WHERE NEW TRAIN SETS MEET INFRASTRUCTURE WITH LACK OF TECHNICAL BARRIERS.

Kurt A. Olsen

Director, Railway Department

Accident Investigation Board, Norway (AIBN)

SUMMARY

A roll-over accident occurred during continuous on-track testing of new train sets that were to be handed over to the train company. The journey was part of the burn-in process, whereby any early faults and defects in the vehicle could be discovered through normal use over a certain period of time. At the same time, it was providing user experience with the personnel who had been trained and checked out for that type of train.

The direct cause of the accident is deemed to be that the train was travelling too fast on the section of track. The driver had overlooked a sign notifying of a speed reduction from 130 to 70 km/h, and initiated braking too late. The train rolled-over and derailed in an area of relatively sharp curves, with a line speed of 70 km/h. The accident took place between 50 and 100 metres past the point where the line speed is reduced from 130 km/h to 70 km/h. The point of derailment was in a right-hand curve in the direction of travel.

The accident involved a new type of train operating on infrastructure with PATC (partial ATC). The scope of the safety investigation included such as technical examination of the accident site, assessment of compliance with laws and regulations, the infrastructure's condition and function, lack of barriers to reduce the probability of incidents, the roll-over speed in relation to the train's centre of gravity etc.

INTRODUCTION

The Accident Investigation Board, Norway is a multi-modal safety investigation body covering aviation, railways (including metro and tramways), road traffic and marine. The railway department came in to service in year 2002, and investigates 10 to 12 accidents or serious incidents every year.

The objective of the investigations is to elucidate matters deemed to be significant for the prevention of transport accidents. The Accident Investigation Board, Norway shall not apportion any blame or liability under civil or criminal law.

The Accident Investigation Board, Norway carried out a safety investigation to shed light on how insufficiently strong barriers can result in an accident of significant scale. The investigation has shown that there were no technical barriers that could detect a train's failure to initiate speed reduction on time on a track section with only PATC (partial speed monitoring).

In the absence of technical barriers against excessive speed, much of the responsibility is left to the driver's knowledge of the line. In the Accident Investigation Board, Norway's opinion, the accident illustrates how important it is to have clear requirements for such knowledge and that systems are established to check whether knowledge is adequate.

THE ACCIDENT

The accident involved a new type of train set operating on "old" infrastructure. There were personal injuries and significant damage to the train and the railway infrastructure. The train was being handed over to NSB (train operator) from the Swiss manufacturer Stadler Bussang AG.

There were five people on board, where two persons suffered serious injuries and two persons minor injuries.

The train recording speed sensor showed that the train was travelling at a speed of 135 km/h when the brakes were activated. The analysis of the speed data shows that it took approximately 11 seconds from the time the brakes were activated until the train came to a halt. The distance travelled was measured to 340 metres.

When the notification of the accident was received, ambulances, rescue helicopters, fire service and police all responded. It was difficult to find precisely where the accident had taken place, since the accident happened in an area not near buildings or roads. The emergency services needed the assistance of an employee of the Jernbaneverket (The Infrastructure Manager) to guide them to the accident site.

The train set involved was totally wrecked in the accident, and none of the carriages could be removed using the tracks; they had to be divided up and removed using cranes and lorries. Approximately 150 metres of track, sleepers, cable ducts, signal cables and catenary masts had to be replaced.

The line is a remotely controlled section equipped with Partial Automatic Train Control (PATC). Traffic control and the signalling system functioned normally.

INVESTIGATIONS CARRIED OUT

The AIBN provided factual information through interview with persons who were present at the accident and other relevant responsible persons. In addition the following investigations were carried out:

- Technical examination of the site of the accident
- Assessment of compliance with laws and regulations
- The safety and emergency response systems of the parties involved
- The infrastructure's condition and function
- Inspection of the section of line using an NSB Type 74 train
- The train set's bogies were examined after the accident
- The roll-over speed in relation to the train's centre of gravity
- Teloc examination
- Front camera examination
- Notification, fire and rescue services
- Survival aspects

This paper will focus on the infrastructure's condition and function and the roll-over speed in relation to the train's centre of gravity.

The infrastructure's condition and function

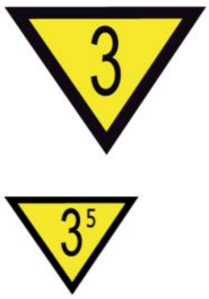
The FATC system provides continuous monitoring of speed. Only approximately 10% of the Norwegian railway network is equipped with FATC.

PATC only monitors the passing of stop signals, driving speed in stations' arrival train routs and the maximum permitted speed given by the train's composition and the speed for the route set in the ATC system.

Neither the drivers nor the Infrastructure Managers want so-called "island" of FATC where a line switches between PATC and FATC. This could confuse the driver, who may be led to believe that he/she is on a FATC section while in reality it is "only" a PATC section. PATC does not have speed monitoring, and thus provides only limited monitoring. The ATC handbook states that when a train is to drive a stretch of tracks with varying speed classification, the procedure is for the ATC system to be set to maximum speed permitted on the route as a whole. In this particular case, the maximum speed was set to 200 km/h.

Changes of speed are indicated in advance by signal 68A or 68B, and the speed indicated applies from a given point, which is marked by a marker signal 68D.

The marker from which the speed reduction applies was correctly located, but is not intended to be sufficient to warn the driver to brake if braking has not already been initiated. The distance between the 'Reduced speed' and the 'Marker' was approximately 1000 metres. The AIBN was not able to establish what distracted the driver's attention for the four or five seconds during which the speed reduction sign was visible.



Signal 68A 'Reduced speed'.

Signal 68D 'Marker' for reduction of speed.

The roll-over accident took place when passing a station area and running into a right hand turn. The speed sign stating the speed on the departure route from the station was missing. This sign would have repeated the line speed for the section of track, and made it clear to the driver by how much the train was overspeeding as it approached the first curve.

In the AIBN assessment, it is likely that a sufficient reduction of speed could have been achieved, but it would have required an optimal course of action in a situation that is not part of the driver's ordinary training. It has been considered what might have caused the driver not to notice the speed reduction and marker signs, such as stress or distracting elements. The comfort and perceived running properties of the type of train in question may also have contributed to a reduction in alertness, leading to the signs being overlooked.

The roll-over speed in relation with the train's centre of gravity

In order to examine the stability of this type of train compared with other types, roll-over calculations were carried out.

The risk of a train rolling over can be expressed as a moment calculation of the outer wheel in which the following parameters are included:

- ʋ – speed in m/s
- g – the acceleration of weight in m/s^2
- R – the radius of the curve in m
- p_c – the height of the centre of gravity measured from the top of the rail to the vehicle's centre of gravity
- s – track gauge in m
- h – cant in m.

The lowest speed at which a vehicle could overturn is thus calculated by the following formula:

$$v \geq \sqrt{\frac{R}{p_c} * g\left(\frac{s}{2} + \frac{h}{s} * p_c\right)}$$

Given parameters:

- The cant h is 135 mm
- The radius R is 250 m
- The track gauge s is 1500 mm.

The calculation shows that vehicles with centre of gravity at 1600 mm or higher will roll over when the speed exceeds 133 km/h. According to the technical specification of this type of train the centre of gravity varies between 1555 and 1691 mm.

The theoretical calculations do not include all factors that could have an effect on how easily a vehicle will roll over. Among other things, if the bogies are at a slight angle to the car body at the start of the curve, that could make roll-over somewhat more difficult, and if the car body tilts outward in the curve, the vehicle will roll over more easily.

Roll-over stability calculations for different types of train operated by NSB were carried out under ideal circumstances, i.e. without taking into consideration any track faults or changes in track geometry. If only the quasistatic values are considered, the calculation show only minor differences between the different types of vehicles.

The height of the vehicle's centre of gravity is a material element in the calculation of roll-over risk. The vehicles on which the calculations are based, have somewhat different centres of gravity. Because different carriages in a train are of different designs and contain different equipment, this height can vary depending on the specific carriage considered. This is summarised in the table below, specified for empty trains and trains carrying load, respectively.

	NSB Type 5	NSB Type 70	NSB Type 72	NSB Type 74
Pc (empty)	1483–1590 mm	1241–1632 mm	1252–1531 mm	1559–1691 mm
Pc (with load)	1644–1767 mm	1368–1741 mm	1384–1601 mm	1555–1681 mm

The calculations concludes that, despite a lightly higher centre of gravity, the type of train involved in the accident does not differ significantly for other comparable vehicles that travel on the line in terms of roll-over risk.

CONCLUSION

The safety investigation shows how insufficiently strong barriers can result in an accident. The direct cause of the accident was that the train was travelling at an excessive speed. The driver had overlooked a speed reduction notification (very weak barrier) to reduce the speed from 130 to 70 km/h, and initiated braking too late. When this happened, there were no technical barriers available in the infrastructure to detect and automatically start reducing the speed or notify the driver.

Before a new train can be introduced on the national railway network, it must meet requirements that are in place to ensure the new vehicle is compatible with existing vehicles and infrastructure. The accident occurred on a section of line with partial ATC, which only monitors the passing of stop signals, driving speed in stations' arrival train routes and the maximum permitted speed, but not continuous monitoring the speed.

Non-conformity with applicable rules, standards, procedures and norms can contribute to the occurrence of undesirable incidents. The Regulations on Safety Management for Railway Undertakings on the national railway network set out the overall requirements. According to the Safety Management System of the Infrastructure Manager, the analysis of a section of track shall provide an overview of risk for the section in question.