriers. This means that types 1, 6 and 7 are the ones we would consider. Unfortunately, type 6 is not reported as a SPAD, because the train does not pass the main signal. Consequently, the remaining events that are available for study are SPADs of types 1 and 7.

1.3 Failure to observe distant signals

As mentioned, failure to observe a distant signal indicating "expect stop" is not recorded as a SPAD unless the train also passes the main signal. (That is the difference between events of type 6 and 7.) Nevertheless, failure to observe the distant signal is an example of a failing barrier, and it would therefore be very interesting to analyse such events in order to achieve a better understanding of the conditions under which train drivers fail to observe signals. We have been informed that modern trains are equipped with a event-recorder system ("Telloc"), which records all instances where the ATC is activated, whether or not it results in passing of a main signal. Further research on railway safety should therefore include analysis of such events in addition to the reported SPADs. The "non-SPAD" failures to observe signals are probably far more frequent than the reported SPADs caused by such failure, and thus they make up a considerable set of useful data that is largely unexplored.

1.4 A brief description of CREAM

The purpose of CREAM (Cognitive Reliability and Error Assessment Method, developed by Erik Hollnagel (1998) is to analyse safety-related errors in MTO (Man-Technology-Organisation) systems, and to determine the cognitive, technological and organisational factors that may contribute to error causation. Although CREAM was originally developed in a setting of nuclear power plant operation, it is a generic approach including a taxonomy of cognitive reliability and error concepts that are relevant to any MTO system. However, to capture the domain-specific technological and organisational factors, the taxonomy needs to be adapted when the method is applied in other domains. The method has been adapted to the railway sector (Hollnagel, Lindberg, Sverrbo, Olsson and Skriver, 1999), to the road traffic domain (Ljung, 2002; Ljung, Furberg and Hollnagel, 2002; Huang & Ljung, 2004) and to maritime accidents (Hollnagel, internet communication, 2006: http://www.ida.liu.se/~eriho/CREAM_M.htm). Although the taxonomies differ between domains, there is a common core in all applications, and the method of causation analysis is the same, which potentially makes this approach useful for comparative studies across domains.

The starting point of a CREAM-based analysis is the identification of the action (by a human operator or by a system such as a driver-and-car) immediately leading up to the critical event. This action is called the *error mode* or, using a biological analogy to designate *observable events,* a *phenotype,* as opposed to a *genotype*, which is a more or less covert cause of a phenotype. For a given incident, the relevant general phenotype is chosen from a list of nine classes, presumed to cover all possible physical relations between objects, which characterise an action: Timing, Duration, Sequence, Object, Force, Direction, Speed, Distance, and Volume. The error modes are specifications of the general phenotypes, such as for example "too short distance", "too high speed", or "wrong direction". Possible causal factors are thus specified in a predefined classification system, and the analysis consists of establishing links backward from the phenotype to the different genotypes that are considered relevant to the phenotype in question. In the analysis, a given genotype is always an *antecedent* either to a phenotype or to a different genotype. At the same time it may be a *consequent* of other genotypes. The taxonomy specifies the possible connections backward from a consequent to an antecedent, which in turn is the consequent of one or more other antecedents. In this way, and according to the rules for the analysis, a network of (assumed) causal relationships is constructed. The relationship between the various categories in the taxonomy is based on a cognitive theoretical model. Thus, the whole analysis is built on three components, which according to Hollnagel (1998) are necessary preconditions for any valid causal analysis; the MCM framework: a Model of human cognition, a Classification scheme, and a Method describing the links between the model and the classification.

An important additional part of the CREAM analysis is the specification of "Common Performance Conditions" (CPCs), which is a specification of the facts regarding the circumstances of the event to be investigated (for example, environment, time of day, work organisation or information) and an assessment of their possible importance in influencing the course of events. The CPCs are specified in advance of the causal analysis, and are used as a background against which to judge the validity of a possible causal factor appearing in the analysis.

In our analysis we both use the original taxonomy (Hollnagel 1998) and a revised taxonomy developed in this RISIT project (Sagberg 2007). Some additional categories were included in the present analysis as an attempt to adapt the method to the rail domain.

1.5 Previous studies of railway events using CREAM – the TRAIN project

In the Swedish TRAIN project ("Traffic safety and information environment for train drivers"), the CREAM method was applied on 33 train accidents/incidents (Hollnagel et. al 1999a; b). The data were accidents reports from the Swedish National Railways (SJ). There were several factors related to the reporting of the accidents/incidents, that made the analysis work difficult: The reports were not written for people with lacking railway knowledge, the level of details varied between reports, many reports lacked data on environmental factors and the reports were in general more focused on describing the work conducted after the incident/accident rather than what had happened before the incident/accident. The major conclusion from the analysis, was that the reports were in most cases not sufficient for conducting a CREAM analysis, mostly due to lacking information on the context and the human aspect.

2 Data

The Norwegian State Railway (NSB) has been the primary source of information in this project, both with regard to the background information on the railway domain, its safety system and with regard to the case studies.

2.1 Background information on the railway domain

The following sources were used to obtain the necessary background information:

- Interviews with safety officials in NSB for information on the safety system in the railway company, and on their way of thinking about safety in rail transport.
- Official laws and regulations regarding train driving and railway safety (i.e. Signalforskriften av 2002 (NSB 2002a), Togframføringsforskriften av 2002 (2002b).
- NSB procedures after an unwanted incident or accident ("unwanted incident" – that is, an unwanted situation that has or could have contributed to an incident/accident (NSB Drift 2005).
- "NSB Skolen" (NSB 2001). An introductory handbook to train driving.
- One short trip by train in the driver cabin from Oslo to Ski. We were accompanied by a NSB official who told us about the safety system and answered questions during the trip.

The preparatory phase of the project was done in cooperation with the University of Oslo, Department of Psychology which did a separate study of latent, system-related factors leading up to an unwanted event in the Norwegian railways (Brotnov 2007).

2.2 The primary data – case studies

NSB has procedures to secure that all unwanted incidents during train driving or shunting are reported a database named Synergi. The Synergi reports from the SPAD incidents contained insufficient information to conduct CREAM analysis. Consequently, it was decided to conduct qualitative interviews with train drivers that had been involved in SPAD incidents.

The search for interesting incidents started in 2005. From the NSB, we got access to the Synergi reports from SPAD incidents less than two years old. As important details related to the incident might be forgotten as time goes by, we focused on the latest incidents.

There were two main criteria for an incident to be considered for a case study:

1) The direct cause of the incidents must be human, that is, the passing of a stop signal must not be related to technical errors per se, i.e. a sudden shift in the signal from "drive" to "stop".
2) The incidents must seem complex, that is to say, involving several of the elements Man-Organisation-Technology. Ideally we wanted incidents that were not fully explained.

Most of the SPAD incidents we went through were directly caused by technical errors. In the end we made a list of 24 incidents from all over Norway that we considered interesting as case studies. NSB was asked to recruit the involved train drivers for interview.

In total we conducted 7 interviews of 1-2 hours each, but in one interview the microphone did not function and we could not transcribe the interview. Transcription of all the interviews was done as the incidents often were complex with many small details.

Each interview started with the train driver describing the incident in short. Then, details of the incident, the context and the train driver's working day were discussed and described further. All relevant CREAM categories were explored through the interview, though not systematically.

For some of the incidents there were also additional reports available. In the more serious cases where train driver error is assumed to be main cause of the incident, the train driver himself and his superior or the safety adviser of the region write a report in their own words about the incident (obligatory) immediately after the incident has occurred, this is according to standard procedures (NSB 2005).

3 Description of relevant signals in the incidents

A short description of relevant signals in the analysed incidents will be given below. The description is based on information from several sources: NSB Skolen (NSB 2001), Signalforskriften (NSB 2002a) and http://en.wikipedia.org/wiki/Norwegian_railway_signalling (for translation of Norwegian terms).

3.1 Main signals

There are four types of main signals on Norwegian railways:

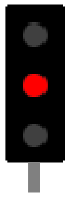
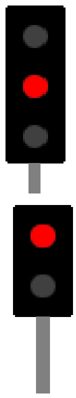
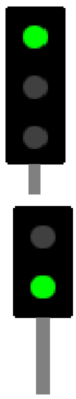
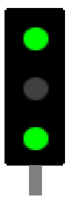
- Home signals ("Innkjørhovedsignaler") – in the station area
- Departure signals ("Utkjørsignaler") – in the station area
- Inner signals ("Indre hovedsignaler") – in the station area
- Block signals ("Blokksignaler") – between stations

In addition, there are distant signals for pre-warning of main signals (details in next section).

Permission to proceed at a main signal means that the train route ("togstrekningen") is set and that switches are secured. All stations in Norway are equipped with both Home signals and Departure signals. Some stations (especially large or long stations) are in addition equipped with Inner signals.

The Home signals mark the station boarder and are placed 200 meters before the outermost switch. Departure signals are placed at the entry at each line. If present, the Inner signals are situated between the Home and Departure signals.

Table 1. Main signals

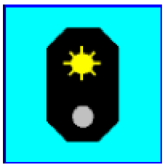
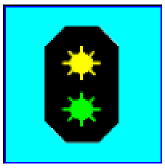
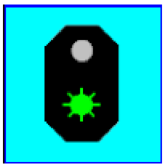
Image	Signal	Meaning	Used in
	Signal 20A - **Stop** – flashes (red light)	The train must stop short of the signal.	Home signals, block signals.
	Signal 20B – **Stop** (red light)	The train must stop short of the signal.	Departure signals, inner signals.
	Signal 21 - **Proceed (to diverging route)** (green light)	The train can proceed, usually via one or more diverging switches.	Home signals, departure signals, inner signals, block signals.
	Signal 22 – **Proceed** (green light)	The train can proceed, *not* via diverging switches.	Home signals, departure signals, inner signals, block signals.

Source: Signalforskriften av 2002 (NSB 2002a)

3.2 Distant signal

Distant signals[1] are placed upon a separate pole or on the pole of the preceding main signal in sufficient braking distance to the corresponding Main signal. All Home signals and Block signals have a corresponding Distant signal placed at least 800 meters before the main signal. Normally Departure signals and Inner signals are equipped with Distant signals as well.

Table 2. Distant signals.

Image	Signal	Meaning
	Signal 23 - **Expect stop** – flashes (yellow light)	The appurtenant main signal shows signal 20A or 20B.
	Signal 24 - **Expect to proceed (to diverging route)** – flashes (yellow and green light)	The appurtenant main signal shows signal 21.
	Signal 25 - **Expect to proceed** – flashes (green light)	The appurtenant main signal shows signal 22.

Source: Signalforskriften av 2002 (NSB 2002a)

3.3 Proceed with caution (signal 32)

The signal is used to notify that the train is about to enter a short track ("avkortet togvei eller buttspor"). The signal appears at the same time as signal 21 "Proceed" (in different track) ("kjør (med avvik)"). 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 pole of the main signal or on a separate pole.

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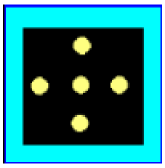
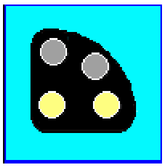
[1] Wikipedia gives a general definition of a Distant signal (the only definition we have managed to find): Distant signal is a term used to denote a type of railway signal that repeats the indication of a following signal and warns a train of the need to stop at that following home signal. The term originated in British English and is used throughout the English-speaking world. In some regions, notably North America, the terms distant signal and approach signal are both in common usage.

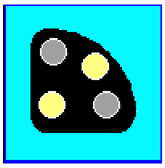

"Proceed with caution" (Signal 32)

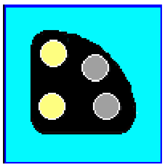
Source: Signalforskriften av 2002 (NSB 2002a)

3.4 Dwarf signals

Shunting signals regulates shunting movements, that is, movement of materials within the station area. 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:


Signal: "Shunting forbidden" (signal 43)


Signal: "Careful shunting allowed" (signal 44)


Signal: "Shunting allowed" (signal 45)

Source: Signalforskriften av 2002 (NSB 2002a)

According to one of the train drivers we interviewed, all movements within the station area, are *shunting movements*, with the exception of arrival at or departure from a station. The latter are thus a *train movements* (as are all other movements outside station areas). Normally shunting signals, such as the dwarf signals, are only related to shunting movements. But, still according to the train driver, when you get the signal "Proceed with caution" (signal 32), you have to pay attention to the dwarf signals as well (even when you do not make shunting movements).

4 Case studies of SPADS using CREAM

In this chapter each case is described and analysed using the CREAM incident causation categories (Hollnagel 1998, Sagberg 2007). Some additional categories were introduced in the present analysis as an attempt to improve the method.

4.1 CASE 1

4.1.1 Facts about the incident

Based on the Synergi report, the train driver's own report and the interview with the driver, the following facts can be stated about the incident:

- The train driver started his shift around 4 p.m. that day, and the shift was supposed to last until 12.00 p.m.
- The incident occured in the evening (around 11 p.m). It was dark and the weather was lightly clouded.
- He fulfilled his train driving education in June 2004, and is relatively speaking a novice train driver.
- The train driver did not feel tired
- There were no factors in his life situation that would affect his physical or mental condition.
- The incident occurred during arrival at a station.

When the train approached the station the Home signal showed "Proceed" and the Distant signal showed "Expect stop". As the train approached the Inner signal, this signal showed "stop" until he was 50 meter away, then it turned into "Proceed" (in different track) while the Distant showed "Expect stop". In the entry train route, the train driver put on the brakes too late and passed the dwarf signal 1424 (number indicating a specific dwarf) by approximately 10 meters.

4.1.2 Description of the incident by the train driver

The following was written in the train driver's own report on the incident: "I am approaching the Home signal in the direction from place "A". The signal shows "Proceed" and "Except stop". As I approach the Inner signal it shows "Stop" until I am approximately 50 meters away, then the signal turns into "Proceed" (in different track) and "expect stop". In addition, the signal "proceed with caution" is shown on the pole of the Inner signal. I observe this, and expect that one of the dwarf signals in the entry train route shows “shunting forbidden”, and I have exactly the signal 1424 in my thoughts. But I am also trying to keep an eye on all the other dwarf signals. This is why I unfortunately do not become aware of the dwarf signal 1424 before I am 10-20 meters before the signal, and I do not manage to stop in time. Therefore, I pass the signal by 10 meters. While I am stopping, I call up the traffic controller. He answers quickly, and I present myself. He “asks” then if I had passed the signal. I respond that that is why I called him. He says that common procedure is to contact DROPS (Driftoperativt senter), the Operating management department. This I accept, of course, and I am soon contacted by DROPS, and get order to be “dismissed from service”.

In the interview the train driver says he was unfamiliar with the situation where the distant signal shows “Proceed with caution”. Furthermore he points out that the situation at that station is special and untidy as there are many switches and thus many dwarf signals to be aware of (normally there is one dwarf signal for every switch). In addition, many dwarf signals at this station is also placed on the left hand side (these signals are supposed to be placed on the right hand side). Also the dwarf signal that he erroneously passed was placed on the left hand side, and it was also, as he puts it, situated “under the ceiling” (it was hanging) above the station platform. The train driver states that it is difficult to see the signal in question and he says that most train drivers agree that this is one of the most demanding stations in the area.

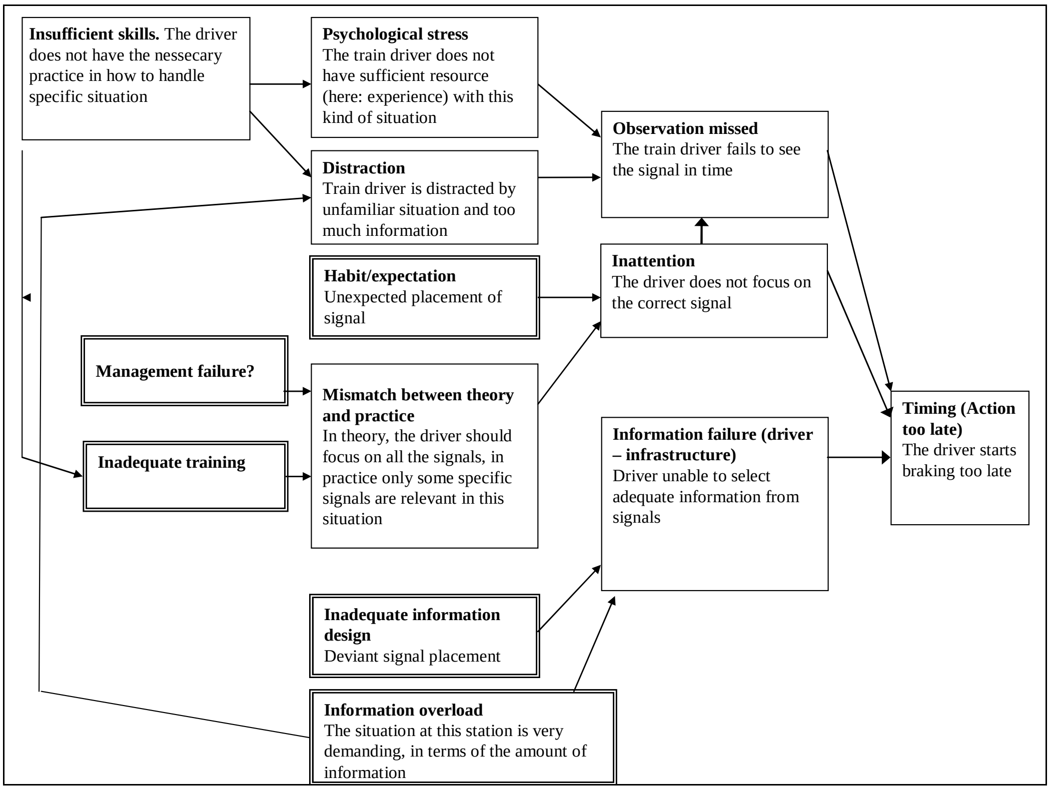
The train driver says it is a difference between theory and practice in situations of signals showing “Proceed with caution” and “Expect stop”. According to the train driver, you are supposed to, in theory, be attentive to all the dwarf signals when approaching the station, but in practice one has to be attentive to only some specific dwarf signals. He says that he has now learned to focus on the one dwarf signal in question, and not all the others, even though some of them in theory (still according to the train driver) might give relevant signals.

In addition, the train driver makes a comment on how he is as a person. He says he is a person that needs experience and time before feeling confident and safe when driving a train.

4.1.3 Results of the CREAM analysis:

The point of departure (the “phenotype”) for this analysis was “Timing” as the train driver starts braking to late when he gets a red light signal. *Psychological stress, distraction*, *inattention* and *information failure* may have caused the driver to fail to see the signal in time. Important contributing factors to these consequents are *habit/expectation*, *inadequate training*, *deviant signal placement* and *information overload*. According to the driver, there is *a mismatch between theory and practice* when it comes to what signals to focus on in situations like this one: In theory, one should pay attention to all the signals when driving into the station but in practice, there are only some specific ones one should pay attention to. As this was the driver’s first experience with this situation (“proceed with caution”) at this station, he was not familiar with which signals to focus on. This lack of knowledge might be explained by inadequate training, but one could also ask if it is a matter of management failure: Could the information system be more standardized so that it is not necessary with specific local knowledge and experience at different stations?

The major conclusion from the CREAM analysis of this case is that the incident is related not only to human factors, but to organisational and technical factors as well. The results of the CREAM analysis is presented in Figure 1.



Source: TØI report 917/2007

Figure 1 Results of the CREAM analysis of Case 1. The emphasized boxes indicates the specific antecedents where the analysis was stopped.

4.1.4 Methodological considerations

Based on the analysis above, we have made some suggestions of how to improve the CREAM taxonomy, both in general and in regard to the rail domain:

- It is difficult to determine whether TIMING (too late) or DISTANCE (too long) was the most important phenotype. As the general causes for DISTANCE is more or less the same as for TIMING ("Observation missed", "inattention", "information failure" etc), a separate analysis for DISTANCE would have given the same results.
- The CREAM scheme does not differ between "general" and "specific" competence (skills and knowledge), which would be relevant in this case. The train driver lacked experience from situations like the one at station X, while he seems to have the general (both practical and theoretical) competence for driving a train.

- "Insufficient skills" could have been included as a cause to "Psychological stress" " (Temporary person related conditions) in the taxonomy ("Insufficient knowledge" is included). In the present analysis, "Insufficient skills" is introduced as an antecedent to "Psychological stress".
- The train driver in question needs more practical experience to feel safe than what is usually the case. There seems to be a need for a category in CREAM that captures person related differences.
- The train driver states that it is a common agreement within the NSB that a train driver at any time may stop the train. In cases of doubt on how to proceed, stopping the train would have been an option for the train driver in question. But he did not stop the train. "Performance variability" (reduced or increased precision of actions) could thus have been included in the analysis. Our hypothesis is that not stopping the train might be related to "Overload, too high demand" in regard to e.g. time pressure (keeping the time table), but it might also be related to the culture among train drivers/within the NSB. In interviews with both NSB safety officials and with train drivers we were told that train drivers traditionally have been looked upon (also among themselves) as people that do not make errors.[2] Maybe stopping the train would be seen as a sign of weakness (hesitation) within this culture and these might serve as a barrier for stopping the train when a train driver is feeling that he is not being in control of the situation. Even if there is no evidence in this case, the reasoning above indicates that the culture among train drivers might be a relevant factor in a CREAM analysis of rail incidents. The most equivalent existing category to this in CREAM, is "Social pressure" among the organisational categories.
- "Mismatch between theory and practice" is introduced in the analysis as an organizational error and as an antecedent to "inattention". The train driver had learned to focus on all signals, but after the incident he was told that he should only focus on one signal in this situation at this station.

4.1.5 General comment:

Many of the causes seem to boil down to two factors. First, the driver does not have the sufficient knowledge/competence with the specific situation. There seems to be two major reasons/causes to this fact:

- The driver needs a lot of practical experience with situations to feel confident when driving (Human factor)
- Lack of proper training (Organizational factor)

Furthermore, both the fact that the information environment is especially demanding (Information failure and Information overload) and that the

[2] According to the NSB officials, former train driver education was very focused on train driver not making errors.

information design is inadequate contribute to increase the effects of inadequate training.

If the driver had had the proper training and/or the information environment and design had been more accessible, there are reasons to believe that the incident would have been avoided.

This way of reasoning about the incident, highlights the importance of organisational and technical factors.

Could and should the CREAM analysis have been conducted otherwise? Or would an intuitive analysis have been sufficient? The answer to these questions depends on the purpose of the analysis. If the purpose is to study causes at a more general level, and not only for the unwanted event in question, systematic analysis, such as the CREAM are more useful as it is possible to aggregate data from multiple events.

4.2 CASE 2

4.2.1 Facts about the incident

In this incident we have access to both the driver's own report[3] and the Synergi report. Based on the data given in these reports and the interview with the train driver (for important comments in the interview, see Annex 1), the following facts can be stated about the incident:

- The incident happened during a shunting operation at station A at about 1 am.
- The driver had started his shift at 21.00 pm and it lasted until 08.00 am in the morning.
- The incident occurred early in January, but there are no reasons to believe that weather conditions could be a contributing factor.
- The driver was neither tired nor exhausted.
- The driver had been an authorised driver for about 6 months when the incident occurred.

In the Synergi report, the following short description of the incident is given:

"Train no. X drove passed the dwarf signal 1420 (number indicating a specific dwarf) showing "stop" (signal 43 "Shunting forbidden"). The train and the block was equipped with ATC. The train was stopped via train radio by traffic controller and train driver. Acoustic alarm was not activated. Inattention by the driver.

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[3] The description of the incident in the Synergi report is based on the driver's own report. According to the train driver, the description in the Synergi report was written by the train driver and his superior almost 3 months after the incident. The train driver had written his report the day after the incident, which is in line with common procedures (right after the incident or the day after if the incident).

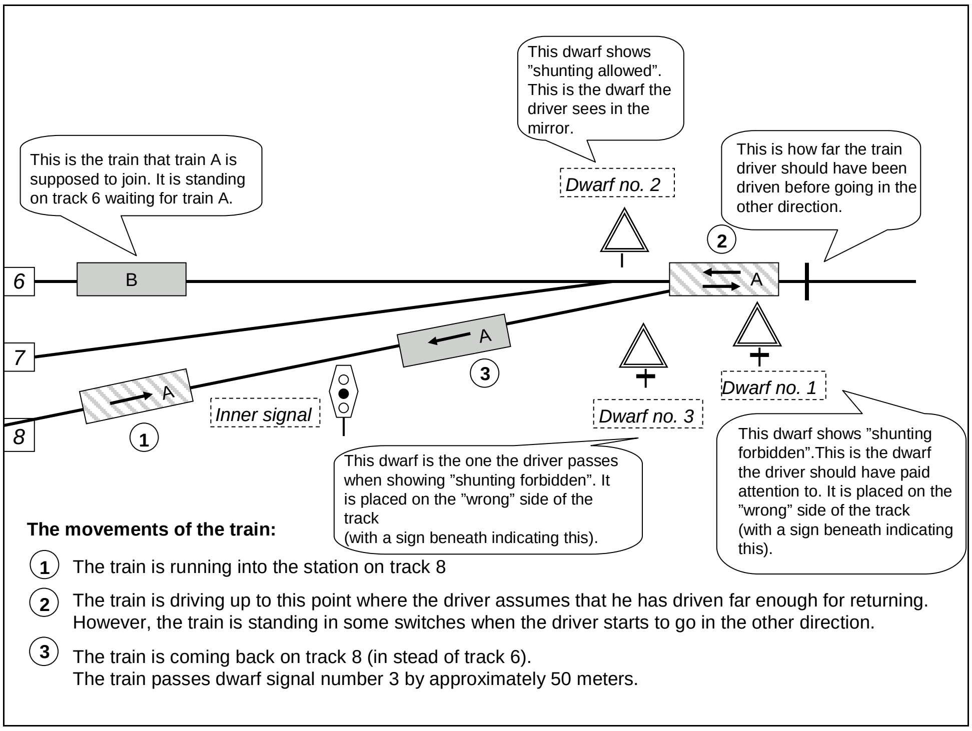
4.2.2 Description of the incident by the train driver (see Figure 2 for an illustration of the incident)

The description of the incident beneath is based on the interview with the train driver (for important comments in the interview, view Annex 1, Case 2) and his own report which is included in the Synergi report.

The driver was driving a local train from station B to station A. He was driving into station A on track no 8. There he was going to join with another train that was waiting for him on track no 6. Therefore, he had to make a switch from track no 8 to track no 6. The driver had no previous experience with shunting operation at station A. According to the driver the problem was that he was uncertain about how far he should drive before returning. It was long distance without anything that limited his train route. He had to go out of the station and to pass some switches before returning and going on to track no 6. The driver says that the common thing to do in cases like this one, is to look in the mirror on the left hand side and look for a dwarf signal that allows you to return. In the mirror on his left hand side he sees a dwarf signal no. 2 that shows "shunting allowed", and assumes that he has driven far enough. According to the train driver, the traffic controller put up this signal too early. He fails to see the dwarf signal no. 1 that should have guided him with regard to how far he should drive. This signal shows "shunting forbidden" and is placed on the left side of the track (which is a deviant position). He then switches driver cabin (that is, he goes to the other end of the train), and the dwarf signal no. 2 that is now in front of him is showing "Shunting allowed". At this point he is standing on the switches that should have been laid into track no 6 (see "train movement no. 2", Figure 2). He then starts driving, but realises that the train is now entering the track he was coming from (track no 8). Then it is too late to stop before the dwarf signal no. 3 that shows "shunting forbidden". He had not driven far enough before returning.

The driver did not call the traffic controller for guidance on how far he should go before returning. In the interview, he confirms that this would have been an option. However, it seems like he was reluctant to use this option (instead of looking for a "return dwarf" in the left side mirror, as he did), for several reasons. He says that calling might be another thing that could disturb you, that you can call the traffic controller if "you do not have any clue of what you are doing" and that not all traffic controllers are happy to receive a phone call at 1.30 am and that he would not bother him. Furthermore, he thinks the traffic controller did not watch over him, because if he did, he would not have put up the dwarf signal too early (that is, dwarf signal no. 2). In the train driver's opinion, he would not have made the mistake if the traffic controller had not put up this signal too early.

In the interview, the train driver also mentions time pressure. As there was another train waiting for him, he tried to drive as short as possible before returning. To be absolutely sure that he had driven far enough (that is, driven past the switches), he could have driven 1 km before returning, but as he had to hurry this was not an option.



Source: TØI report 917/2007

Figure 2 Description of the incident in case 2. The inner signal is showing "stop", dwarf no. 3 is connected to this signal.

4.2.3 Lack of information in the Synergi report:

When comparing the information given by the train driver on the incident with that in the Synergi report, there seem to be some information lacking in the latter:

- It is not reported that the purpose of the shunting was to join another train (empty) that was waiting for him. This might be important information in a time perspective/regarding time pressure.
- It is not reported that the dwarf signal no 1 that he should have paid attention to, for knowing if he had driven far enough, was placed on the "wrong" side of the track. This was marked with a little arrow (it should have been placed on the other side of the track). The driver was looking only in the left hand side mirror as he was expecting a dwarf signal there, and then sees dwarf no 2 that is not applicable for the train movement in question (how far he should go before returning).
- It is not reported that the dwarf signal no 3 that he passed showing "shunting forbidden" also was placed on the "wrong" side of the track.

Both of the dwarfs that were placed on the "wrong" side of the track, had a sign beneath with an arrow indicating that the signals should have been on the other side of the track. This is the standard way of indicating that a signal is placed on the left hand side instead of the right hand side of the track (NSB 2002a**).**

There is some uncertainty about the course of events as there is a discrepancy of the description of the incident between the Synergi report and the driver:

- In the Synergi report it is stated that "the train was stopped via train radio by the traffic controller and the train driver". According to the train driver, this statement is not correct if it means that the train was stopped by the traffic controller. It was the train driver who stopped the train when discovering he was heading back in the same track (no 8) that he came from instead of track no 6.
- In the description of the incident in the Synergi report it is suggested that the traffic controller should not put up dwarf signals for returning before the train has driven far enough. This description is written by the train driver himself and his superior. However, in the description in the Synergi report, "inattention by the driver" is stated as the major cause. According to the train driver, he was not inattentive.

4.3.4 CREAM analysis

4.3.4.1Results of the CREAM analysis (see Figure 3)

"Distance" (too short) was chosen as phenotype for this incident as the problem starts when the train driver does not drive far enough before going in the other direction. The train driver admits that time is a factor for not going too far before making the return.

A substantial factor in this case is that the train driver misses to observe ("*observation missed*") the dwarf signal applying to the train movement in question. There seems to be many contributing factors to this missed observation.

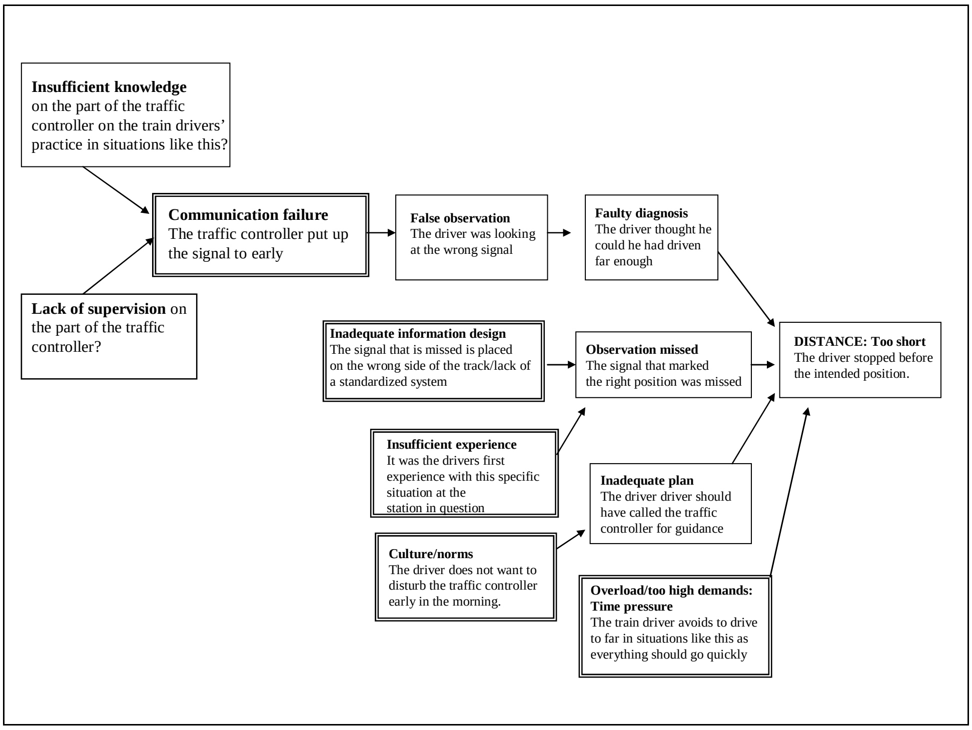
One cause is related to *inadequate information design.* The dwarf signal that should guide the train driver with regard to how far he should go before returning, was placed on the "wrong" side of the track. The standard placement of dwarf signals is on the right hand side of the track. Only a small sign with an arrow was placed on the signal in question so as to indicate that the signal applied for the other side. The driver was unfamiliar with shunting operations at this station area and did not know about this deviant signal placement. It is questionable whether more training can compensate for the lack of experience. According to the train driver, it is impossible to be trained in all possible situations. The solution would rather be on how to design the information system in such a way that it does not require local skills in order to handle new situations, that is, to make the information system more standardized or universal.

Moreover, as the train driver is relatively *inexperienced* and unfamiliar with shunting operation at this station, he follows common (informal) procedures by looking for a dwarf signal in the left hand side mirror. There he sees a dwarf signal showing "shunting allowed", this signal is however put up too early. The traffic controller does not seem to watch over the train driver's movements, and there is no communication between the traffic controller and the train driver. In fact, there seem to be a mismatch between the driver's practice on how to collect information in deviant cases like this and how the traffic controller gives information. In this case, it does not seem like the traffic controller has knowledge about the drivers practice of looking for a return dwarf in the mirror as she puts up the sign too early (and according to the driver, did not watch over him).

Another contributing factor seems to be *faulty diagnosis* by the train driver, as he thought he had driven far enough before returning. This is seems to be caused by both *communication failure* between the driver and the traffic controller, as the traffic controller put the signal up too early and the driver was looking at the wrong signal (“*false observation*”).

The incident can also be related to an *inadequate plan* on the part of the train driver, who could have called up the traffic controller for guidance when starting to feel insecure of how far he should drive (before returning). However, the train driver seems to have second thoughts about calling up the traffic controller, especially in the middle of the night, as he thinks the traffic controller will be bothered. This might be related to *culture and norms* (informal rather than formal) regarding interaction and communication between traffic controllers and train drivers. The train driver also mentions *time pressure* when he is explaining why he did not call the traffic controller. A hypothesis might be that by calling the traffic controller, the train driver will somewhat admit that he does not handle the situation, which might be inconsistent with the dominating culture and norms among train drivers (again, informal rather than formal).

This incident seems to be related several MTO-elements: the driver (inexperience with the specific situation at the station in question), technology (inadequate information design) and organisation (time pressure, communication failure between the driver and the traffic controller and informal culture/norms). The communication failure might be explained by the traffic controller’s lack of knowledge of the train drivers’ practices in situations like this and lack of supervision on the part of the traffic controller. These are hypotheses based on the interview with the train driver. The results are presented in Figure 3.



Source: TØI report 917/2007

Figure 3 Results of the CREAM analysis in Case 2. The emphasized boxes indicates the specific antecedents where the analysis stopped.

4.3.4.2Methodological considerations

- The genotype Experience/knowledge is not included as a category to "Observation" in the CREAM taxonomy. There are reasons to believe that with sufficient experience with and thus knowledge at the station in question, the train driver would have known about the dwarf (that he missed to see) was placed on the left hand side instead of the right hand side of the track. Thus, we suggest including "Insufficient experience/knowledge" as an antecedent to "Observation".
- "Time pressure" is in the analysis defined as a specific genotype to the general genotype "Overload/too high demands". "Overload/too high demands" is not specified as an antecedent to the phenotype DISTANCE in the original CREAM analysis, but in the analysis above it is seen as one factor that might explain why the train driver did not drive far enough before returning. The reason for this is that "time pressure" seems to have imprinted the whole situation the driver was in. Thus, we suggest to include "Overload/too high demands" as an antecedent to the phenotype DISTANCE.
- "Culture/Norms" is an introduced organisational category.

This CREAM analysis of the incident in question has brought up some new aspects in terms of categories to use analysis of incidents/accidents in the rail domain:

- For classification in the rail domain a relevant category is "Communication failure" between traffic controller and train driver. When analysing train incidents the description of the category "communication failure" should be "communication failure between train driver and traffic controller/other".
- In an analysis of why communication failure occurred between the train driver and the traffic controller, it would be relevant to define different actions on the part of the traffic controller that could explain communication failure between the train driver and the traffic controller. In the analysis above we have suggested two antecedents to communication failure: "Lack of knowledge on the part of the traffic controller" and "Lack of supervision on the part of the traffic controller". Both of these might be regarded as organisational categories.

4.3 CASE 3

4.3.1 Facts about the incident (based on reports and interview)

- The incident happened around 23.00 p.m.
- The driver had had a long shift, but he said he had had sufficient breaks during the day.

- The driver felt neither tired nor exhausted.
- There were no factors in his life situation that would affect his physical or mental condition.
- The train driver had more than 20 years of experience.

In the Synergi report the incident is described as follows:

"Train X passed the dwarf 25 showing "stop" at station Y. Inattention by the driver."

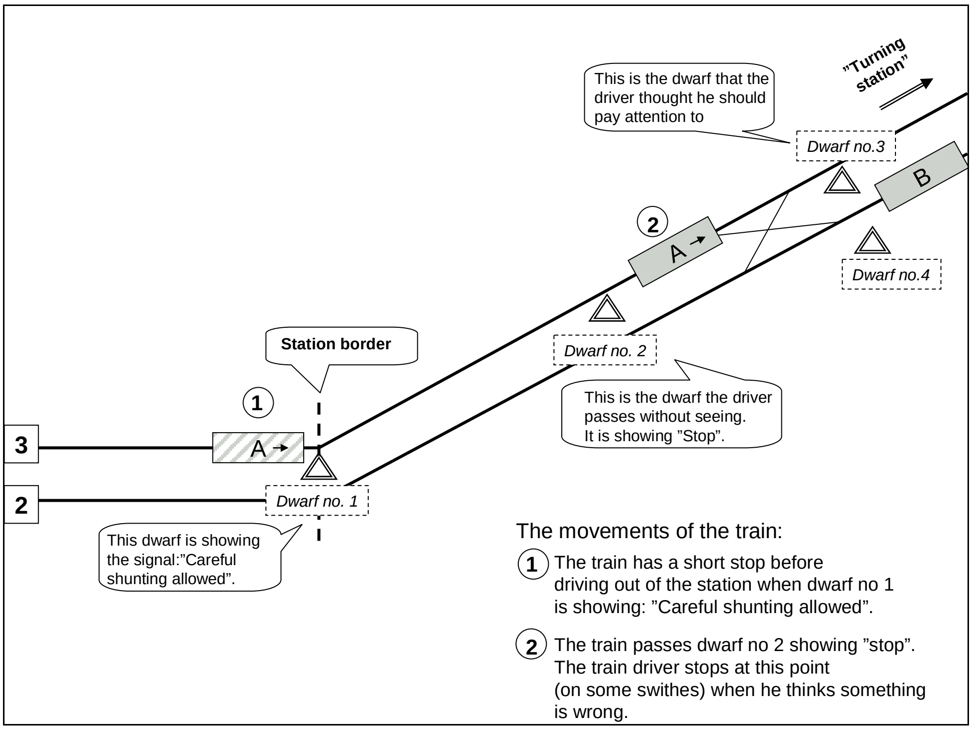
4.3.2 Description of the incident by the train driver (see Figure 4 for an illustration of the incident)

In this case, the train driver's own report on the incident is missing in the Synergi report. The following description is thus based on the interview with the train driver. The train driver described the incident as follows (for important comments on the incidents, se Annex 1, case 3).

The train drove in on track no 3 at station Y from direction A. Usually track no 3 is used by trains coming in the opposite direction. There are four tracks into this station from direction A and usually the train driver in question drives into the station on track no 2. This time the train was empty and the train was going to station Y to change direction. The train driver makes a short stop at the station. Here he makes a call to the traffic controller to ask if he should make a turn "on the platform" (expression indicating that the train driver goes to the driver cabin on the other side of the train when standing on the platform and then drives back in the other direction). The traffic controller, however, wants him to go out at the "turning station" (that is, continue to drive in the same cabin and make a turn further outside the station, at something called the "turning station"). The traffic controller tells the train driver that he will get a signal at the "turning station". The train driver says that this might have confused him to believe that the track was clear all the way up to the "turning station", but he thinks the main problem was that he had "disconnected" dwarf no 2 (the one he passes when showing "shunting forbidden").

When still at station Y, the train driver gets the signal "careful shunting allowed" on the dwarf no 1, placed beneath the main signal (which is showing red) at the end of the platform and he starts to drive. With this signal in mind, the train driver was prepared for a stop, but not as soon as it actually occured. On track no 2, where he usually drives, it is a longer distance between the dwarf just before the station border to the next dwarf (approximately the same distance as between dwarf no 1 and dwarf no 3 on track no 3, see placement of dwarf 4). He thought he should pay attention to a dwarf further out (dwarf no 3), he did not think about the dwarf before this one on this track dwarf no 2) because: 1) there is no signal before dwarf 4 (approximately the same position as dwarf 3) on track no 3, and 2) he is used to the track being clear all the way up to dwarf 4 and usually all the way up to the "turning station".

The train driver realizes that something is wrong as he did not get a signal to continue (in dwarf no 3) and the switches his train was standing in were turned in towards another train. He understands that something is wrong and calls the traffic controller. At this point he did not think he had done anything wrong. Neither the traffic controller did realize at once that the he had passed a dwarf signal showing "stop" (dwarf no 2), but then she asked if he had passed this dwarf (dwarf no 2). The train driver denies at first, because he could not understand that he had done that, but after having reflected on it, he realizes that he had actually passed dwarf no 2. He had passed the signal with the whole length of the train, approximately by 100 meters.



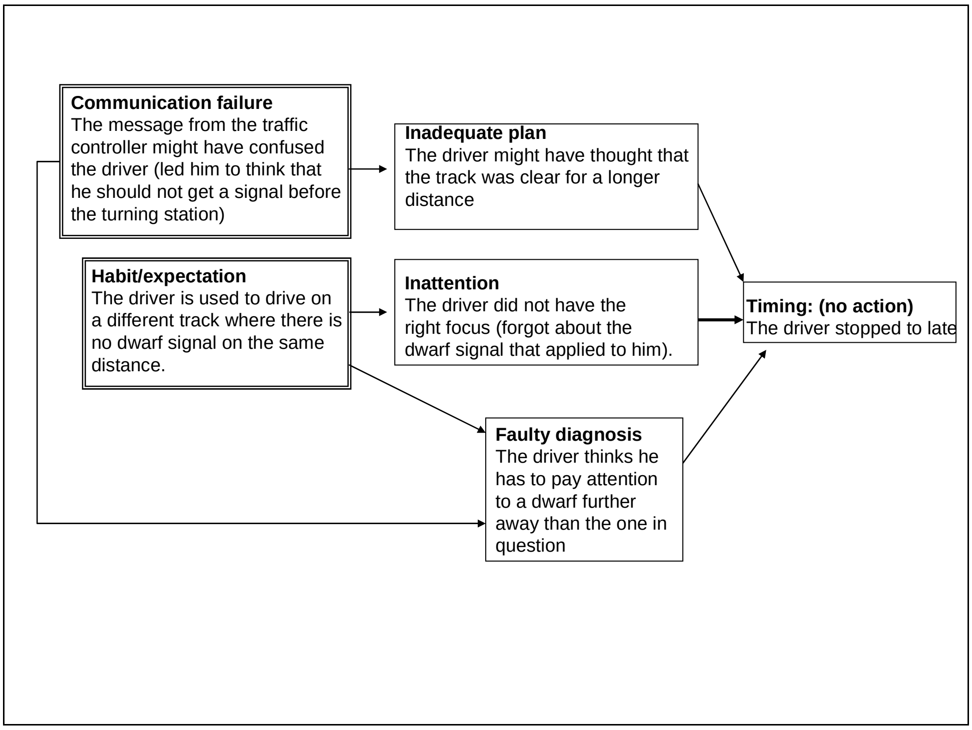
Source: TØI report 917/2007

Figure 4. Description of the incident in Case 3

4.3.3 CREAM analysis

4.3.3.1 Results of the CREAM analysis (see Figure 5)

"Timing" was chosen as the phenotype for this incident as the train driver does not act (stop the train) at the time he was supposed to. This is probably due to *inattention* (the driver forgot about the dwarf that applied to him), *faulty diagnosis* (the driver thinks he has to pay attention to a dwarf further down the track) and *an inadequate plan* (the driver thought that the track was clear for a longer distance than it actually was). Important contributing factors to one or several of these errors are *habits* and *expectations* (the driver is used to drive on a different track where there is no dwarf signal on the same distance) and *communication failure* (the traffic controller told him that "he would get a signal at the turning station", this might have led him to think the track was open all the way to the turning station.



Source: TØI report 917/2007

Figure 5 Results of the CREAM analysis in Case 3. The emphasized boxes indicates the specific antecedents where the analysis stopped.

4.4 CASE 4

4.4.1 Facts about the incident (based on reports and interview)

- It was a sunny day in the spring.
- The incident happened around 12.00 p.m.
- The shift had started at 5.30 a.m.
- The driver had not had a break since the shift started.
- The driver was neither sleepy nor fatigued, and was feeling rather fit that day.
- There were no disturbing factors in the driver's life situation.
- The driver had 24 years of experience as a train driver.

In the Synergi report the incident was describes as follows:

"The train driver is approaching station X with train nr. A. The train driver cannot remember that the signal was showing "proceed with caution" (signal 32), but remembers the dwarfs along the track into the station. The train was a bit delayed, but the driver did not feel this as a stress factor. The speed was about 20 km/hour. When the train enters track no 6, the train driver notices that there are many people on the platform. They are standing behind dwarf 1424. After having stopped where the travellers are standing, the driver notices that the departure signal is still showing "stop". She then sends a fixed message[4] with the following message: "Waiting for a signal to drive" (message no 56) to the traffic controller. After a while, the traffic controller calls and says that the driver has passed dwarf 1424. The train driver says she cannot remember this dwarf. Common procedure was then executed."

In a comment below the description it is stated that there have been several incidents with the dwarf in question and that the efforts are required.

4.4.2 Description of the incident by the train driver

The train driver's description of the case in the interview is more or less the same as in her own report included in Synergi report, but with further specifications.

As stated above, the train driver does not remember seeing the signal 32 showing "proceed with caution". According to the train driver, the sun might have been shining on the signal and this might have made it difficult to see what the signal was showing, but she is not sure about this. It is a white signal on black background, formed like a cross. She wore sunglasses.

She does not find a reasonable explanation to why she missed to see this first signal and why she also missed to see the dwarf at the platform showing "shunting forbidden". Even though the shift started early this day, at 5.30 on a Sunday, she felt very fit this morning, even more fit than she usually feels on this shift. There were no phone calls or other disturbing factors.

In the interview she also states that she drives into station X on that track only once a month and that the dwarf (1424) that she passed when showing "shunting forbidden", always have been showing "shunting allowed". As she seldom drives there she was extra on guard, and thus drove very slowly into the station. She had also been on an "acquaintance tour" to this station and on this train route section two years earlier. On this tour the peculiarities are explained to the drivers. This is a tour that everybody has to attend before they can drive a route which they have not been driven before. The dwarf in question is special because it "hangs" in the ceiling in the middle of the platform, and it is placed on the wrong side of the track (an arrow below is indicating this). But she says she does not know how much she remembered from this tour as it was a long time ago and the "guide" was talking very much.

She states in the interview that her focus was very much on the new passengers on the platform. Some of them were standing far up at the platform, behind the dwarf that she passes. She was trying to stop so that the passengers did not have to walk so far. She says that there was no sun that could have made it difficult to see what the dwarf that she passed was showing (here "shunting forbidden").

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[4] A fixed message can be sent by the train radio from the train driver to the traffic controller. Each of the fixed messages has a specific code (a number). A specific set of code messages also exits for the traffic controller to use for sending messages to the train driver (Togframføringsforskriften kapittel III (JD 341) 06.12.2002).

4.4.3 CREAM analysis

4.4.3.1 Results of the CREAM analysis (see Figure 6)

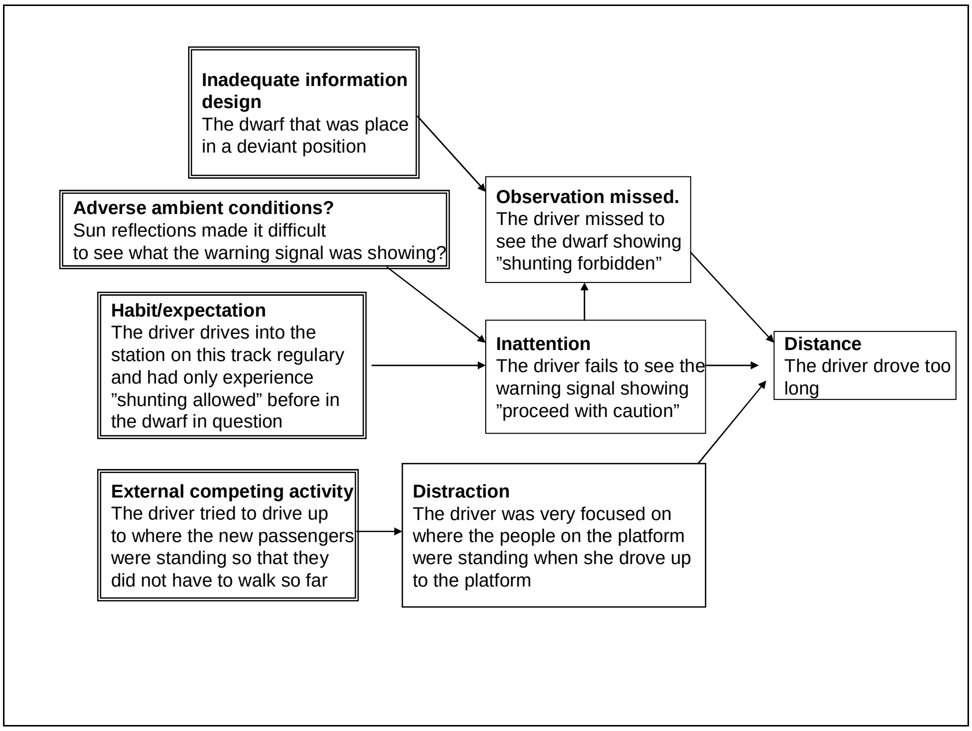
As the driver drove too far without knowing, "distance" was chosen as the phenotype. One major contributing factor to the event was that the driver missed to see the dwarf showing "shunting forbidden", partly due to deviant placement of the dwarf ("*inadequate information design*") and due to *inattention* to the warning signal (signal 32 "proceed with caution").

She does not understand why she failed to see the warning signal and her only explanation is that sun reflections ("*adverse ambient conditions*") might have made it difficult to see what the signal was showing (she herself was *not* blinded and she also wore sunglasses). One could also question the information design of the signal if it does not sufficiently protect against sunshine.

The explanations for why the warning signal was missed are not complete as there is not much information on this. However, in this case, there are several other plausible contributing factors to the event (the driver passed a signal at danger and drove to far). Even though she says she was very attentive when driving into the station, the fact that she had only experienced instances with the dwarf signal showing "shunting allowed", might have caused her not to pay too much attention to this dwarf signal. Thus, "*habit/expectation*" might be one contributing factor.

In addition, she was very focused on the people on the platform and where they were standing. Many people were standing on the other end of the platform, and this might have distracted her ("*distraction*") when trying to stop the train so they could easily enter ("*external competing activity*"). The train driver confirms that they have fixed positions where to stop the train at a platform, these are marked by signs. However, she does not give a sufficient answer why she nevertheless was so occupied of where the new passengers were standing. Her statement indicates that there is some flexibility to where a train can stop on a platform.

The incident seems related to both human (habit/expectation), technological (inadequate information design) factors and external factors (the placement of the new passengers on the platform, sunshine).



Source: TØI report 917/2007

Figure 6 Results of the CREAM analysis. The emphasized boxes indicates the specific antecedents where the analysis stopped.

4.4.3.2 Methodological considerations

One could gather that if the driver had seen the warning signal "proceed with caution", she might not have failed to see the dwarf that she passes on the platform.

The incident illustrates that the placement of new passengers on the platform might be a source of distraction to the train driver. Even though there is, according to the train driver, fixed positions to where to stop the train on a platform, there seems to be some flexibility in the system with regard to this (if not, she would have not have focused so much on this). This indicates that system should be stricter in regard to where the trains are to stop at a platform.

4.5 CASE 5

4.5.1 Facts about the incident (based on reports and interview)

- The train driver starts his shift at 5 p.m.
- It was a Sunday. The train driver should normally not have worked on this particular Sunday, but he worked in order to get another Sunday off.
- The driver had just had dinner before the shift started.

- The train driver states that every train driver has to give notice if he thinks he is not mentally fit to drive the day he is going to work. However, he says he did not have any emotionally "highs" or "lows" the day in question.
- The incident occurs during departure from a station.

In the Synergi report the incident is describes as follows: "The train driver gets a written order to pass the inner signal in order to drive out of the station (the order he received gives permission to pass the inner signal when the signal shows "Stop"). The departure signal also shows "stop", but the train driver drives passed this signal as well. The traffic controller then talks to the train driver and the train driver continues to drive until he got a message from DROPS (Driftsoperativt senter). At station Y the train is stopped and the train driver is taken off duty".

4.5.2 Description of the incident by the train driver (as described in the interview)

When the train was about to leave the station, it was not possible for the train dispatcher to set neither the departure signal nor the inner signal in "proceed" (according to the train driver there was some technical problems with the signal system). There was nothing wrong with the track, all of the switches were in the right positions. And the dwarfs were also giving the right signals. Then he got an order from the train dispatcher to pass the first signal, the inner signal, which was showing "stop". The train dispatcher came out and gave him a physical note with this order, which the train driver put on his dashboard. The inner signal was placed about 200 meters before the departure signal. Not all stations have inner signals, but this one did, albeit only in one direction (that is, there was no inner signal in the other direction out of the station). The train driver states the following about the order to pass the inner signal while the signal shows "stop": "This is fine, I have done it before, it is a situation that happens from one time to another".

An order is always valid until the next signal. In this case it meant that the train driver could pass the inner signal while showing "stop". Usually the train driver has to push a button on the panel which temporarily disables the ATC when driving on an order to pass a signal in "stop". Then the train can pass the signal without being stopped by the ATC. In this case it was not necessary to push the ATC button, because there were no balises[5] in the track, and the train driver in question drove passed the signal without using the button.

The train driver states the following about the issue above: *" … at some stations you have to use it (the button), but at this station, there is no "balise" in the track that give a message to the train. The "balise" tell the train to stop."*

The order is still lying on his desk while he is arrives at the departure signal. When passing this signal the train is outside the station area. It is now the traffic

[5] A **balise** is an electronic beacon or transponder placed between the rails of a railway as part of an Automatic Train Protection system (http://en.wikipedia.org/wiki/Balise)

controller who is responsible for the block from the departure signal. The departure signal is operated by the traffic controller. A train dispatcher is present at all the big stations and he/she is responsible for the signals within the station area. The order from the train dispatcher did not apply to the departure signal.

The normal procedure for the train driver when arriving at the next signal (as the order is only valid until the next signal, cf. above) is to call the traffic controller.

If the traffic controller does not manage to set the signal in “proceed”, then the train driver has to get an order to pass the departure signal (it is not clear in the interview whether the also were technical problems with the departure signal or if the departure signal actually was showing “stop”).

The train driver did not call the traffic controller when approaching the departure signal showing “stop”. But as the train driver puts it himself: “It is more complex than that, as a train driver you are used to watch the dwarfs as well, so I see that the dwarfs are giving the right signals. But I have to have an order as well, I cannot drive pass the departure signal by myself, even if the dwarf is showing the right signal.”

The driver pushed a button on the panel which temporarily put the ATC out of function. The train driver describes the reasoning for doing this, as follows:

“We know that the order is only valid until the next signal. In the beginning I thought that the order was valid through the inner signal, that is, the first signal, but in the mean time … it disappeared from me, that I had already passed that signal. So I thought, “OK, there is the departure signal, there I have to push the button to avoid the breaks to be turned on”.

The driver then passed the departure signal while this signal was showing “stop”. He continued to drive even after realising that he had made an error. He discovered his mistake as one of the dwarfs behind the departure signal is showing a deviant signal picture (it was showing “careful shunting allowed”). However, as he could see the home signal at the next station (with a normal signal picture) and as it was a straight section, he judged it to be safe to continue. When approaching the next station, the traffic controller called him and asked about his position. Normally, the traffic controller would have seen the train pass the departure signal if he had set the signal in “proceed”. In this case, he had not set the signal and thus he could not know where the train was.

The train driver admits his error and the two of them discuss what they should do about the incident. They agree that the train driver should call the DROPS first, and then the traffic controller should call them afterwards. The person the train driver talks to at DROPS is familiar with the station in question and with the block. This person thinks it is OK for the train driver to continue to drive without any further actions. The train driver informs him that the traffic controller is going to call him afterwards so that they could agree on how to handle the situation.

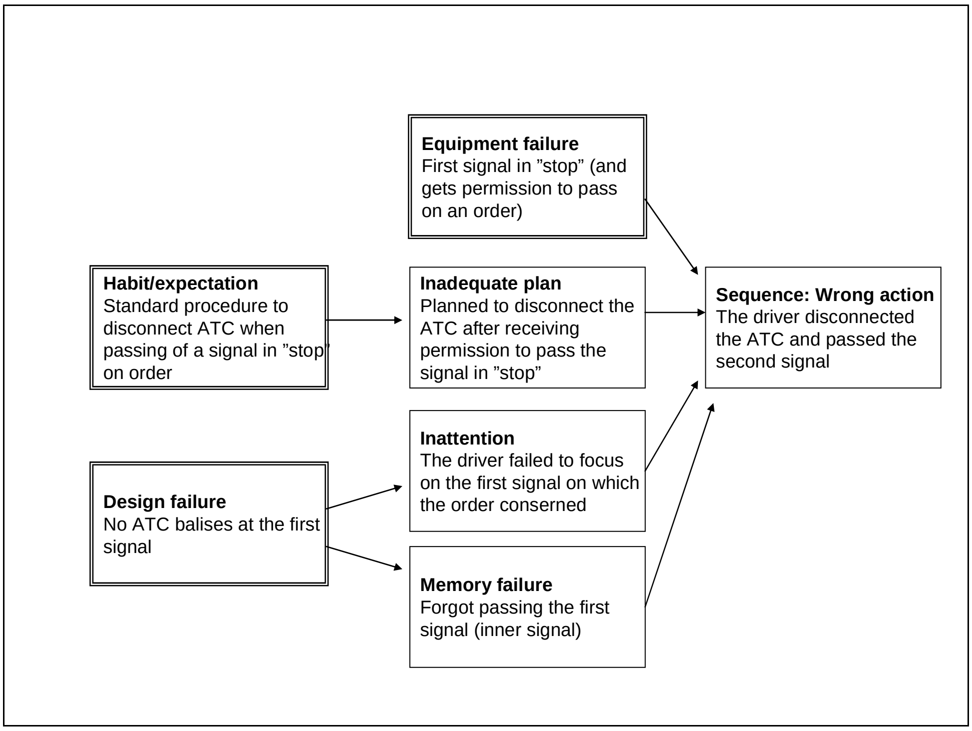
The train drivers continue to drive for some time, about ten minutes without hearing anything. Then he gets a call and is ordered to stop the train. This was at a station three stations from the departure station. The traffic controller had talked to another person at DROPS.

4.5.3 CREAM analysis

4.5.3.1 Results of the CREAM analysis (see Figure 7)

The driver disconnected the ATC when he was not supposed to, and thus "wrong action" (Sequence) was chosen as the phenotype for this incident. One cause for this action was that the first signal (the inner signal) was out of order and could not be set to "drive" when it was clear ("*equipment failure*"). The driver gets an order to pass this signal in "stop". Usually, a train driver has to disconnect the ATC when passing a signal in "stop" on an order. This ("*habit/expectation*") led him to think that he also had to disconnect the ATC when passing the signal ("*inadequate plan*"). However, he knew it was not necessary on this track (design failure; there were no balises on this track) and passes the signal without disconnecting the ATC when passing the first signal. The order of passing the signal in "stop" applied only until the first signal, but probably due to *inattention* the driver fail to focus on the limitations of the order (which might be explained by the missing balises on the track, thus design failure). As there is no balises in this particular track ("*design failure*") he forgot ("*memory failure*") that he had passed the first signal. Thus, he stills thought he had to disconnect the ATC at the next signal. There are reasons to believe that if there had been balises on the track, he would have disconnected the ATC at the first signal and not on the second signal.

Important contributing factors to the incident are both of organisational character (design failure), technical character (equipment failure) and of human character (inattention, habit/expectation).



Source: TØI report 917/2007

Figure 7 Results of the CREAM analysis in Case 5. The emphasized boxes indicates the specific antecedents where the analysis stopped.

4.5.3.2 Methodological considerations

- "Equipment failure" is not included as an antecedent to the phenotype "Sequence" in the original CREAM taxonomy. It is included as an antecedent to several other phenotypes. We suggest not to make a distinction between the different phenotypes when it comes to the possible antecedents.
- The effect of the deviant design on the track (normally there would be balises on the track) on attention and memory illustrates well the important interface between man and system. A standardized system with balises on all tracks could probably have prevented the incident. We suggest including "Design failure" as an antecedent to both "Memory failure" and "Inattention".
- The normal procedure when passing a "stop" signal with permission, is to disconnect the ATC (in the case where there are balises on the track). This is what the driver was expecting, even though he knew it was not the case on the first signal. There are reasons to believe that habit/expectation might have led to an inadequate plan, though habit/expectation is not included as an antecedent to the category "Planning" in the original CREAM taxonomy.

4.6 CASE 6

4.6.1 Facts about the incident (based on reports and interview)

In the Synergi report the incident is described as follows:

"A SPAD (signal passed at danger) incident at station X. Empty train no xx. The departure signal no XX was passed at track no 3 while the signal showed "stop". The train driver was taken off duty until he had delivered a report and had a conversation with his superior. They went through the case. The importance of being sure of the signal picture was pointed out. The train driver takes this advice."

4.6.2 Description of the incident by the train driver (based on the interview)

It was an empty train that was supposed to go from station X to station Y. He drove into a sidetrack at the station to make a turn. A sidetrack is a track which one only can get in to and out of from the same side. When you enter the sidetrack, the traffic controller activates a track lock. The train is thus physically locked up in the station (if the train tries to pass the track lock it will derail). After having entered the sidetrack, the driver stops the train and switches driver cabin to the other side of the train. Then he awaits the green signal in the departure signal. It was a very sunny day and the sun was very low so early in the morning. The sun reflections made it difficult for the train driver to see what the signal was showing; whether it was green or red.

The train is supposed to depart from the side track according to a timetable also. After 30 minutes on the sidetrack and approaching departure time, the train driver sends a fixed message to the traffic controller with the following message: "Waiting for a signal to drive" (message no 56). At the time when one usually expects a green light, the track lock is taken off and the switches are placed in the right position for the train in question. The train driver watches all these things that happen. He can also see all the departure signals on the main tracks. It was four of them, two for each track, in each direction. All of them are showing "stop". In his reasoning it was nothing serious that could happen (if he had driven out from the sidetrack into the main track).

But he still could not see anything in the departure signal at the sidetrack. The train driver assumes that the reason for this could either be the sun or that a light bulb in the signal was broken. He then drives carefully, in "walking speed", up to the signal to *"see if I could get so close that I was able to have a look at the signal from a different angel with regard to the sun, to see whether the signal was green, to be hundred percent sure that it was green"*, as the driver himself puts it.

And then, when the train driver has driven up to the side of the signal, the balise that belongs to this signal, interferes and stops the train.

On the question from the interviewer if he had passed the signal, the train driver answers: "Yes, I did, I had the signal close up by my side and before the ATC stopped the train, I had passed the signal by one or two meters … I was driving very slowly, you could walk beside the train, I would never had driven very fast. I had assumed it was green, and then, if it was … yes." (The interviewer believes he means that he would have continued to drive if it was green).¨

After the ATC had stopped the train, the train driver backs up. Still he cannot see anything in the signal. He then calls the traffic controller and asks whether he had put up a green signal for him. The traffic controller does not answer this question, but he asks him whether the train driver had passed the signal. "Yes, I did" replies the train driver. The traffic controller then asks if the ATC had "taken him", which the train drivers confirms. "Then you must back up and be taken off duty", the traffic controller replies.

According to the train driver, departing from a sidetrack is a hectic and stressful situation as they stop all the traffic, in this case, on two tracks so that the train in the sidetrack can cross them and enter the station. The train driver says that this operation has to go very quickly in order not to delay the other trains.

He says the following about why he started to drive towards the departure signal: *"You got three minutes, the whole station closed, that is a long time. I felt very uneasy when I saw all these switches made ready for me and thinking "It just has to be a green light", that is why I started to roll very carefully up to the signal from a different angel. Then it was suddenly too late."*

On the question why he did not call the traffic controller to know whether he had set up a green light or not, the driver replies that he that is what he should have done, but thought it might be a stupid question:

"Maybe I felt a little stupid asking whether the signal was green or red? "Does he think I am colourblind or more or less blind? Why in the whole wide world does he ask that question?".

The train driver did not get a reply back from the traffic controller on the fixed message that he had sent him. In the train drivers opinion there is a need for more communication between the traffic controllers and the train drivers, especially in specific areas. According to him, train drivers are usually quick with updates for the traffic controllers, but the traffic controllers are not good at that. He says for instance that the train driver never gets an answer on a fixed message, as in this incident.

In the Synergi report there is no mentioning of the possibility of a broken light bulb in the signal. If that was the case, the ATC would have reacted as if it was “stop” in the signal. In the interview the train driver states that he still does not know whether the light bulb was broken or not, and whether the traffic controller had set up a green light or not.

4.6.3 CREAM analysis

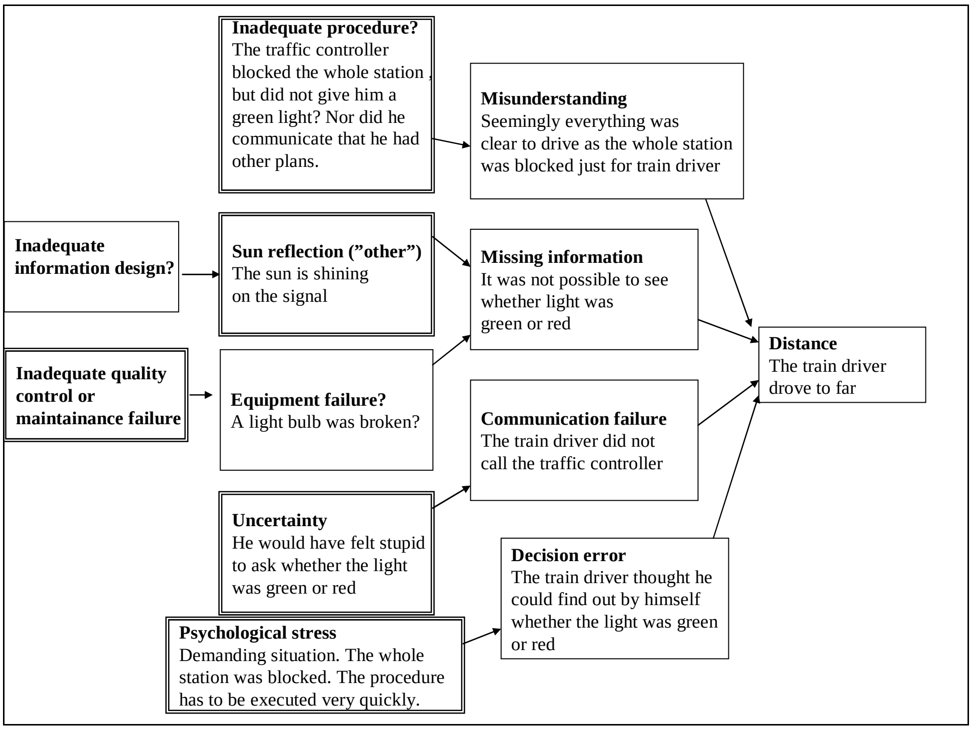
The point of departure here is the phenotype “Distance” as the driver drives further than he had intended. One major contributing factor to this incident was that the train driver was unable to see whether the signal was green or red (that is, showing “drive” or “stop”) and thus can be defined as *missing information.* Sun reflections might have made it difficult to see what the signal was showing, which is an external factor. However, one could imagine that the signal was designed in such a way so the it was protected against sunshine. Thus, a contributing factor would be *inadequate information design*, a technical factor. Another reason why the driver could not see what the signal was showing, could be that is was showing nothing at all, that is, the light bulb was broken. If this was the case, this could be connected to *inadequate quality control* or *maintenance failure* (depending on how this is defined within the railway system), both related to organisational factors.

The driver makes a *decision error*. He thought that he would find out by himself whether the light was green or red (or if the signal did not show anything at all) if he just could drive close enough to the signal. This might be explained by *psychological stress* as everything had to be executed very quickly in order not to delay other trains.

Another cause of the incident is clearly linked to the *uncertainty* of the train driver. He states in the interview that he would have felt stupid to call the traffic controller and ask what the signal was showing. Not calling the traffic controller may be seen as a *communication error* on the part of the driver.

If the traffic controller had not yet set the signal in green (this was never examined), one could relate the incident to a *misunderstanding* on the part of the train driver, which again might be explained by *inadequate procedure* on the part of the traffic controller. Seemingly, the traffic controller had set everything in a ready position so that the train driver could cross the tracks. He had blocked the whole station just for the train driver in question: he had removed the track lock and he had put the switches in the right position for the driver just on the time when the train driver was supposed to drive out from the side track (according to the time schedule). In addition, all the other departure signals indicated that no other train could enter the station without permission.

Both human (psychological stress, uncertainty) and organisational factors (misunderstanding, perhaps caused by inadequate procedure on the part of the traffic controller) are likely to explain the incident, in addition to external factors (weather conditions). A broken light bulb would also be defined as an organisational related factor (inadequate quality control/maintenance failure). If the traffic controller had put on a green light not showing because of a broken light bulb, the hypothesis of inadequate procedure on the part of the traffic controller fails. Whether the another design of the signal could have protected against the sun, is also just a hypothesis, but would be related to a technological related explanation of the incident. The results of the CREAM analysis are presented in figure 8.



Source: TØI report 917/2007

Figure 8. Results of the CREAM analysis in Case 6. The emphasized boxes indicate the specific antecedents where the analysis stopped.

4.6.3.1 Methodological considerations

Based on the analysis above, the following considerations are made with regard to CREAM:

- In CREAM the category "inadequate procedure" is defined as a technology related genotype and to the system specific procedures or prescriptions for how a task shall be performed (Hollnagel 1998). There seems to be no category in CREAM that captures how these procedures are executed. In the analysis above, "Inadequate procedure" is understood as procedures that are not executed correctly on the part of the traffic controller, and thus considered as an organisational category.
- The strength of the CREAM analysis is that it manages to capture the different communication and information challenges between two systems.

These systems have, to our knowledge, traditionally operated with separate follow up routines of incidents: if the cause of the incident can be directly related to error made by the driver, the NSB takes care of the investigation and the reporting of the incident. If the direct cause is more related to the responsibilities of Jernbaneverket (The Norwegian Rail Administration) they take care of these reporting routines and the investigation. The responsibilities of Jernbaneverket include the tracks, the signal system and the traffic controllers/train dispatchers. When seeing these systems together, as CREAM does, it is easier to observe relevant communication/information factors between these two systems, especially the ones concerning the communication between the train driver and the traffic controller/train dispatcher.

- In order to adapt the CREAM method to the rail domain, we suggest expanding the "communication" category to include more informal information channels that train drivers use while driving. The case described above illustrates how the traffic controller gives information to the train driver through the technological system, either through more formal information channels, i.e. signals, but also through different actions/procedure that constitutes checkpoints for the train driver that he uses for guidance in a situation. As the train drivers use these actions/procedures actively when driving, these actions/procedures should be understood as information channels in the CREAM analysis.

5 Summary and suggestions

5.1 Summary of methodological considerations

In all of the incidents examined here, human error is stated as a direct cause in the Synergi reports. In almost all the incidents that were analysed, the CREAM method manages to capture more contributing factors than in the original analysis as documented in the Synergi report. Moreover, CREAM manages to capture the interaction between different contributing factors.

Our analysis shows that technical and especially organisational factors are important contributing factors in most of the cases even though not always mentioned in the Synergi reports. And if mentioned, the CREAM analysis revealed also other technical or organisational factors. One could perhaps relate these findings to the qualitative method used here, and not so much to the CREAM method itself. By using qualitative interviews one gathers more information than in simple standard interviews based on the Synergi reporting form. But on the other hand, the qualitative interviews are based on what the CREAM method asks for. This highlights the importance of asking the right questions when examining incidents and accidents.

A general remark to the original CREAM classification scheme is that it could be expanded with regard to organisational categories, especially concerning more informal parts of an organisation and relations/interactions between people within the system of an organisation. The human and technical categories seem to be dominating.

It should be noted that some changes have already been made in other applications based on CREAM such as the DREAM (Drive Reliability and Error Analysis Method) which was assessed in a different part of the present project (Sagberg 2007).

Based on the findings in our case studies, we have suggested some new organisational categories in order to adapt the CREAM method to the rail domain. The most important suggestions are:

- ❖ The mismatch between theory and practice in how to handle different situations as in Case 1 where the train driver had learned that he should attention to all the dwarfs, but in practice there was only one dwarf he should pay attention to, at that specific station. This case also illustrates the train drivers' need for local skills at specific locations, indicating lack of a standardized system.
- ❖ There are many formal procedures for how work should be carried out in the railway system. The qualitative interviews reveal that there are also "informal procedures" among the train drivers for how a task or work should be carried out in a specific situation. Such "procedures" might be developed when there is lack of a formal procedure. As in Case 2, where the driver had to drive

beyond the switches before going back on a different track. He says that he could have driven far out on the track to be sure that he had driven far enough, but for several reasons he does what he says drivers usually do in situations like this: To look in the left hand mirror to see if there is a dwarf signal that allows you to return. Based on this we suggest to include "informal procedure among the train drivers" as an organisational category. This is an important category for two reasons:

- It might stress the lack of a formal procedure in a specific situation, and perhaps the need for one.
- It is important that the train dispatchers have knowledge of these informal procedures. In Case 2, the train dispatcher does not seem to know about this procedure as she puts up the dwarf to early.

❖ There seems to be a need for a category which describes how a procedure was carried out by the train dispatcher as a representative for the organisation. In CREAM "Inadequate procedure" (in the "Procedure" category) relates more to the design or text of a procedure than how the procedure was carried out. Another genotype, sorting under the "Organisation category", is "Inadequate task allocation". This category describes how a procedure was carried out, but at a management level (i.e. inadequate work plan, irregular working hours). As for now, there is a lack of a genotype describing how a task or procedure was carried out by the train dispatcher.

In the rail domain there is widespread communication between the train driver and the train dispatcher/traffic controller. We suggest to include a category under "communication" that specifically relates to this kind of communication.

In addition, the analysis revealed that the definition of the "Communication" category should be expanded when applying the CREAM method in the rail domain. Case 6 illustrates that the train driver uses information from train dispatcher/traffic controller. The train driver "reads" the actions by the train dispatcher/traffic controller through the technological system and uses this as information. Even though not considered as an information channel in the original CREAM classification scheme, this is an information channel which is actively used by the train drivers. It is important for revealing possible errors on the part of the train dispatcher/traffic controller. Thus, we suggest to include this information channel in the definition of the "Communication" category in analyses in the rail domain.

A general point, which summarises many of the remarks and suggestions above, is that the interaction between train driver and the train dispatcher has to be more fully described in the CREAM classification scheme, if used in the rail domain.

5.2 Suggestion to the Norwegian railways

Based on the findings in the case studies, the following suggestions can be made to the Norwegian railways:

Standardization

The most common contributing factor in the case studies was the deviant placement of a dwarf signal (that is, placed on the left hand side of the track instead of on the right hand side, marked with an arrow on the pole of the signal). In most of the cases when this was a contributing factor, the train driver did not have knowledge of this deviant placement of the signal. This indicates that the system, as it is designed today, at times requires local skills on the part of the train driver. The need for local skills is a particular problem in situations that are new to the train driver. It is impossible for a train driver to be trained for all different situations, and accordingly the system design should be more standardized.

Standardization is also an important factor concerning the train drivers' habits and expectations. Much of their actions are carried out according to habits and expectations, as revealed in several of the case studies. The case where the train driver pushes the ATC button (and deblocks the ATC) when he was not supposed to and then passes a signal in "stop", is a good illustration of this. Usually this is an action he has to take when he gets an order to pass a signal in "stop" as there usually would be balises in the tracks at the station. At this specific station there were no balises. If there had been balises at every signal, the train driver would most likely not have passed the signal in stop.

Knowledge about the train drivers working conditions and practices

The findings suggest that more knowledge among the train dispatchers/traffic controllers about the train drivers' working conditions and their practices would increase their understanding for the train drivers information needs and how they interpret different kinds of information given by the train dispatcher/traffic controller. This would possibly increase the communication between them, and hence possibly increase the efficacy of the system on the one hand and increase the train drivers feeling of control on the other. One of the cases studied revealed that there are informal practices among train drivers about how to handle a situation. In the case in question, the train driver looked in the left hand mirror to see if there was a dwarf allowing him to return. It appears that there were no other way to handle the situation, besides driving far out on the track, which might have been very time consuming. What happened in this case, was that the traffic controller put up the dwarf to early. Thus, it seems like this traffic controller was not aware of the train driver's practice to look in the left hand mirror when making a return and changing track within the station area. Knowledge about this practice could perhaps have prevented the train driver from passing the signal in "stop". This example illustrates the importance of thorough knowledge among the train dispatchers/traffic controllers of the train drivers formal and informal practices.

Furthermore, the findings suggest that the use of fixed code messages among train dispatchers/traffic controller and the train drivers, should be further explored. For example, it is said in one interview that the train drivers always has to reply to fixed code messages from the train dispatcher/traffic controllers, but that this is normally not the case the other way around. It is reasonable to think that a reply (as compared to no reply) would enhance the train drivers' feeling of control of the situation and thus, reduce the probability of making errors, as in the case where the train driver drives close up to the signal since he did not get a reply on his fixed message.

With regard to the use of fixed code messages, we raise the following questions: Could better use of the fixed messages make the system more effective and safer? If the train dispatchers/traffic controller had a duty to reply, how would this effect the train drivers working condition? How would this effect the train dispatchers/traffic controllers working conditions? Would a regulated obligation to reply lead to misuse of this "right" on the part of the train drivers? Could better knowledge among the train dispatchers/traffic controllers about the working conditions of the train drivers and the challenges they meet increase their willingness to reply to the train drivers?

Separate follow-up routines - a challenge

Today the responsibility for the follow-up of an unwanted incident is divided between NSB, when the incident is said to be directly caused by the train driver and Jernbaneverket, when the incident is said to be directly caused by factors under their responsibility (the track, the signalling system and the train dispatchers and traffic controllers). As our findings reveal that there are often more technical and organisational contributing factors to a SPAD event directly caused by the train driver, we question this way of following up an unwanted incident. Furthermore, the case studies show that there are extensive communicational and informational challenges between the train drivers and the train dispatchers/traffic controller, and we question the follow-up routines' possibility to explore further the possible implications of this on a SPAD incident. One suggestion is to coordinate, in the case where human error is said to be the direct cause of an event (either by the train driver or the train dispatcher/traffic controller), the investigation and reporting between NSB and Jernbaneverket.

The CREAM classification scheme as a basis for reporting a SPAD event

As the Synergi reports turned out to be insufficient for a CREAM analysis, and our findings show that the CREAM analysis reveals more contributing factors than stated in the Synergi reports, we suggest to use the CREAM classification scheme as a basis for the reporting of SPAD events. This will secure necessary information to be reported. Even though CREAM analysis is not used in the investigation of an incident, it would be benefitial to use the CREAM classification scheme in the reporting of an incident.

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Annex 1 Important comments in the interviews

Below follow transcription of selected parts of the interviews to highlight some of the important issues discussed in the report.

CASE 2

- (when describing the incident) "At track no 6 another train is waiting for me to join with it. And, I was unfamiliar with this situation, but that is not really the problem, then I get a signal about shunting at the north of the station A. And then I do not know how far I will have to drive before returning. And that was what the problem was about, because I did not see any signals in front that would limit my train route, as it is called, or my shunting route ("skiftevei"), and it is very, very far up because of goods train and so on.

  And what we always have heard and done and what is the common thing to do, is to look in the mirror at the other side (here: left side) to see if you get a dwarf signal allowing you to return. That is common, when you see that, you know you are inside (here: by this he means that a train has driven passed the switches in question and that he has driven far enough for making the return). And this signal was set up (here: "shunting allowed") and then I thought I was ready to go back. And then I switched driver cabin (here: cabin in the other end of the train) …".

  Interviewer: "And that is what you are taught? (to look in the mirror on the left side in situations like this)

  Train driver: "Yes, when you are not familiar at a station, you do not know how far you will have to drive. And in this case it is a very long distance without anything limiting my train way ("togvei"). And then I looked after a "returndwarf" (a informal term for the dwarf indicating how far the train should go before returning when shunting) in the mirror at the left side, because that is where it is supposed to be (on the left side).

- (when describing the incident) " … and when I start driving the train goes in the wrong direction … or back to where I came from. And there is a dwarf signal placed on the wrong side … in addition. And that one I did not see before I started to drive and then I stopped immediately. Then I contact the traffic controller and tell him I have driven in the wrong direction ("kjørt feil"). What is stated here (refers to the Synergi report) is that the traffic controller stopped the train, but that is not correct. So, I stopped and called the traffic controller. And I talked to a women … and this I did not write in my report on the incident … and told her I had driven in the wrong direction, "Yes, we saw that, wait a minute, and I will consult with my collegue". Then she is talking to the chief controller ("vaktleder") while she is holding the telephone receiver against her shoulder so I can hear all what they are saying. And then she says: "I put up a dwarf signal too early for him" (refers to the dwarf signal no. 2 on the drawing, the one the train driver saw and made him assume that he had driven far enough).

- Interviewer: "Do you have any thoughts of why she did that (put up the signal too early")? Were there any other trains arriving?

  Train driver: "No, no, the signal was put up for me, no, it is to save time".

- " … if the traffic controller had taken care of me while I was driving here (refers to driving far enough before making the turn) then he/she would have seen all the time, maybe he/she did … but I doubt it as she was surprised when I called … then the traffic controller would have seen that I had not driven far enough, because they can see that immediately, that you have moved out of a "sporfelt" "Ok, now he is out of there".

- Interviewer: "In your opinion you should have called up the traffic controller (when not knowing how far he should go before returning)?

  Train driver: "Yes, I could have done that".

  Interviewer: "But did you have to stop for making this phone call?".

  Train driver: "No, it can be done while driving … that could be another thing that might disturb you if you are on the phone."

- Interviewer: "Do you get instructions about calling the traffic controller when you are unfamiliar with a station?

  Train driver: "If you do not have any clue of what you are doing, and that happens (laughs), then you call the traffic controller. If not, you do as I did, you look for a "returndwarf" in the mirror … Not all traffic controller are happy to receive a phone call … that you bother them at 01.30 hours in the morning, right?

  It is required that things should go rapidly. That train is waiting for me (train B on the drawing) and is about to drive, and I have to hurry and so on and so on. And that is also a reason for not driving 1 km up to where I cannot drive anymore and rather to drive as short as possible. There are many, many factors."

- Interviewer: "And then you passed the dwarf signal (dwarf no. 3 showing "shunting forbidden") only by a couple of meters?"

  Train driver: "No, I passed by almost 50 meters because it stood about where I was standing. If it had been placed further up I might have seen it and not driven passed it, but that one I drove passed almost immediately … I was not even aware of that I had passed a dwarf signal, I had noticed that. I only thought that I had driven in the wrong direction ("kjørt feil"). I was not really sure of happened, because I was sure that the train would go straight ahead, but then it goes to the left "but "I alle dager", this is wrong", I think, and then I stop. I never saw that dwarf (dwarf signal no.

3), it was placed both on the wrong side and very close to the train ("helt inn til toget").

- "The traffic controller can set up the dwarf signals independent of each other. If she had not put up the signal (dwarf signal no. 2, see figure 1) too early, I would not have made the mistake." ("kjørt feil")

CASE 3

- Interviewer: "When you are on track no 2, do you often get the signal showing "careful shunting allowed" at the station?".
- Usually I get "drive" and then you allowed to drive all the way in to the turning station passed the dwarf no 3. But it happens that you get "careful shunting allowed, but it is rare, and then you always get here (dwarf no 3). So that was what I thought, that it was to be a stop here (dwarf no 3), but that one (dwarf no 2) I had kind of "disconnected". Even thought I probably saw it (dwarf no 2), I did not mind it.
- "I did not think about this one (dwarf no 2), because we usually drive on track no 2 when having passengers on board. And then we drive out to the turning station and change directions, and then there are no signals before here (dwarf no 4). I have never really stopped here before (at dwarf no 2). I am used to the track being clear all the way up here (dwarf no 3), and usually all the way up to the turning station. So I had decided that I should at least go all the way up here (dwarf no 3)."
- Interviewer: "Were there any background factors that could have contributed to the incident?"
- Response by train driver: "No, it was just that I was sure that I was familiar with the area, that I should go there … (dwarf no 3), but it was not that dwarf, because I was on another track than I usually drive. Then that dwarf (no 2) did apply to me."
- "It was like I did not see it (dwarf no 2), I am used to that it does not mean anything, normally we drive on track no 2 …".
- About the call to the traffic controller when stopping at the platform: "And then she said that I should have a signal at the turning station. That happens sometimes during the evening when it is quiet, that you just make a turn on the platform, but she (the traffic controller) wanted it at the turning station, for one reason or another. Maybe she planned to have another train in at the station … She said that I would get at signal out at the turning station, I might have been confused by this, that I thought I was going out at the turning station … But that dwarf (dwarf no 2), usually I am very familiar with the area and I am used to the dwarfs that are there, but … that specific dwarf I disconnected. I did not care about it.

CASE 6

- About why he passed the signal: "It was probably a mixture of stress and the signal, that it was not easy to see."
- About the question from the train driver to the traffic controller whether the light was green or not: "He could not tell me, if it was green, he would not answer this. Today, I still not know whether it was a light bulb that was broken or what happened. I am a little bit curious on that … That is what I wonder about, it happens that the traffic controller cannot see if the light bulb is broken, he sees that it is green and then …" (probably indicating why everything else was made ready for the train driver in order to cross the main tracks).
- About the possibility of another train coming into the station: According to the train driver, an accident could only had occured if another train was driving on a red light or if the traffic controller had allowed another train to drive on a red light. In the latter case, the traffic controller would have had to give notice of this to the train driver. "the traffic controller cannot put up a single green light at the entire station when he puts the switches up in my direction (which means that the track is occupied). Then the entire station is closed only for me. Physically it is not possible for the traffic controller to put up a green light for other trains, but he has the possibility to let them in. In that case, the train would drive on a red light and would then drive at 40 km/hour, that is "sight speed" ("sikthastighet").
- About the communication between train drivers and traffic controller in different areas: They (the traffic controllers) always want to be updated if something has happened, i.e. the traffic says that we will be standing for one minute too long or similar things, they always want to be given notice as soon as possible, and I believe that we (the train drivers) are good at that. But when it comes to the traffic controllers, it can go very slowly, we can be standing for a long time before we have any message from the traffic controller on why we are standing there. Then we have a kind of code system where we send messages to them and we get certain codes back with questions on why we are standing there … They do not have call us … There I would have liked to have more communication, as in this incident.
- On the question from the interviewer if it happens that train drivers refuse to call traffic controllers, the train driver replies the following: "No, generally you don't, but traffic controllers are very busy. The one place that on might "refuse" to call, is in the area X, because they have such an enormous work pressure. Usually you await the situation before you call to see if something happens. It happens often that we get "stop" in a signal and then send a fixed message to the traffic controller: "We are waiting for green signal, can you set it up?" or something like that, but I can just say, (as in hundred percent), we never get an answer. Never get answer on a fixed message in the area X …