Systematic review of the train collision at Åsta on the Røros line, 4 January 2000 with the aid of the STEP method.

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Foreword

This paper is a summary of the final report from the Norwegian National Rail Administration, Accident Investigating Commission after the Train Accident at the Røros line 4 January 2000.

Under its mandate the Accident Investigating Commission (AIC) has reviewed the train accident on the Røros line on 4 January 2000. The Commission worked diligently with the experts and other resources available to find explanations for the accident from point of view of Railway technology.

The Commission has utilised specialised methods (including the STEP method) to review the accident in order to systematically consider all the events of the train collision. The results of the STEP analysis have contributed to a common understanding of the sequence of events in the accident.

The work has been comprehensive and demanding but it has contributed to a positive focus on rail safety within the Norwegian National Rail Administration. The AIC has indicated a number of areas where resources should be devoted to preventing similar events in the future.

Introduction

The Accident Investigating Commission (AIC) is appointed by the Norwegian National Rail Administration (Jernbaneverket - JBV) to independently and objectively review the sequence of events and causal relationships in operational accidents on the public Railway network. The AIC was established in 1958 and is chaired by the JBV Director of Safety. The members are selected from a background of Railway operational experience. The work of the Accident Investigating Commission is defined in terms both of determining the primary causes of events and evaluating underlying causes. Normally the AIC produces 10-15 reports per year.

The AIC is charged with recommending whether practical measures shall be taken to prevent similar accidents from happening again. Responsibility for the practical planning and execution of such measures is delegated to the respective line managers in the JBV and the Railway Operators.

The recommendations presented in the report are the Commission's suggestions for reducing the number of undesirable events in the future. The suggestions are prioritised and are presented on the basis of the STEP analysis and the actual sequence of events during the Åsta accident. The conclusions given in the report are the independent evaluations of the Accident Investigating Commission.

Background

On Tuesday, 4 January 2000 at 1312:35 passenger trains 2302 and 2369 collided at Åsta on the Røros line. The accident site is located on the southern portion of the Røros line at km 182.750 between the stations at Rena and Rudstad. The Røros line is a not electrified single-track line, and all traffic consists of diesel-powered trains.

The stations on the section have safety equipment and main signals for both entry and exit. The equipment was installed between 1988 and 1995. The line's blocking system does not have track circuits between stations. Monitoring of the line blocks and the entry and exit of trains from stations takes place with the help of a "tail magnet" that activates detectors placed by the track.

The train controller at the Hamar Control Centre remotely controls the safety equipment at the stations. Remote control of the stations on this section was implemented during the period from 1990 to 1995. At the time of the accident ATP was under installation, but not yet taken into use.

3. Conclusions

3.1 The Accident

On Tuesday, 4 January 2000 at 1312:35 passenger trains 2302 and 2369 collided at Åsta on the Rørosline. The accident occurred when a northbound passenger train unauthorised passed exit signal L at Rudstad station and moved out onto the blocked section where a southbound passenger train was already approaching from the opposite direction. The trains met at Åsta at speeds of 70 and 90 km/h respectively, which led to a powerful collision with subsequent fire.

The AIC has tested the technical installations according to well-known methods. These tests have given no indications of failure in these installations previous to the accident. Consequently the AIC finds it probable that the primary reason for the accident's occurrence is that train 2369 passed a "stop" sign (red light) on the exit signal at Rustad station.

The direct cause of the accident is assumed to be that the train passed a signal light indicating STOP when it passed the main exit signal at Rudstad station.

A routine train meeting of train 2369 and train 2302 should have taken place at Rudstad and no notice had been issued concerning a transfer of the meeting station.

The AIC has not found any violation of applicable traffic safety rules before the train stopped at Rudstad station. There was also no violation of regulations concerning shift orders or duty rosters for the train drivers, conductors or train controllers. As far as the Commission knows, there was no failure or defect in either of the trains that would have caused or contributed to the accident. After thorough engineering investigations and reconstructions the AIC concludes that there was no technical cause for the accident.

However, no final answer was found for why the train proceeded out from Rudstad station without a PROCEED signal and before its scheduled departure time.

3.2 The Røros line

The AIC has evaluated the safety between Hamar and Røros at the time of the accident. It found that the actions of a single person were the sole barrier against a train passing a "stop" signal and that collisions may occur. The Commission acknowledges that this single barrier has traditionally been perceived as being sufficient for train operation, nevertheless AIC questions whether it is adequate according to current standards.

The AIC has identified several conditions that could have prevented or reduced the scope of the accident if they had been put into effect previously. These concern primarily the lack of installed engineering coverage measures such as Automatic Train Protection (ATP) and Track to Train Radio Communication (TRC). An acoustic alarm for the train controller and better routines for reporting mobile telephone numbers would have improved capabilities for reducing the scope of the accident. The AIC has identified 12 points in the sequence of events as safety critical factors and suggests measures to be taken with regard to each of these.

3.3 Underlying Causes.

At the time of the collision, there was only one safeguard in effect on the Røros line. If the train driver overlooked or misinterpreted the light signal, there was no other safeguard in place to warn or stop the train immediately. The underlying cause for the train being able to pass the signal without the train driver being warned or stopped is because the main exit signal L at Rudstad station was not equipped with an automatic train control system (ATC).

The point in the northernmost end of Rudstad station was at the time of passage set for entry onto track 2 and was trailed by the northbound train. The point was of the type that can be trailed, so this had no consequences for the train. Passage of the main signal was immediately indicated to the train controller. The trailing of the point was indicated to the train controller after 24 seconds. Passing warning field B caused a short warning tone (2.5 seconds) to sound immediately accompanied by a text message on the train controller's screen. The train controller was at this time occupied with traffic control on another section of the line. The train controller became aware of the event after approximately three minutes. No acoustic danger alarm had been installed to warn the train controller of a point being trailed or an unauthorised passage of a main exit signal. The train was equipped with a mobile telephone, but the collision had already taken place by the time the controller managed to contact the trains.

The section between Røros and Hamar on the Røros line had been equipped with Centralised Traffic Control (CTC) operated from Hamar during the period from 1990 to 1995. It was intended during the introduction of remote control that the entire section would continue to be controlled by Automatic Train Protection (ATP). In the budget preparations of 1994 resources for ATC on the Røros line had low priority and fell below the level for funding over the budget. Funding priority continued to be low in 1995 and 1996. The matter was discussed in the NSB safety forum in 1994 and the discussion was repeated in two memorandums from the then Director of Safety in 1996 and 1997. A draft for the master plan was submitted in 1995. The master plan was approved in 1997.

4. Choice of methodology

It was desired to reach the following goals in the review of this accident:

- Form a mental image of the course of the accident.
- Ask the right questions and defined the types of data to be gathered.
- Check that all relevant data has been gathered.
- Evaluate the gathered data into meaningful information.
- Analyse to find the relationships between various parts of the information.
- Identify and evaluate preliminary measures.
- Establish a common basic model.
- Establish rules for stopping the search for new causes.

The Accident Investigating Commission had a requirement for a method that could determine the relationships in a complex series of accident events, particularly for technical equipment. The Commission considers it important to describe possible secondary causes and to identify and evaluate possible preventive measures. The STEP method is a method that is easy to learn and to communicate. It can be used and understood by all, even outside the academic environment.

4.1 The STEP analysis

The sequence of events is represented by making a logical STEP-diagram (flowchart). A horizontal time axis includes the sequence of events beginning with the first anomaly that affects the disaster or accident and ending at or immediately after the time of the accident. Events that occur simultaneously are drawn on the vertical axis.

For the Åsta accident, a flowchart was constructed from the first anomaly on 3 January 2000 to 4 January 2000 immediately after the collision at 1330. The flowchart includes 126 events. The STEP analysis consists of adding a description of the sequence of events, identifying safety factors and suggesting preventive measures. A STEP analysis is an objective description of the sequence of events. Responsibility and blame are not discussed.

STEP analysis is a recognised method of accident investigation. The theory and methodology are described by Kingsley Hendricks and Ludwig Benner, Jr. in the book Investigating Accidents with STEP (ISBN:08247-7510-4). The book was first published in 1986.

4.2 Description of the method

The method of developing the flowchart is simple and is done by systematic charting of observed or documentable events. The method has proved to be a efficient way to obtain an accurate and unified understanding of the sequence of events. Many complex technical facilities are involved in the investigation of the Åsta accident. The flowchart was improved and quality-controlled many times by means of systematic investigations.

In order to check that the interactions are correct, a “reach test” is carried out for each actor. A “horizontal test” is carried out to check for simultaneity. It is desirable for the diagram to contain only relevant and necessary events. This is checked repeatedly throughout the process

The STEP-method has been used in several well-known accidents in Norway and is accepted in the field of accident investigation. The method was previously used in the following accidents, among others: Gissur Viking, Nordstrand, Sleipner and Namsos.

5. The object of STEP analysis

The STEP analysis is an independent document and forms a portion of the JBV report on the Åsta accident. The object of this systematic STEP (Sequentially Timed Event Plotting) analysis is primarily to develop an objective description of the events of the Åsta accident with all actors and relevant events.

A graphic presentation will lead to a complete and objective description of what took place and why. The representation of sequence of events is made on a non-linear time axis, in which each actor, (person or object), has a separate line on the graph.

The object is for all parties involved, the police, the Commission, JBV management and NSB BA to agree on a sequence of events based upon the STEP analysis. The STEP analysis takes no position on blame or responsibility.

In attachments to the sequence of events itself, the analysis will, where possible, identify and evaluate any safety problems and underlying causes. Emphasis in this STEP analysis has been upon the events. A separate flowchart has been included in order to obtain an objective picture of organisational changes during the period 1990-2000.

The analysis includes only situations directly connected to the Åsta accident and conditions that led directly or indirectly to the train collision. Situations associated with a general discussion on safeguards are not treated in this document.

6. The Actors

An actor in the STEP diagram is a person or an object who is involved in the events of the accident and who was active during the course of these events. An actor may influence the course of events.

The following actors are included in the analysis:

- Locomotive dispatcher in Trondheim. The locomotive dispatcher issues lists concerning the utilisation of locomotives and cars.
- Train driver of the southbound train (2302)
- Train driver of the northbound train (2369)
- Southbound train 2302. The train had a type Di3 diesel locomotive (No. 625) and three passenger cars.
- Northbound train. The train was a type 92 diesel multiple unit (DMU) (No. 9214/84).

- Train controller (1) at the remote control centre in Hamar. This train controller went off duty before the collision.
- Train controller (2) at the remote control centre in Hamar. This train controller was on duty at the time of the collision.
- The JBV telephone network. Telephone conversations were carried via JBV's internal network.
- The remote control centre at Hamar. The centre includes technical systems, visual screens, service systems, data logs, and graphic displays.
- The safety equipment at Rudstad station. The safety equipment includes indoor and outdoor facilities with signal lights and points.
- The safety equipment at Rena station. The safety equipment includes indoor and outdoor facilities with signal lights and points.
- The train dispatcher at Elverum station. Elverum station is a junction station and has a train dispatcher on duty.
- The Telenor telephone network. Telephone conversations were carried via the network to public telephone operators.
- The boarding passenger at Rudstad station.
- The conductor on northbound train 2369.
- The conductor on southbound train 2302

7. The signalling systems

Considerable resources have been expended in examining all aspects of the signal facilities at Rudstad and Rena stations. In addition, many investigations and test have been carried out on the remote control centre at Hamar and on the data communications between the various facilities. A general evaluation of type NSB-87 interlocking was also performed. The Accident Investigating Commission has engaged both internal and external experts to perform an evaluation of NSB-87 interlocking with the aim of determining whether any of the safety functions of the equipment are localised in the PLC unit.

The Accident Investigating Commission concludes that no deficiencies were found in the technical signalling systems that could have caused the accident.

8. The train controllers

The remote control installation at Hamar is a CRT-based system. The facility was put on line in 1990. The facility was last upgraded in 1999 in connection with Y2K measures. The screen images were improved during this project.

The data logs were removed and copies made in collaboration with a police investigator from the Hamar police. The data log, represented by the train controllers' screen images, gives clear indications of the sequence of events.

9. Trip recorders

An important task for the Accident Investigating Commission was to locate and read out the trains' speed recorders (trip registers). The trip register from the locomotive on the southbound train was the electronic type and was totally destroyed in the fire.

The trip register from the northbound train was found in the woods off the track. The trip register was the mechanical type and it was possible to read off the train's speed for the entire trip from Hamar station to the accident site. There is complete agreement between the information recorded on the train and that on the data log at the remote control centre.

10. Safety Problems

Possible safety problems are indicated in the diagram by letters. This indicates events where procedures and/or technical processes could have been done in another way with diminished impact on the further evolution of the accident.

11. JBV Organisation

Jernbaneverket was established as a state enterprise on 1 December 1996. Employees in the former Norwegian State Railways (NSB) infrastructure, the corporate traffic safety staff, train dispatchers and four business units were transferred to JBV on the same date.

The remote control centres remained under NSB until 1 January 1998. They were then transferred to JBV. Until 1 July 1999, the corporate head of NSB was also administrative director of JBV. On the same date, JBV and NSB became two independent organisations and JBV got a new Director of Railways reporting directly to the Ministry of Transport and Communications.

A flowchart is prepared to obtain an overview of organisational changes, responsibility for safety and changes in safety regulations for the period 1990-1999. The analysis focused on circumstances that affected decisions and responsibilities for the technical facilities on the Røros line and for JBV traffic safety regulations.

The analysis shows that the years 1994/1995 were the most decisive for the postponement of expansion of Automatic Train Protection (ATP) to the Røros line. The Accident Investigating Commission is including the organisational analysis as an objective basic document and makes no comments on the analysis with regard to responsibility.

12. Investigations and general conditions

The JBV Accident Commission undertook a series of independent investigations. These investigations are presented in three partial reports. Because of privacy considerations the partial reports are not available to the public.

13 Recommendations from the Accident Investigating Commission

In this step analysis, the Accident Investigating Commission has made a systematic and detailed investigation of the sequence of events in the Åsta accident. By examining the origin of each individual event, safety-critical conditions that could have prevented or reduced the scope of the accident have been identified.

The AIC has identified 12 specific safety factors in the STEP analysis that have contributed to the scope of the accident. These measures are divided into engineering factors, human factors and organisational factors.

13.1 Engineering factors

The Accident Investigating Commission recommends the introduction of a uniform mode of operation on all rail lines in JBV. This can be accomplished by the introduction of Centralised Traffic Control (CTC), Automatic Train Protection (ATP) and Track to Train Radio Communication (TRC) on all lines. This measure must apply to all rolling stock that moves on the various line sections.

In the short range, special alarms (acoustic, for example) should be considered at those remote control centres that currently notify train controllers of the passage of a light signal set to STOP, trailing a point or other dangerous anomaly. The alarms must be installed in all types of installations including older operating centres without computer monitoring. As part of this same measure, all remote control centres must have installed permanent data logs with the capability of recording sequences of events. Routines for permanent storage and monitoring of data logs must be put in place for the entire organisation.

13.2 Human factors

The AIC recommends that a risk analysis be conducted on those remote control centres that have several different types of remote control equipment. This applies particularly to facilities in which the man/machine interface (MMI) is different for train controllers in the same operations room.

13.3 Organisational Factors

The AIC notes that there must be improvement in routines for reporting and changing mobile telephone numbers in trains. It is recommended that additional routines be introduced for train controllers and train dispatchers such that a train cannot be put into motion until communication has been established and checked. Ringback in order to check the actual number of a mobile telephone must be introduced if the Track to Train Radio Communication (TRC) is not installed and in permanent operation on a rail line. Radio coverage for mobile telephone operations online should be monitored once per year by a measuring car. Until TRC is fully installed, the capability for making multiparty calls to the mobile telephones should be investigated and introduced if technically feasible. Transition from the NMT mobile telephone system to the GSM system should be evaluated as a short-range measure.

In order to avoid moving trains because of blockage of track circuits behind the train, standardised stopping patterns for platforms should be reviewed.

A risk evaluation should be carried out by traffic operating personnel to determine what risk factors are involved if the train conductor occasionally stays in the train driver's compartment. The evaluation must include the risk of evacuating the train driver's compartment and in exercising the conductor's tasks in connection with passenger safety on the train.

14. Other accident commissions

The train operator NSB BA has its own accident group. This accident group concentrated its work on the fire in the southbound train, damages to rolling stock and the man/machine interface (MMI).

The Government established a public investigation commission as an aftermath of the accident. Under its mandate, this commission undertook a series of investigations of the technical facilities and participated in the reconstructions. In addition, the commission undertook more than 100 interviews with witnesses, rescue personnel, passengers, employees and management in NSB BA and JBV.

Contacts between the JBV Accident Investigating Commission and the Government investigation commission have been of an informative nature. In addition, the commission’s members have participated in technical informational meetings and courses in order to familiarise themselves with the operation of the technical facilities. Individual members, consultants and magistrates have participated in these meetings.

The Government investigation commission has received the Accident Commission’s partial reports as information, as have NSB BA, the NSB BA accident group and Østerdal Police District.

All other information to the Government investigation commission has been furnished by the JBV line organisations.