Accident
Investigation Board
Norway

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REPORT ON DERAILMENT NEAR NYKIRKE STATION, THE VESTFOLD LINE, ON 15 FEBRUARY 2012, TRAIN 12926

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Photos: AIBN and Ruter As

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Report on:	Derailment near Nykirke station, the Vestfold line
Train number:	12926
Train data:	Length 105.5 metres, total weight 218 tonnes
Vehicle involved:	Multiple unit NSB Type 74
Registration:	74 105 – 74 505
Owner:	Stadler Rail AG
User:	NSB AS and Stadler Rail AG
Crew:	Three
Passengers:	Two of the supplier's employees
Accident site:	The Vestfold line, Nykirke station between Skoppum and Holmestrand stations at the 92.14 kilometre point
Time of accident:	Wednesday 15 February 2012 at 10:30

NOTIFICATION OF THE ACCIDENT

The Accident Investigation Board Norway (AIBN) was notified of the accident on Wednesday 15 February 2012 at approx. 10:50. Three accident investigators went to the scene of the accident. The group was reinforced with two more persons later in the day. The scene of the accident was mapped by means of photos and preliminary measurements. The recording units in the train set were secured, and the work of extracting the data started. This work continued in the days that followed.

NSB AS, the Norwegian National Rail Administration (NNRA), the Norwegian Railway Authority and Stadler Bussnang AG were notified that an investigation had been initiated in letters dated 17 February 2012. The European Railway Agency (ERA) was notified on 18 February 2012 that an accident investigation had been initiated.

SUMMARY

On Wednesday 15 February 2012 at 10.30, northbound train 12926 derailed at Nykirke station on the Vestfold line. The train was an NSB Type 74 train that was being handed over to NSB AS by the Swiss manufacturer Stadler Bussnang AG. There were five people on board the train. One person was seriously injured, while three people suffered minor injuries. All five carriages in the train were completely destroyed.

Based on the AIBN's investigations, the immediate cause of the accident is deemed to be that the train was travelling too fast on the section of track in question. The driver had overlooked a sign notifying of a speed reduction from 130 to 70 km/h, and initiated braking too late. The AIBN has considered potential sources of distraction, but found none that can with certainty be linked to the driver overlooking the sign.

The new Train Driver Regulations introduced new requirements for follow-up and control of personnel's knowledge of the line. The AIBN expects the change in requirements to have an effect. It has therefore chosen not to propose a safety recommendation concerning competence in relation to sections of track so soon after the regulations were amended.

NSB AS's restructuring in 2011 had not been implemented into the organisation's operational entities. However, it is the AIBN's opinion that this has no effect on the final outcome of the investigation.

Most of the Norwegian railway network is not equipped with any type of speed monitoring capable of preventing a train from exceeding the line speed. It is the AIBN's opinion that, in the absence of Full Automatic Train Control (FATC), the NNNRA must look into the possibility of introducing sufficient barriers to prevent such railway accidents, and the AIBN proposes a safety recommendation about this. The recommendation aims to identify the places where a rapid reduction of speed could represent a hazard, and implement barriers to identify such places and prevent accidents.

1. FACTS

1.1 Description of the incident

On Wednesday 15 February 2012 at 10.30, northbound train 12926 derailed at Nykirke station on the Vestfold line.

Figure 1: Overview map with the site of the incident marked (www.norgeskart.no).

There were personal injuries and significant damage to the train and the railway infrastructure. The train was an NSB Type 74 train that was being handed over to NSB AS by the Swiss manufacturer Stadler Bussnang AG. The incident occurred during continuous on-track testing of the new train sets that were to be handed over, and the journey was part of the burn-in process, whereby any early faults and defects in the vehicle can be discovered through normal use over a certain period of time. This was combined with a function test of the train's passenger information system (PIS). At the same time, it was providing user experience with the train for personnel who had been trained and checked out for that type of train.

There were five people on board the train. There were two locomotive supervisors and a train inspector from NSB on the train. One of the locomotive supervisors acted as the driver and was responsible for the operation of the train. The other locomotive supervisor's task was to function as a point of contact between NSB's procurement project and the train, and to provide technical assistance should the need arise. There was also one employee from the supplier Stadler Bussnang AG on the train, and one from Stadler's sub-contractor, Mitron, which supplied the PIS system. The train inspector's task was to assist in the testing of the PIS system.

The route originally planned for the train that day was Drammen–Skien–Drammen, but this was changed to Drammen–Larvik–Drammen due to work on the tracks between Larvik and Skien. The train was on its way back to Drammen when the accident occurred.

The train set was split into three parts in the accident. When the train came to a halt, the persons on board were all conscious, but had injuries of varying degrees of severity.

Figure 2: Overview photo of the accident site. The carriage furthest away from the camera belongs to the rescue unit. (Photo: the police)

The train inspector and the Mitron employee were in the passenger compartment nearest the driver's cab. The latter suffered a fissure fracture in the back, while the train inspector suffered only minor injuries. The locomotive supervisor had sustained the most serious injuries, and was helped into the passenger compartment by the driver and train inspector. The train inspector then went to find one of the first aid kits in the train. On his way, he checked on the condition of the person from Stadler Bussnang AG who had been in the compact conductor's cabin in the fourth carriage in the train. Even though the carriage had rolled onto its right side in the direction of travel, that person had only suffered minimal injuries, and made his way out of the carriage unaided.

The driver first notified the shift supervisor at NSB’s operations centre (DROPS) about the accident using his private phone, since the train radio on board the train was no longer working. Due to the rough treatment the train set had suffered, there was a great deal of damage to the driver's cab and passenger compartments, and technical equipment and aids had been thrown about.

The police and rescue services had problems finding out how to get to the scene of the accident, since it is in an inaccessible location. Nykirke station is a crossing station, not a station in the traditional sense with a station building and platform. A member of staff from the NNRA's infrastructure management department who knew the area reported to the traffic controller, and contact was established between this person and the rescue services so that they could be guided to the site of the accident. Once they had arrived, the fire service disconnected the electricity supply and earthed the overhead contact line system.

See Section 3 for a more detailed description of the chain of events, notification and rescue work.

1.2 The accident site

Nykirke station is located between Holmestrand and Skoppum stations on the Vestfold line, and the railway track at Nykirke has been moved. The present Nykirke station was taken into use in 2002, and is a crossing station that is not suitable for passenger exchange.

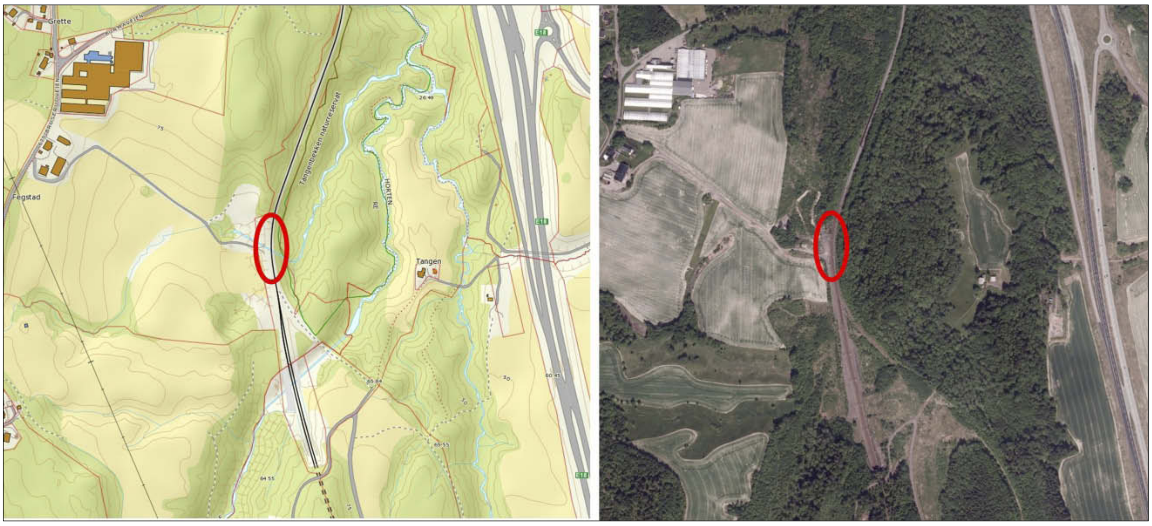


Figure 3: The site of the derailment is marked in red (www.norgeskart.no).

The train derailed in an area of relatively sharp curves, and the line speed is 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. Notification of the reduction of speed is given on a sign placed 1,048 metres before the point from which the reduction in speed applies.

The point of derailment is in a right-hand curve in the direction of travel, and there are several rock cuttings on the left-hand side of the tracks. Otherwise, this is a wooded area with several fields. See Section 2.2 for more details.

1.3 Notification and rescue efforts

1.3.1 Notification

Traffic controllers were first alerted of the accident at 10:31, when the derailment indicator alarm was triggered for Nykirke station. It indicated that train 12926 had derailed at the 92.0 kilometre point, near points 1 at Nykirke station. The traffic controllers were unable to contact the train via the train radio. DROPS was contacted, and confirmed that it had just been notified by the driver that the train had derailed. The traffic controllers called the police emergency phone number 112 at 10:35, and the call was received by the police operations centre in Drammen, from where it was transferred to the Vestfold police district's operations centre. They had problems getting through to the correct unit, and had to call several times. See Section 2.11 for more details.

1.3.2 Rescue efforts

When notification of the accident was received, ambulances, a Sea King rescue helicopter, the air ambulance, fire service and police responded. It was difficult to explain precisely where the accident had taken place, since the place is not near buildings or roads. Therefore, the emergency services needed the assistance of an employee of the NNRA to guide them to the right place.

1.4 Injuries and damage

1.4.1 Personal injuries

An initial assessment at the scene of the accident defined two of the five persons on board as having serious injuries, two as having minor injuries, and one as being uninjured. This was later amended to one person with serious injuries and three with minor injuries.

Table 1: Personal injuries at the scene of the accident

Injuries	Crew:	Passengers*:	Others:
Dead	-	-	-
Serious	1	1	-
Minor	2	-	-
Uninjured	-	1	-
Total	3	2	-

** Stadler Bussnang AG and Mitron personnel*

1.4.2 Damage to vehicle involved

The train set involved was totally destroyed in the accident. None of the carriages could be removed using the tracks; they all had to be divided up and removed using a crane and lorries.

Figure 4: The front of the train (photo: AIBN).

Figure 5: The train set was split into three parts (photo: AIBN).

Figure 6: The side of the rearmost carriage (photo: AIBN).

Figure 7: Carriage rolled on its side (photo: AIBN).

1.4.3 Details of damage to railway infrastructure

The NNRA had to replace approx. 150 metres of track (300 metres of 49 kg/m rails), approx. 350 fastclip sleepers, approx. 500 metres of cable ducts, several kilometres of signal cables and two masts for the overhead contact line. The overhead contact line and some of the cables were found to be undamaged, and could thus be reused.

1.4.4 Other damage:

The AIBN is not aware of any other damage caused by the accident.

1.5 Circumstances surrounding the incident, the persons and vehicle involved

1.5.1 Staff

There were two locomotive supervisors in the train, both of whom were in the driver's cab. They were both approved NSB Type 74 drivers. They have made unambiguous statements to the AIBN that one of them was acting as the driver of with responsibility for the operation of the train as part of extended training for the train set. The other locomotive supervisor had been checked out with extended training for the type of train in question, and was to provide technical assistance and guidance to the driver in the event of a technical fault. See also Section 2.3.3 for information about the NSB organisation.

Table 2: NSB AS's personnel on board the train

NSB AS's personnel on board the train	
Driver	Trained as a train driver, but usually works as a locomotive supervisor. Is 36 years old and has 11 years' experience. This journey was his fourth in the NSB Type 74 train, and was part of a programme of extended training to enable him to provide user support at DROPS.
Locomotive supervisor	Trained as a train driver, but usually works as a locomotive supervisor, is 56 years old and has 39 years' experience. The locomotive supervisor participated in the on-track testing of both type 71 and type 73 trains (the Airport Express Train and Signatur) when these train types were phased in. He joined the NSB Type 74 project at the turn of the year 2011/2012, and has a technical support function relating to the vehicles. He was trained in the use of the train in summer 2011, and then drove daily test runs with this train type.
Train inspector	The train inspector is 33 years old and has 9 years' experience. The train inspector is a senior conductor and acts as instructor for the procurement project at NSB AS's competence centre. He has been affiliated with the procurement project for NSB Type 74 for about a year, and has taken part in approx. 10 test runs. He had also spent a lot of time on board the train sets to familiarise himself with them.

1.5.2 Other personnel involved

In addition to NSB AS's personnel, there were two other persons on board. One was an electromechanic from Stadler Bussnang AG's Polish branch, who was participating in order to observe the train's technical systems and assist in the event of any faults that may arise during the testing of new trains. He was also to log any error messages, log the number of kilometres driven and contact Stadler if any problems arose, in addition to re-starting the train if necessary.

The other person represented the Finnish company Mitron, which is a sub-contractor to Stadler Bussnang AG and supplied the passenger information system (PIS), among other things. His job on this journey was to test the PIS system.

1.5.3 Vehicle involved

The train was an NSB Type 74 train that was being handed over to NSB AS by the Swiss manufacturer Stadler Bussnang AG (see Section 2.3.4). The circumstances surrounding the delivery and the project organisation at NSB AS are described in Section 2.3.3.

Figure 8: NSB Type 74 (source: Stadler).

The derailed train set was a five-carriage train set, no 74.105-74.505. The train set was driven from BMb 74 505. The total weight of an empty NSB Type 74 is 218 tonnes, and its overall length is 105.5 metres. NSB Type 74 has 264 ordinary seats and 24 tip-up seats. This train type has three power bogies, one trailer bogie and three Jacobs bogies (Figure 9).

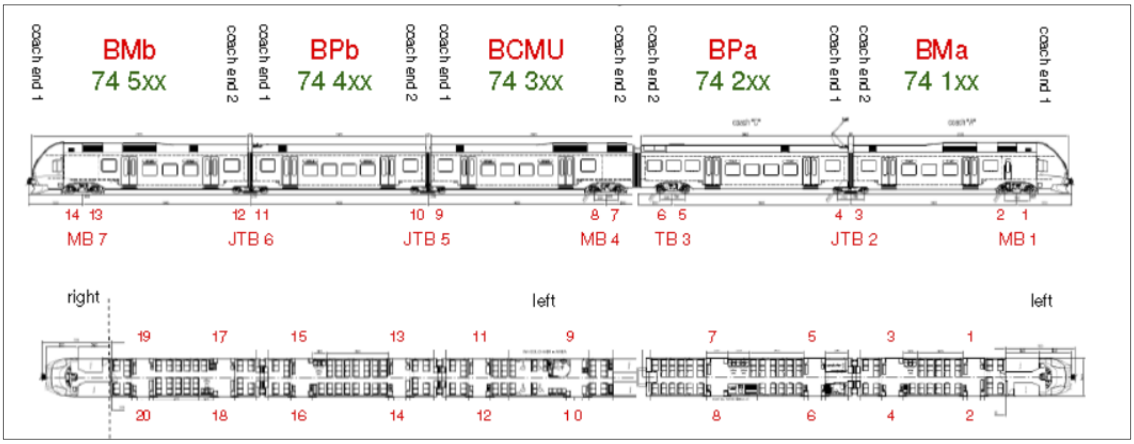


Figure 9: Schematic drawing of Type 74 (source: NSB AS).

1.5.4 Railway infrastructure

The NNRA manages the Norwegian railway infrastructure, which includes tracks, platforms, bridges, tunnels, level crossings etc. The abbreviated term 'infrastructure' is used in many contexts. The Vestfold line is electrified, and runs between Drammen and Skien. It is a mix of single-track and double-track sections, and the derailment site is at a single-track section. At the derailment site, Nykirke, which is a relatively new, straight section of tracks, is connected to the original tracks, which have far more curves.

The Vestfold line has a double-track section from the 60.98 km kilometre point, Kobbervik station, to the 76.75 km kilometre point, Holm station, and the maximum permitted speed is 200 km/h. The rest of the line is single-track with 130 km/h as the maximum permitted speed. At the derailment site, the maximum permitted speed for northbound trains changes from 130 km/h to 70 km/h.

The rail weight at the derailment site is 49 kg/m on fastclip concrete sleepers in crushed stone ballast. The derailment site is in a 250-metre curve with a maximum cant of 141 mm. There is a downward gradient towards the derailment site in the northbound direction of 10‰.

1.5.5 Traffic control and signalling system

The Vestfold line is a remotely controlled section controlled by Drammen traffic control centre. Nykirke station has a type NSI-63 interlocking system with PLC (SattCon 200 provided by ABB). The ATC equipment at the station/section of track is Partial Automatic Train Control (PATC). The interlocking system was built for simultaneous entry pursuant to the NNRA's technical regulations *JD550, Chapter 6, Section 2.2.1, alternative III*. See Section 2.9 for a more detailed description.

Traffic control and the signalling system functioned normally. No indications were found to suggest that defects in the infrastructure contributed to the incident.

1.5.6 Communication systems

The communication between traffic control and the train personnel regarding the train's operation was by train radio via the GSM-R system. A private mobile phone and the train inspector's hand-held train radio (OPH) were used to give notification of the accident. See further details in the sections about notification (1.3.1 and 2.11), and the description of the operational conditions in Section 2.4.

1.5.7 Work in progress on or near the track

No work was being carried out on or near the track that could have had a bearing on the incident.

1.5.8 Weather conditions

The morning of 15 February was sunny, with a temperature of -1 °C and no wind. Video recorded from the camera at the front of the train shows that the visibility in relation to signals and signs was excellent. Neither weather conditions nor the driver's report indicate slippery tracks that could cause poor braking conditions.

2. INVESTIGATIONS CARRIED OUT

2.1 Investigations – methods and scope

The AIBN's investigation is based on factual information about relevant circumstances gathered from known sources. Sources of information include interviews with the personnel involved and inspections of the scene of the accident. The AIBN has interviewed external personnel who were present at the accident, the project management for NSB AS's procurement project and the person responsible for training for the train set in question. The NSB traffic safety entity, the train manufacturer Stadler Bussnang AG and the NNRA have also provided factual information for use in the investigation.

In addition, the following investigations were carried out:

- Technical examination of the site of the accident (see Section 2.2)
- Assessment of compliance with laws and regulations (see Section 2.7)
- The safety and emergency response systems of the parties involved (see Section 2.8)
- The infrastructure's condition and function (see Section 2.9)
- Inspection of the section of line using an NSB Type 74 train (see Section 2.9)
- The train set's bogies were examined after the accident (see Section 2.10.1)
- The roll-over speed in relation to the train's centre of gravity (see Section 2.10.2)
- Teloc examination (see Section 2.10.3)
- Front camera examination (see Section 2.10.3)
- Notification, fire and rescue services (see Section 2.11)
- Survival aspects (see Section 2.12)

2.2 Technical examinations at the site of the accident

When the AIBN representatives arrived on site, they immediately started work to map and document the scene of the accident (see Figure 10). The positions of the carriages and parts that had come off on impact are described in Figure 11.

Figure 10: The scene of the accident (photo: the police).

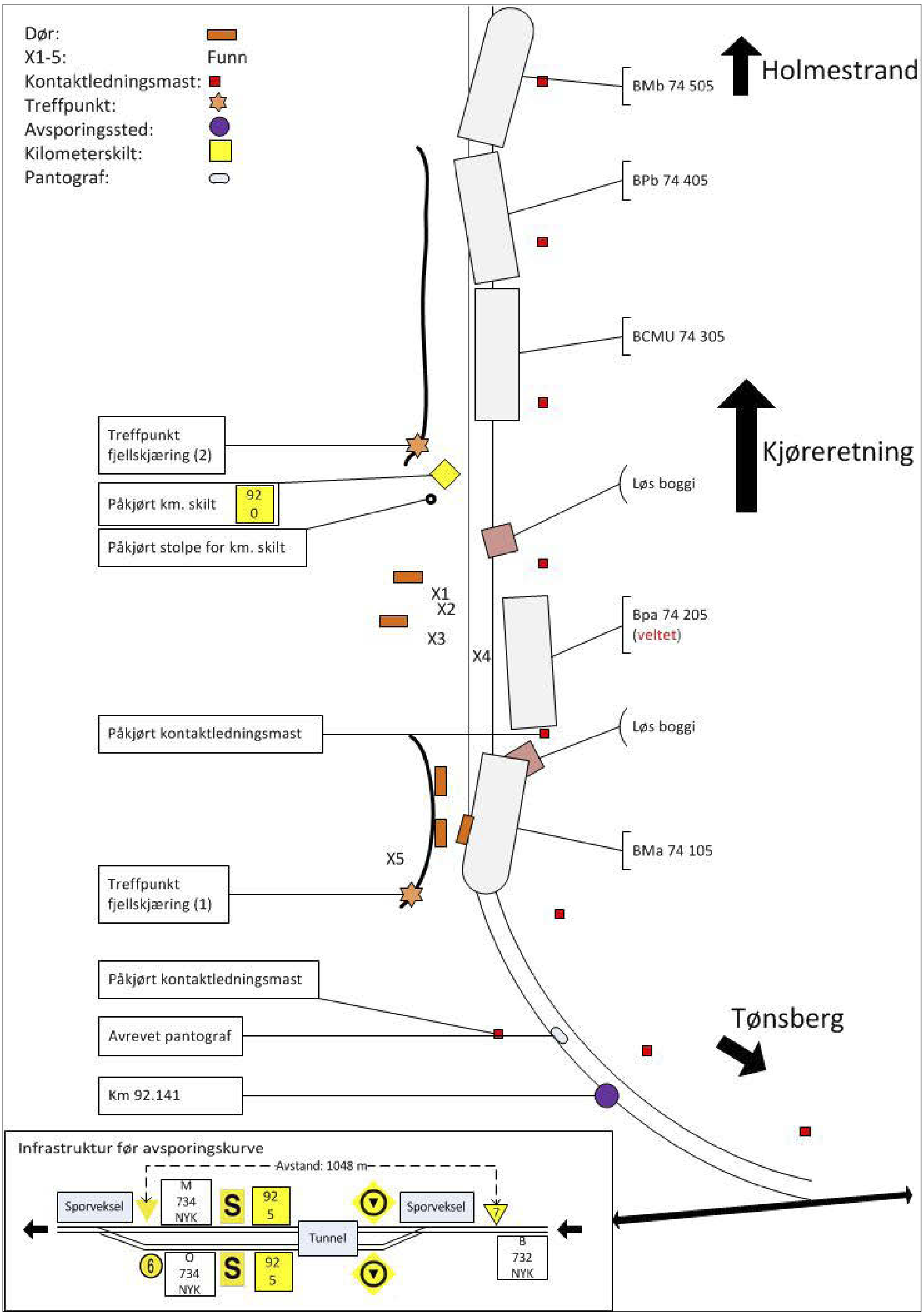


Figure 11: Diagram of the scene of the accident.

After a derailment, there will normally be marks known as climb marks on the rails where the wheel climbed up onto the rail head. At the site of this accident, the marks were minimal, and were only found on the left rail in the direction of travel (Figure 12). Even at an early stage of the investigation, this indicated that the speed of the train had been so high that the weight of the wheels on the rail was minimal. The fact that marks were only found on the left rail suggested that the train had lost contact with the right rail and was in the process of rolling over.

Figure 12: Derailment marks only on the left rail (photo: the AIBN).

The tracks were measured by the NNRA on 15 February 2012 in the presence of the AIBN, but no defects were found. Measurements were carried out to check for faults in the cant and warp on a two-metre basis between the 92.215 and the 92.131 kilometre points. The measurement was carried out on tracks not under load.

2.3 Parties involved

This section describes the parties involved in the procurement of the new NSB Type 74 trains.

Figure 13: Parties involved in the procurement process.

2.3.1 <u>The Norwegian Railway Authority</u>

The Norwegian Railway Authority (NRA) reports directly to the Ministry of Transport and Communications, and is the supervisory authority for railway activities, including tramways and underground railway systems, in Norway. The role of the NRA is to actively promote safe and expedient railways in line with the overall transport policy objectives. The NRA is also responsible for drawing up regulations, approving rolling stock and infrastructure for use and awarding safety authorisation, licences and safety certificates.

In connection with the NSB Type 74 procurement process, the NRA has processed NSB AS's applications relating to use of the vehicle listed in Table 3.

Table 3: The application process for NSB Type 74 (source: the NRA)

The application process
21 Sept. 2010 – NSB AS applied for permission to use type 74 multiple unit for transport and on-track testing.
21 Feb. 2011 – The NRA granted such permission for a type 74 multiple unit.
11 Mar. 2011 – The NRA granted permission to start using the type 74 multiple units with European Vehicle Number (EVN) according to the enclosed list for transport and on-track testing. The permit was valid until 31 March 2012 or until the NRA replaced it with a new one.
18 May 2011 – The NRA granted permission to start using the type 74 multiple units for on-track testing at speeds up to 210 km/h.
16 June 2011 – NSB AS applied to start using the type 74 multiple units for on-track testing at speeds up to 220 km/h.
5 Aug. 2011 – The NRA granted permission to start using the type 74 multiple units with European Vehicle Number (EVN) according to the enclosed list for on-track testing at the Gardermoen line at speeds of up to 220 km/h (200 km/h with 10% additional speed) provided that the on-track testing was not carried out in mixed traffic. The permit was valid until 31 March 2012 or until the NRA replaced it with a new one.
12 Dec. 2011 – NSB AS applied for permission to start using the type 74 multiple units for on-track testing on the Vestfold line between Kobbervik and Holm at speeds up to 220 km/h.
13 Mar. 2012 – The NRA granted permission to start using the type 74 multiple units with European Vehicle Number (EVN) according to the enclosed list for on-track testing on the Vestfold line between Kobbervik and Holm. The permit was valid until 31 March 2012 or until the NRA replaced it with a new one.
21 Mar. 2012 – The NRA granted permission to start using the type 74 multiple units (short regional train) with European Vehicle Number (EVN) according to the enclosed list for transport and on-track testing. The permit was valid until 30 May 2012 or until the NRA replaced it with a new one.
23 Apr. 2012 – The NRA granted permission to start using the type 74 multiple units (short regional train) with European vehicle number (EVN) according to the enclosed list. The permit was valid until 31 October 2012 or until the NRA replaced it with a new one.
19 Oct. 2012 – The NRA granted permission to start using the type 74 multiple units (short regional train) with European Vehicle Number (EVN) according to the enclosed list of 12 October 2012. The permit was valid until 31/03/2013 or until the NRA replaced it with a new one.

At the time of the derailment, the procurement project was in its final stage, and, as a result of the delay, the NRA extended the test period to 30 May 2012. NSB Type 74 was introduced into ordinary scheduled service on 2 May 2012.

2.3.2 The Norwegian National Rail Administration

The Norwegian National Rail Administration (NNRA) is a government administrative agency responsible for railway infrastructure, including systems and equipment, infrastructure operation and traffic control. The NNRA reports directly to the Ministry of Transport and Communications.

The NNRA has system responsibility for civil protection and emergency response relating to the Norwegian railway network, and coordinates this work with the railway companies. The NNRA is responsible for traffic control on the public railway network and regulates access to the tracks by means of access contracts with the individual railway companies.

Before a new type of train can be introduced on the national railway network, it must meet many requirements that are in place to ensure that the new vehicle is compatible with existing vehicles and infrastructure. The NNRA's technical regulations JD590 (Appendix 1.a, Norwegian) describes the conditions considered by the NNRA in its compatibility report. The purpose of this report is to evaluate the technical compatibility between the train type in question and the NNRA's technical installations in order to ensure that the infrastructure functions as intended and its operating economy remains satisfactory. The compatibility declaration is based on evaluations of:

- Description of use / general specifications
- Tracks and profile (except pantographs) – compatibility and functionality
- Power supply – compatibility and functionality
- Signalling and interlocking systems – compatibility and satisfactory functionality
- Telecommunications installations – compatibility and satisfactory functionality
- Handling of non-conformities. Suitability for rescue / extraordinary situations.
- Compatibility with preconditions for traffic control and the capacity of sections of track
- Environmental protection / other forms of impact on the surrounding environment

The risk of rolling over is not specifically considered during the track and profile assessments.

During the various phases of the project, the NNRA has issued several temporary compatibility declarations:

- 7 Mar. 2011 – The NNRA issued a temporary compatibility declaration for on-track testing.
- 11 May 2011 – The NNRA issued a temporary compatibility declaration for on-track testing.
- 22 July 2011 – The NNRA issued a temporary compatibility declaration for on-track testing.

On 12 December 2011, NSB AS submitted an application to the NNRA for a compatibility declaration for on-track testing. On this basis, on 4 January 2012 the NNRA granted a temporary compatibility declaration for NSB Type 74 for on-track testing on the Skoger and Sande sections. The declaration was based on an assessment of adequate compliance with the technical conditions relating to the vehicles in the section analyses for the sections where traffic is permitted, and compliance with the speed limitations stipulated. Furthermore, the declaration covered several sections, including Drammen–Larvik–Nordagutu. However, the temporary compatibility declarations required the test runs to take place in accordance with the test schedule and with the specifications and requirements set out in JD590.

2.3.3 Norwegian State Railways (NSB)

The NSB's Passenger Train Division consists of NSB AS and its subsidiaries NSB Gjøvikbanen AS and AB Svenska Tågkompaniet. Its head office is in Oslo.

NSB AS established a project organisation that invited manufacturers to participate in the tendering process for new trains. The process started in August 2007, and a contract was signed with Stadler Bussnang AG in September 2008. The final decision regarding the design of the train sets was made in December 2009, and NSB Type 74 was scheduled to be introduced on 29 March 2012.

The AIBN has been informed that NSB AS has had a stable project staff throughout the project, and that the technical departments, employee organisations and the company health service has participated in the project to ensure that employees had the best possible working conditions.

The resources assigned to the project by NSB AS have been phased in and out as required in accordance with its progress. Nevertheless, it is NSB's respective business units that are responsible for the driver resources.

NSB carried out a reorganisation with effect from June 2011 for the purpose of establishing two business units (business unit East and business unit National). The operating licence was transferred to NSB AS from what was NSB Region East. In this reorganisation, all responsibility for the locomotive staff was moved to the locomotive supervisors for each section. This also resulted in some responsibility being moved from DROPS (under NSB Traffic) to the locomotive supervisor (under NSB East and NSB National).

NSB AS's traffic safety entity have informed the AIBN that this reorganisation has not been fully implemented in the operational parts of the organisation, and that the testing of and training for NSB Type 74 has taken place in accordance with the old organisation model. The same applies to the extended training completed by the locomotive supervisors at DROPS. The consequences of this are discussed in the analysis part of the report.

2.3.4 Stadler Bussnang AG

Stadler Bussnang AG (http://www.stadlerrail.com/) manufactures NSB Type 74, which the manufacturer calls FLIRT (Fast Light Innovative Regional Train). The company is based in Switzerland, where the train production is located in Bussnang. According to Stadler, the first vehicle of the FLIRT type was delivered in 2004, and as of January 2012 approximately 600 FLIRT sets had been delivered or ordered. Versions of the FLIRT train are supplied to France, Switzerland, Hungary, Germany, Poland, Italy, Austria, France and Algeria, among other countries, but considerable adaptation and modification has been necessary to ensure that the version to be used in Norway will meet Norwegian needs. Throughout the project, Stadler has had a permanent project organisation in Norway that has followed up the delivery to NSB AS.

At the time of the accident, Stadler was the owner of the train undergoing on-track testing, and therefore had a representative on board. There was also a representative of Stadler's sub-contractor for the passenger information system, Mitron.

2.4 Documentation of operational conditions

This section covers the conditions in the operational situation relating to the running of the train on its test journey.

2.4.1 Pre-trip inspection of vehicle

On the day of the accident, the locomotive supervisor from the project carried out the agreed pre-trip inspection of the train at Sundland in Drammen. For this trip, the driver was to come to Drammen station, where he received orders concerning the route the train was to drive. The route was allocated in route order TD - 747, which covered the period from 13 to 17 February 2012.

The driver had been ordered to undergo extended training in order to be able to provide technical support for the vehicle in his capacity as a locomotive supervisor, and driving the test trip on this day was part of this training programme. The locomotive supervisor had already completed this training, and was present to provide technical assistance if the need arose.

When a vehicle is taken out, the maximum permitted speed is set in the train's ATC unit, depending on the route to be driven. ATC handbook JD 347 states that when a train is to drive a stretch of tracks with varying speed classifications, the ATC shall be set to the maximum permitted speed on the route as a whole. For the journey from Larvik to Drammen, this is 200 km/h, although long sections of the track have a lower speed classification. For journeys that cover sections of track with different speed classifications, it is deemed inexpedient to have to enter new information in the ATC system several times.

The purpose of this setting is that ATC would initially trigger a warning light and an audible warning that the speed was exceeding the maximum speed set by 5 km/h. Nykirke station is located on the part of this section of track where the maximum permitted speed is 130 km/h. In this case, the ATC would have detected the excessive speed because the balises at Nykirke station were encoded at 130 km/h, and a warning would be given at 135 km/h. According to the NNRA, this is not the norm, since the balises would normally be encoded with a speed of significantly more than 200 km/h.

2.4.2 Knowledge of the line

Both the locomotive supervisors had approved knowledge of the Vestfold line. The driver has stated that he had driven the route several times before and deemed himself to be sufficiently familiar with it. It had been a while since he had last driven this route. The locomotive supervisor had driven daily test runs with NSB Type 74, including on the section in question, since summer 2011.

2.4.3 Organisation of testing and driver training on the journey in question

The operating responsibility was clearly defined between the two locomotive supervisors before the service began, and the driver held the authorisations necessary to drive the train. The test run was carried out in accordance with the procurement project's ordinary procedures for this kind of driving. According to NSB AS's traffic safety entity, however, this was not in accordance with the company's new organisation, nor in accordance with the applicable duty plan that defined their roles for the day. Nor was the driver role sufficiently documented and clarified with the shift supervisor at DROPS, according to NSB AS's traffic safety entity.

The plan for the day was burn-in testing. The passenger information system (PIS) was being tested at the same time for reasons of efficiency, but this was not documented in writing. The PIS tests were to be carried out by stopping as normal for intercity trains on the way to Larvik, and checking that the announcements and information screens gave the correct information. The system did not function on this journey, and when the section from Larvik to Skien was closed due to infrastructure work, the train turned round in Larvik and returned to Drammen. After the incident, both the driver and the locomotive supervisor described the journey as a quiet one without distracting elements.

The locomotive supervisor was sitting on the extra seat in the driver's cab when the accident happened. The infrastructure and speedometer are not visible from that seat in the driver's cab. The location of the locomotive supervisor is compatible with the fact that he was not responsible for operating the train, and therefore did not have to monitor operations.

On the return journey, the locomotive supervisor was called up once on his hand-held train radio (OPH) (according to the locomotive supervisor, it was in silent mode the whole time) by the project, asking whether they could perform a function test of the passenger emergency brake. It was necessary to verify the actual function in relation to the functional specifications. They carried out three emergency brake tests between Larvik and Stokke, approximately 30 minutes before the derailment (see the time line in Appendix C). The locomotive supervisor called the project back to inform them about the result of the test. Two of the calls between the train and the traffic control were carried out by the locomotive supervisor using the train radio in the train set. This included a call to clarify the expected duration of the journey from Stokke to Tønsberg, and whether they would have time to get back without delaying trains in ordinary scheduled service.

The train inspector perceived his own role on the train as unclear, other than for the defined testing duties. He carried out the duties defined as the responsibility of the head conductor function, and gave the driver the 'ready for departure' signal. The train inspector was also responsible for the technical personnel from Stadler and Mitron who were on the train. The train inspector sent an e-mail to the shift supervisor at DROPS after departure from Drammen, listing the external personnel on the train. He also checked that no unauthorised persons entered the train when it stopped at stations and the exit doors were unlocked. The train inspector was going to help with the PIS testing, but since the system did not function on this journey, he spent his time testing other functions, including the emergency phones in the passenger compartments. He had taken part in test runs before, and knew that Stadler was responsible for the rest of the testing and had their own test programmes. Any defects discovered by the personnel were reported to a contact point in the procurement project, in addition to being reported to the shift supervisor at DROPS, who entered the defects in an error message database.

It is possible to connect to the train's computer system from the conductor's cabin in carriage 4 and access much of the same information that is displayed to the driver. Stadler's representative therefore observed the train's functions from that cabin without being a distraction in the driver's cab. According to the Stadler representative, the journey was completely normal. He was also in contact with Mitron's representative, who came in several times to check the status of the PIS.

2.5 People – Technology – Organisation

This section deals with the interaction between people, technology and organisation.

2.5.1 Personnel working hours and shifts

Before the incident, the personnel were on normal service in accordance with the applicable regulations.

Table 4: The personnel's service (source: NSB AS).

Personnel	Date: 13 Feb. 2012	Date: 14 Feb. 2012	Date: 15 Feb. 2012
Driver	Shift 08:00 – 15:30	Shift 08:00 – 15:30	Shift 06:55 – 15:00
Locomotive supervisor	Shift 06:31 – 14:55	Shift 06:12 – 13:57	Shift 06:55 – 15:00
Train inspector	Shift 07:30 – 16:30	Shift 07:30 – 16:30	Shift 07:30 – 15:00

2.5.2 Medical and personal circumstances

The personnel involved in safety-related service had undergone medical examinations at the prescribed times. There were no dispensations or provisos of any kind. No other circumstances with a bearing on the incident were identified.

However, there are circumstances relating to the fact that this was a training run in order to gain experience to be able to guide other drivers, and that there was a more experienced locomotive supervisor present in the driver's cab. This is discussed further in the analysis section of the report, see section 3.3.

2.5.3 The design of the workplace and work equipment

NSB AS has been involved in the design of the driver's cab from the start of the project, and it is therefore deemed to represent best practice. Among other things, controls, switches and instruments are positioned and colour-coded on the basis of what are deemed to be the best ergonomic and functional solutions. Stadler states that the solutions chosen as a result of this participation mostly correspond to the standards used by the manufacturer.

The extra seat in the driver's cab is positioned so that people sitting there can neither see the instruments in the driver's panel nor signals or signs along the track (see Figure 27). This means that in a training situation, the instructor will be standing next to the pupil. In this case, the extra seat was used for the exchange of experience between the driver and locomotive supervisor.

The possibility has been considered that the driver was receiving an unnecessarily large amount of information from the error information system in the driver's cab during the journey. The investigation has shown that there were no special distractions from the information system during the journey in question.

In cooperation with NSB AS, the AIBN carried out an inspection of the section of track using the same type of train on 6 June 2012. The purpose of the inspection was to experience the driving properties of the train and evaluate the driver's workplace and the visibility of relevant signals. Photos from this inspection are shown for example in Section 2.9.2, and also in Section 2.12 on survival aspects.

The investigation has left the AIBN with the impression that the drivers consider NSB Type 74 to be a train type with very good running properties and excellent acceleration. The driver's cab is described as comfortable, and the train set runs quietly.

2.6 Interviews with the personnel involved and witnesses

In connection with the accident, the AIBN has interviewed a number of persons, both those directly involved and others. The information is not reproduced directly, but has been used to shed light on lines of enquiry and describe the chain of events.

In interviews with the AIBN, those involved in the accident describe a situation that arose without warning and which they had previously considered unthinkable with this new type of train. Several state that the robustness of the new type of train may in fact have made a difference to the survival rate. The considerable reduction in speed is also mentioned as a factor of significance to the incident.

The train inspector's tasks were changed during the journey when the PIS system did not function. The project requested the personnel to carry out emergency brake testing. Three such tests were carried out on the return journey from Larvik. The two representatives of the train supplier and the information system supplier had regular duties on board, but neither of them had participated in test runs as the sole representative of their enterprise before. They both stated that they were busy with computer-based contact with their own servers during the journey, and only sporadically had any contact with or cooperated with the others on board.

During the notification and rescue phase, the situation of the people on board differed as regards the extent of injuries. The rest of the persons on board the train emphasise that the train inspector's behaviour was significant. He took on the role of incident commander until the rescue services arrived at the scene of the accident. Among other things, he obtained an overview of the other persons on board the train, found first aid equipment and administered first aid to those who needed it.

Describing the location proved to be a challenge during notification, and ideas have emerged that direct notification of the emergency services in order to save time should be a possibility.

2.7 Compliance with applicable laws and regulations

One element of a safety investigation is to check whether the involved parties' activities deviate from the applicable laws and regulations, and, if so, what the reason is for their failure to comply.

2.7.1 Licences, safety certificates and safety authorisation

The overriding regulations for railway operation are laid down in the Norwegian Railways Act (Act of 11 June 1993 No 100) with pertaining statutes and regulations. The following refers to sections that are relevant to this accident:

Whoever intends to operate infrastructure or rail transport services are subject to the *Regulations on railway operations on the national railway network* (Regulations of 10 Dec. 2012 No 1568, the Railway Regulations). Infrastructure managers shall hold safety authorisations, and railway undertakings shall hold licences and safety certificates.

Both the NNRA and NSB AS have the necessary permits.

The Regulations on the obligation to notify and report railway accidents and railway incidents (Regulations of 31 March 2006 No 379, the Notification and Reporting Regulations) specify for railway accidents that:

'Personnel in a railway operation who are involved in a railway accident shall promptly notify the nearest rail traffic control unit, the nearest police authority or the nearest joint rescue coordination centre of the accident. The recipient of notification shall immediately notify the other authorities mentioned in the first sentence as well as the investigating authority.

Notification shall be verbal. '

The NNRA has incorporated these regulations into its safety management system, among other things by preparing special instructions for the notification of accidents, incidents, threats, sabotage and suspicious objects (STY601061). See Section 2.8.2.3 for more information.

2.8 Safety and emergency response systems

2.8.1 Requirements for safety management

Section 2 of the Regulations on safety management for railway undertakings on the national railway network (Regulations of 11 March 2011 No 389, the Safety Management Regulations) set out the overall requirements for safety management:

Section 2-1. Overall responsibility for safety

'The railway undertakings are responsible for safe operations on their part of the railway system and for controlling risks where they arise in the railway system. The railway undertaking has a duty to implement necessary risk management and, where relevant, cooperate with other undertakings in the railway system.'

Section 2-3. The single fault principle and barriers

'Operations must be planned, organised and implemented with a view to ensuring that no single fault can lead to a railway accident.

The railway enterprise shall have barriers in place that reduce the probability of faults, hazards and accident situations developing. The barriers must be identified, and the established barriers and their functions must be known throughout the undertaking. If several barriers are required, they must be sufficiently independent of each other.'

2.8.2 The Norwegian National Rail Administration – responsible for infrastructure

2.8.2.1 *Analyses of sections of track*

According to the NNRA's safety manual on safety management in the NNRA, the analysis of a section of track provides an overview of risk for the section in question. The historical analyses were carried out in the period between 1999 and 2001, and document that each section is within an acceptable risk range – that is, in the ALARP area (As Low As Reasonably Practicable).

The electronic analyses of sections provide an overview of risk for the national railway network. The analyses of sections are based on models, analyses by skilled personnel with local knowledge and historical data. The analyses of sections are linked to other computer systems such as Synergi and BaneData, and retrieve information from these systems on a daily basis. The section analyses also cover other parties' activities. The analyses are available from the NNRA's intranet, BaneNettet. Other types of risk analyses are available in the risk analysis archive and in project-specific archives in ProArc.

The NNRA has stated that the risk of derailment as a result of changes to the centre of gravity of rolling stock is not identified by the analysis of sections, since this type of analysis is not intended as a replacement for the traditional risk assessment required when changes are made. The centre of gravity used as a basis for previous stability calculations is 20–30 centimetres lower than in today's vehicles (1.4 metres compared with 1.6–1.7 metres today). Nor has there been a focus on great reductions in speed and the risk this entails for vehicles capable of running at high speeds.

2.8.2.2 *Qualification requirements for the NNRA's traffic controllers*

According to the NNRA, a traffic controller must be a trained local traffic controller, have completed the traffic control course and have taken the written traffic controller examination. When a traffic controller takes up his/her position, he/she is trained in the use of the respective remote control systems which he/she will operate, and must then take a practical test in these systems. Traffic controllers must sit an exam on the safety provisions every three years. They must pass this exam to have their approval renewed.

2.8.2.3 *The NNRA's notification instructions*

In an accident situation, it is the traffic controllers' responsibility to notify the emergency services of the accident. The NNRA's instructions for the notification of accidents, incidents, threats, sabotage and suspicious objects (STY601061), together with a support document in the form of a notification template specific to each traffic control centre, state what services to notify.

Initially, the instructions specify that notification of railway accidents shall be done in accordance with the Notification and Reporting Regulations (Regulations of 31 March 2006 No 379):

> - *Contact the nearest traffic control centre.*
> - *If you are unable to contact the traffic control centre or do not have the number, call the police emergency phone number 112 or the Joint Rescue Coordination Centre for South Norway 51 51 70 00 of North Norway 75 55 90 00.*

Later in the instructions, the notification responsibilities and activities are described as follows:

> ***Notification***
> *Initiate notification in accordance with the traffic controller' notification list. Notification shall take priority over ordinary traffic control.*
>
> *The traffic controller shall notify the rescue services and delegate further notification to the traffic control centre's person on emergency response duty.*
>
> *It is specified that only the emergency phone numbers 110, 112 and 113 should be used (i.e. no local numbers for the emergency services).*

It is unclear whether the order in which the emergency services are listed is in order of priority for notification or whether the order is random.

In the notification template prepared specially for each traffic control centre, notification is described for each of the NNRA's main incident categories (fire, collision between trains, persons on the tracks etc.). It reads as follows, without specifying whether one emergency service should be notified before another:

- *For isolated sections of track and sections where access is difficult, the Joint Rescue Coordination Centre shall be notified.*
- *Only the emergency phone numbers 110, 112 and 113 shall be used for notification.*

In addition, the template contains a table listing which parties *must* be notified for each main incident category, and which services one should *consider* notifying in addition to this:

Jernbaneverket

Mal for varslingsliste for xxx toglederområde

Hendelse/ sted:

Hendelsen er meldt av: | Dato: | Kl: | Varslet etter TH /H nr:

VURDERING AV MOTTATT MELDING OM JERNBANEULYKKE OG/ ELLER ALVORLIG JERNBANEHENDELSE

- *Det skal tas høyde for "Verst mulig hendelse" og varsles i henhold til dette.*
- Dersom en topphendelse eller hendelse meldes inn og situasjonen er avklart og under kontroll og det ikke er personskade, kan omfang av varsling vurderes.
- *På uoversiktlige strekninger og strekninger med vanskelig framkommelighet skal Hovedredningssentralen varsles.*
- *Kun nødnr.110, 112 og 113 skal brukes ved varsling.*

Hovedredningssentralen Sør-Norge Alarm 51 51 70 00
Hovedredningssentralen Nord-Norge Alarm 75 55 90 00

Togleder varsler:	Telefon-nummer	Varslet klokken	TH 1: SAMMENSTØT TOG-TOG TH 2: SAMMENSTØT TOG-OBJEKT TH 3: BRANN	TH 4: PASSASJER SKADET PÅ PLATTFORM TH 5: PERSONER SKADET VED PLO TH 6: PERSONER SKADET I OG VED SPOR	TH 7: AVSPORING H 8: Skifteuhell	H 9: Tog savnet (etter 20 min. uten kontakt)	H 10: Ikke planlagt togstopp og hvor evakuering kan bli et resultat. • Tog stoppet pga nedfall av kontaktledning. • Etter 15 min. skal det rekvireres trekk kraft, og umiddelbart i tunneler over 500m.	H 11: Akutt forurensning.	H 12: Trussel over telefon, Mistenkelig gjenstand/ person(er)
			TH = Topphendelse, H = Hendelse. ☎ = Skal varsles, · = Skal vurderes						
Brann	110		☎	·	·	☎		☎	
Politi	112		☎	☎	·	☎	·	·	☎
Ambulanse AMK	113		☎	☎	·	☎			

Figure 14: Excerpt from the template used by the traffic control centres (source: the NNRA).

The table shows that for a derailment (main incident category 7), it is up to the traffic controllers to assess which emergency service to notify first, based on the nature of the incident, since none of the emergency services take priority over the others.

In 2011, the NNRA sent map coordinates for the kilometre points for each full kilometre of the NNRA's network to the Directorate for Civil Protection and Emergency Planning (DSB). This was done so that the traffic controllers can use the railway kilometre points as reference points for location when notifying the emergency services, and the kilometre points will then be converted into map coordinates. As of May 2012, the DSB has reported back that all 110 emergency communication centres (both in the old and new system) have been offered the kilometre point data. However, the DSB states that it has no overview of how many centres are actually using the data, since this decision is left up to each centre. However, the NNRA has emphasised to the DSB how important it is to enter the information. It was later found that Vestviken fire service, which was the relevant 110 organisation for this accident, uses this map basis and was therefore able to pinpoint the precise site of the accident on the basis of the kilometre points, which the police were unable to do.

At the turn of the year 2011/2012, the NNRA received electronic maps that are also available to the traffic controllers. According to the NNRA, these maps are not perceived as a suitable tool in a notification situation, and they were therefore not used.

2.8.3 Norwegian State Railways (NSB AS)

2.8.3.1 *Competence requirements for the on-board personnel*

NSB AS's train crew undergo annual refresher training and in-service training in disconnecting electricity and earthing the overhead contact line system. Every other year, they undergo training and refresher courses in the company's internal procedures, in-service training and a test on the Safety Regulations, as well as a refresher course in first aid. They must pass the test on the Safety Regulations in order to have their approval and authorisation renewed.

Table 5: Competence requirements for the different roles

Role	Competence requirements
Driver	Drivers shall have completed driver training in accordance with Regulations of 7 February 2005 No 113 on requirements for the competence and authorisation of operators of traction vehicles on the national rail network (the Authorisation Regulations). A driver must have undergone type training for the relevant vehicle, have sufficient knowledge of the line, be trained in the traffic company's internal procedures and have passed an approved safety test. The driver had all the required approvals.
Locomotive supervisor	The function of a locomotive supervisor is to carry out condition assessments and provide technical user support and technical vehicle training for the different types of vehicles. A locomotive supervisor's competence shall meet the requirements for managers in the authority matrix for the NSB Passenger Train Division. This includes traffic safety relating to vehicles and operations/shunting, Synergi, competence management on an operational level and traffic safety management systems. He/she must have upper secondary education or relevant experience, and have teaching qualifications. A locomotive supervisor shall be a qualified train driver with at least three years' experience of independent work as a train driver. When the person is responsible for the operation of a train, he/she is has the function title 'driver'. The locomotive supervisor had all the required approvals.
Train inspector	The train inspector shall be a qualified senior conductor and must have completed training in the general traffic safety provisions and NSB AS's internal procedures, have training in and approval for the type of vehicle in question and have completed NSB AS's courses in all emergency procedures. The train inspector on board the train had all the required approvals.

2.8.3.2 *Type course and extended training*

The purpose of the type course is to teach drivers how to operate the vehicle in an expedient manner as regards safety, customer satisfaction, punctuality and energy efficiency. The type course for NSB Type 74 totals ten days. The course is a combination of theoretical tuition, practical training in train sets and use of a simulator and mock-up. Eight days of the course consist of theory and practical training, and two days are driving training.

The extended course for locomotive supervisors is a detailed training course about NSB Type 74, provided to locomotive supervisors at DROPS who are to perform a support function for drivers during operations. The course was held in accordance with a previous course model used in NSB AS's previous organisation model. No new course model had been prepared for NSB Type 74 after the reorganisation in June 2011.

The driver had completed the type course for NSB Type 74 and been checked out for this type of train in late November 2011. The journey on the day of the accident was training as part of the driver's extended training for the train type in question.

The locomotive supervisor had completed the type course in summer 2011, and after that drove daily test runs with this train type. He had completed the extended training for NSB Type 74 in late summer 2011.

2.8.3.3 *Requirements for drivers' knowledge of the line*

The requirements concerning knowledge of the line are described in NSB's management system. Two documents are relevant in this context, of which one describes the general requirements for knowledge of the line and the other one concerns the relevant section. At the time of the accident, the first was described in the procedure *Strekningskunnskap for togpersonalet i NSBs tog under togframføring og på stasjon* [3] *('Knowledge of the line for train crew on NSB's trains during operation and at stations' – in Norwegian only).* According to NSB AS, the purpose of this procedure is to ensure that the train crew has sufficient knowledge of the local conditions at stations and along sections of track to carry out their duties relating to traffic and customer safety. Table 6 lists the requirements for knowledge of the line that applied to the driver.

Table 6: Excerpt from the procedure concerning knowledge of the line [3]

Knowledge of the line: ***The train driver shall know:*** • *Form of operation* • *Where the main signals are located at stations and along the line* • *Station/stop: the train's location at the platform and other circumstances with a bearing on safety* • *Tunnel with special measures* • *Downward gradients that influence the braking distance* • *Use of the section book for the section in question as a reference book* ***The train driver shall be familiar with:*** • *Other signals on the section* • *Upward/downward gradients with a bearing on fuel economy* • *Other special circumstances depending on the region* ***Local knowledge:*** ***The train driver shall know:*** • *The signal structure at the station with a bearing on shunting operations at the station* • *Special dwarf signals where a stop signal involves a conflict with train route* • *Pathways for walking to and from parked rolling stock* • *Places for parking and preheating facilities (external connection)*

As a basis for reviews of the specific sections, NSB has prepared special documents that describe the local conditions. At the time of the accident, the section between Skien and

Drammen was described in *Strekningskompetanse Regiontog Skien – Drammen* [4] *('Section competence, regional trains Skien–Drammen' – in Norwegian only).* The local conditions that applied at Nykirke, and to the line between Nykirke and Holmestrand, are shown in Table 7. The great reduction in speed followed by a curve is not mentioned here, but as the AIBN understands the matter, it is not normal practice to include such information in the descriptions.

Table 7: Excerpt from the description of the section [4]

Nykirke	• *The station has simultaneous entry. (Simultaneous entry requires active ATC on both trains.)* • *Dwarf signals are part of the signalling system* • *Dwarf signals shorten the arrival train route* • *Signal 66 'train route ends' is located at the dwarf signals*
The line between Nykirke and Holmestrand	• *Risk of snow avalanches*

It is difficult to measure knowledge of the line, and it has only been tested and checked to an extremely limited extent. In practice, it has been up to the drivers, in consultation with their superior, to decide whether they had sufficient knowledge of a line. New and stricter requirements have now been introduced in the Train Driver Regulations (*Regulations of 27 November 2009 No 1414: Regulations on certification of operators of traction vehicles on the national rail network*), which came into force on 19 July 2012 (excerpts reproduced in Table 8). The new requirements are considered in section 3.2.

Table 8: Excerpt of new requirements in the Train Driver Regulations

Section 18. *Training requirements for certificates*

Drivers shall undergo training and pass an exam that shows their specific professional competence. As a minimum, the training must cover the training goals relating to rolling stock in Appendix V and infrastructure in Appendix VI. Operators of traction vehicles on sections where the infrastructure manager's working language differs from the operator's home language must meet the language requirements in Appendix VI. Furthermore, operators must receive training in the relevant parts of the enterprise's safety management system.

Training assignments and evaluation of knowledge about infrastructure, including knowledge of the line and operating regulations, shall be carried out by persons or bodies accredited or approved by the EEA state in which the infrastructure is located.

Section 19. *Periodic examinations*

Operators shall undergo periodic training and examinations relating to the requirements in sections 17 and 18.

The railway enterprises' safety management systems shall stipulate the frequency of periodic examinations to be held pursuant to the first paragraph. They shall apply to all operators associated with the enterprise. As a minimum, examinations shall be held:

a) For language skills: Every three years or after more than one year's absence.
b) For knowledge about the infrastructure: Every three years or after more than one year's absence from the relevant section.
c) For knowledge about rolling stock: Every three years.

The railway enterprise shall confirm that the operator has passed each of these examinations by entering a declaration that the operator passed on the certificate and in the register of certificates.

2.8.3.4 *Procedures for on-track testing and practice runs*

The operating licence/train operator responsibility for the on-track testing rested with NSB AS. Regular test runs with NSB Type 74 had taken place since winter 2011. It was a requirement that the driver had to be checked out for the vehicle. Drivers applied to participate in the project, and were largely selected on the basis of their experience and former participation in the testing of new vehicles.

In this phase of the project, NSB AS had no test plans for the drivers to familiarise themselves with in advance.

The procurement project decided which tests to carry out in accordance with its test programme. The driver were normally informed either via the personnel on board the train or by phone about which tests to carry out.

The incident occurred during continuous on-track testing of the new train sets that were to be handed over, and the journey was part of the burn-in process, whereby any early faults and defects in the vehicle can be discovered through normal use over a certain period of time. This was combined with a function test of the train's passenger information system (PIS). At the same time, it was providing user experience with the train for personnel who had been trained and checked out for that type of train.

After the accident, NSB AS chose to stop the on-track testing of NSB Type 74 until technical faults in the vehicle had been ruled out. On-track testing was resumed on 19 March 2012.

2.9 The condition and function of the railway infrastructure

Figure 15 shows an outline of where the infrastructure elements were located before the site of the accident.

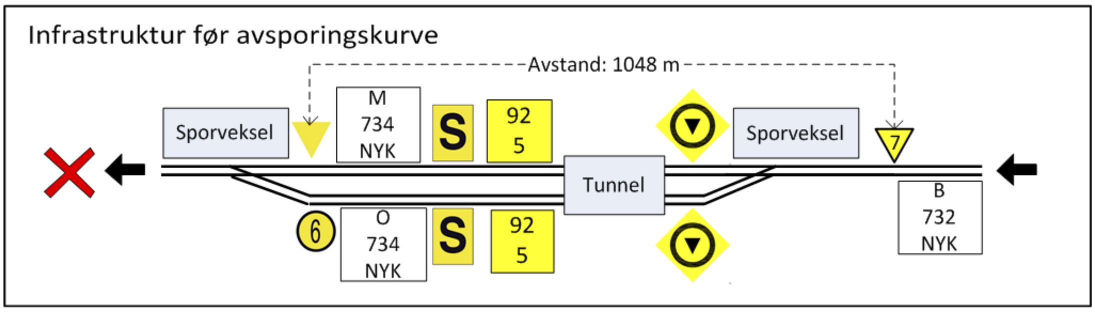


Figure 15: Outline of the infrastructure at the site.

2.9.1 PATC/FATC

Train operations are based on the line block principle. This means that traffic control shall be carried out in a manner that ensures that a train cannot enter a section (block section) or set of tracks where there is already a vehicle. This is ensured either by messages being exchanged between the local traffic controllers for the block section between manned stations, or between interlocking systems at stations, line blocks between stations and remote control.

After the Tretten accident in 1975, a decision was made to introduce a barrier to prevent collisions between trains on an open line. This work resulted in the introduction of automatic train stop (ATS) in the early 1980s. This was subsequently changed to automatic train control (ATC), which is now known as partial automatic train control (PATC). Regulations of 2005 set out a requirement for full ATC (FATC) when material modifications are made to existing infrastructure, and when new tracks are built. The difference between full and partial ATC is in the level of monitoring. PATC monitors the passing of stop signals, driving speed in stations' arrival train routes and the maximum permitted speed given by the train's composition and the speed for the route set in the train set's ATC system. FATC also provides continuous monitoring of speed. Only 10% of the Norwegian railway network is equipped with FATC. By comparison, FATC has been installed on all Swedish lines since around 1980.

Nykirke station is located between Holmestrand and Skoppum stations on the Vestfold line. The section near Nykirke station has partial ATC (PATC). The station was taken into use on 11 June 2002, i.e. before the FATC requirement entered into force. On the Vestfold line, FATC installation has only been completed on the section between Skoger and Holm. The Vestfold line is currently under modification to replace several of the sections that have many curves with a new and better track alignment. The section between Holm and Nykirke, which will replace the curve at the accident site and connect to Nykirke passing loop, is scheduled for completion in 2015.

Neither the drivers nor the NNRA want so-called 'islands' of FATC where a line switches frequently between PATC and FATC. That 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. When new tracks are built for speeds of over 130 km/h, on the other hand, they are equipped with FATC. The NNRA has prepared a priority plan for existing PATC sections, detailing which of them should be equipped with FATC, in addition to the new tracks built. The Vestfold line at Nykirke is number 17 of a total of approximately 30 sections on this list, since, according to the development plan, new double tracks will be built. Whether PATC sections will be supplemented depends on the NNRA's assessment of the safety benefits for each section, since new double tracks are to be built within a reasonable period of time (cf. the plan for the Vestfold line).

ERTMS stands for European Rail Traffic Management System, and is a system that facilitates European railway interoperability. The Government has decided that ERTMS will be introduced in Norway [2], and the system consists of two parts: GSM-R (already established in Norway) and ETCS - European Train Control System (not established in Norway). Among other things, ERTMS will involve continuous speed monitoring, and brakes will be activated automatically if necessary. The present plans are for the installation of ERTMS to start in 2015 on a test section, which will be the Eastern line on the Østfold line. The NNRA will use this line to gather experience before deciding which other lines to equip with ERTMS. ERTMS equipment must be installed in all rolling stock before it can be put into operation on an ERTMS section.

As a consequence of the development and uncertainty relating to ERTMS, it is improbable that any large-scale FATC development will take place in the time ahead, since it must be ensured that new installations are compatible with ERTMS.

2.9.2 Speed signals

Changes of speed are indicated in advance by the NNRA's signal 68 A (Figure 16) or 68 B. The signals are located such that there is sufficient time for braking, and the speed indicated applies from a given point, which is marked by a marker (signal 68 D, see Figure 17). As shown by the sketch in Figure 15, the speed reduction sign was located 1,048 metres before the marker.

Figure 16: Signal 68 A 'Reduced speed' (the example shows 30 and 35 km/h) (source: the NNRA).

Figure 17: Signal 68D 'Marker' for reduction of speed (source: the NNRA).

The Regulations on the operation of trains on the national rail network (Train Operation Regulations, III signal signs etc., Section 9-42, Speed signals no 4) state that information about the speed at which a train is to depart from a station shall be given by means of speed signals on the departure train route. The primary purpose of this is to remind the driver of which speed the train should accelerate to after stopping at a station. The signal would therefore be of type 68B 'Increased speed', i.e. a yellow triangle, point up, with a black edge, showing the number 7 for 70 km/h. This signal was missing from the A end of Nykirke station where the derailment took place.

During the inspection on 6 June 2012, the section was filmed from the driver's perspective. Figure 18 and Figure 19 shows the speed signal that was overlooked and the speed reduction marker at the site.

Figure 18: The speed signal for 70 km/h (photo: the AIBN).

Figure 19: Speed reduction marker (photo: the AIBN).

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 AIBN also found that the extra seat in the driver's cab is located in such a way that the person sitting on it cannot see and keep an eye on signs along the tracks or the instruments in the driver's panel.

2.9.2.1 *Speed reduction*

At the site of the accident, the speed was reduced from 130 km/h to 70 km/h when entering a curve. According to the NNRA, corresponding reductions in speed at curves are found in approximately 30 other locations on the Norwegian railway network. Many of these locations require the vehicle to have a relatively high centre of gravity before a risk of rolling over will arise. After the incident, the NNRA has decided to assess these locations and either put up double signs or reduce the speed gradually in two steps. See Section 5.1.2 for further details about the measures introduced by the NNRA.

2.9.3 Track and substructure

The investigation has not uncovered any technical faults or defects in the track or substructure that are deemed to have had a bearing on the accident. The NNRA's track geometry car carried out line measurements of the site on 26 October 2011, and these measurements found no defects at the derailment site (see Figure 20). The area highlighted in yellow represents the requirements. No places fail to meet the requirements. The area outlined in red covers the derailment track, and goes from kilometre point 91.830 to kilometre point 92.350.

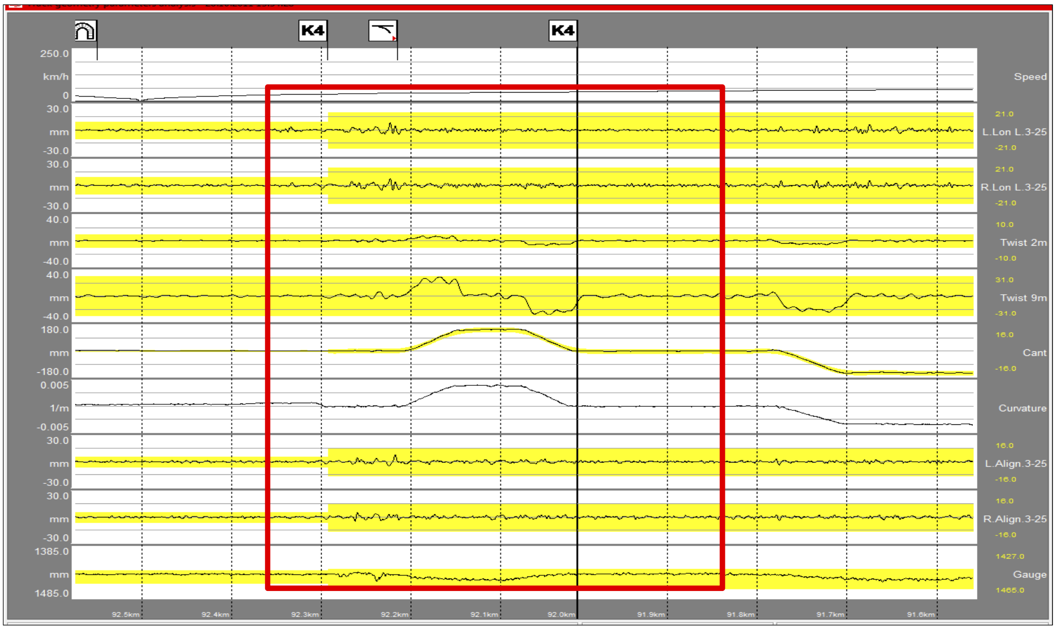


Figure 20: Rail diagram from the analysis tool used for measurements by the track geometry car (source: the NNRA).

2.9.4 Traffic control and signalling systems

The Vestfold line is controlled from Drammen traffic control centre. The remote control system is of the VICOS type, with SattCon 200 substations. SattCon 200 interfaces with the stations' interlocking systems and controls them in accordance with orders from the traffic control centre and indications to the centre. Orders and indications (see Figure 21 and Figure 22) are transferred by modem to the operations centre in Drammen. The interlocking system was put into operation on 11 June 2002, and it was built by the NNRA. The system, type NSI 63, interfaces with the relay line block systems in the direction of Skoppum and Holmestrand stations.

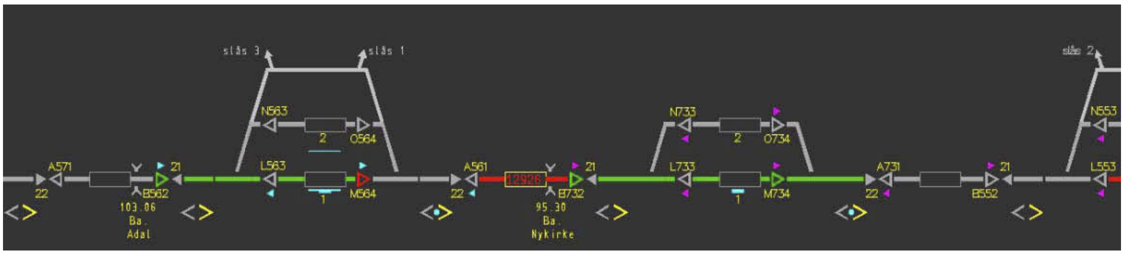


Figure 21: Shows the indication for the train (red line) just before it entered Nykirke station (source: the NNRA).

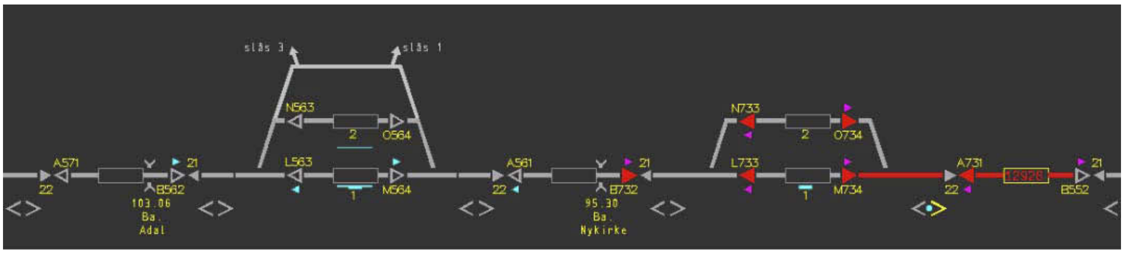


Figure 22: Shows the indication in the traffic control centre after the derailed train had cut the cables (source: the NNRA).

All generic work procedures for the station and surrounding sections had been carried out. Generic work procedures entail control and maintenance of the signalling system. They are intended to ensure that the interlocking systems are functional as regards safety and operating condition. They include the testing and control measurement of electrical and mechanical components and their replacement at stipulated intervals, as described in the NNRA's technical regulations regarding signalling systems.

A review of logs after the accident showed that both the signalling system and remote control system were functioning normally and had no bearing on the course of events. Replay of the CTC log shows many error indications and alarms for Nykirke station. Among other things, the derailment indicator was triggered because the train cut cables in the infrastructure. These cables are in a cable duct along the tracks. The error indications immediately alerted the traffic controllers of the accident.

2.9.5 Communication equipment

Communication between the driver and the traffic controllers was by train radio via the GSM-R system. This was working as intended before the accident. After the accident, the damage to the driver's cab and the rest of the train set was so extensive that the integrated GSM-R system was no longer functional. The driver did not have his hand-held train radio (OPH) with him, and therefore used his private mobile phone to give notification of the accident.

2.10 The condition and function of the vehicle

This section describes the technical examinations of the vehicle involved.

2.10.1 Technical examinations of bogies

The examination took the form of a visual inspection of the bogies after they had been moved from the accident site and placed on the floor of hall E at Sundland workshop area. The AIBN carried out the inspection of the bogies on 23 and 24 February 2012. The inspection report is reproduced in Appendix A.

Figure 23: Leading bogie (photo: the AIBN).

The inspection was carried out without dismantling components. The condition of the bogies were documented by photos, and any damage observed was recorded. A decision was made to measure the wheel profiles of the wheels in the bogie denominated MB7 (first bogie in the direction the train was travelling). A visual assessment of the wheel profiles of the other bogies during the inspections on 23 and 24 April concluded that they did not deviate significantly from the profiles of MB7.

The wheel profiles in bogie MB7 (axle positions 14 and 13) were measured by a representative of Stadler.

Individual occurrences of damage and the overall damage were both considered, with a view to determining whether the damage observed was consequential damage.

The review and assessment of the damage to the bogies did not find any faults or defects that could be assumed to have been present before the derailment. All the damage observed can be explained as a result of the train's movements after the derailment or of the dismantling and transport of the bogies from the accident site to the Sundland workshop.

There are certain limitations and uncertainties relating to the examinations. As regards the drive shafts, the transmission system and elastic couplings prevent inspection of the whole shaft. However, any initial faults in these components would cause other observable faults, and no such faults were found. For some of the observable damage, it cannot be determined with certainty whether the damage was caused by the derailment or by the subsequent dismantling of the bogies and their transport to the workshop.

2.10.2 Roll-over stability calculations

In order to examine the stability of this type of train compared with other types, roll-over stability calculations were carried out for NSB Type 74. This section describes the results of these calculations carried out by NSB AS and the tolerance limits for tracks carried out by the NNRA.

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:

- υ – 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:

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

2.10.2.1 *The NNRA's calculations of roll-over risk at the accident site*

The NNRA is responsible for verifying that new vehicles intended for use on the Norwegian railway network meet the requirements set for use of the infrastructure. Roll-over calculations are not part of this verification process.

Based on the properties of the track at the site in question, the NNRA has calculated the critical roll-over speed for vehicles with different centres of gravity (see **Feil! Fant ikke referansekilden.**). It is important to specify that these are general calculations, and are *not* based on any specific vehicle. The calculation shows the lowest centre of gravity H (in metres) that a carriage can have and still roll over in a curve with a radius of 250 metres when travelling at a given speed.

Given parameters:
- The cant h is 135 mm
- The radius R is 250 m
- The track gauge s is 500 mm.

Table 9: Roll-over speed as a function of the height of the centre of gravity in a given curve (source: the NNRA)

Roll-over speed (km/h)	Height of centre of gravity (mm)
150.8	1200
145.6	1300
141.1	1400
137.0	1500
133.3	1600
130.0	1700
126.9	1800
124.2	1900
121.6	2000
119.3	2100
117.1	2200
115.1	2300
113.2	2400
111.4	2500

Roll-over speed (km/h)	Height of centre of gravity (mm)
109.7	2600
108.2	2700
106.7	2800
105.3	2900
104.0	3000
102.8	3100
101.6	3200
100.5	3300
99.4	3400
98.4	3500
97.4	3600
96.5	3700
95.6	3800
94.8	3900

As the table shows, the NNRA has calculated that vehicles with a centre of gravity at 1,600 mm or higher will roll over when their speed exceeds 133 km/h. According to the NSB, the centre of gravity for NSB Type 74 varies between 1,555 and 1,691 mm (see Table 10).

According to the NNRA, 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 a 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.

2.10.2.2 *Calculations carried out by NSB AS*

On behalf of NSB AS, Interfleet Technology (www.interfleet.no) has calculated the situations that arise in connection with special kinds of sideways acceleration for different types of vehicles when the centrifugal forces overcome the vertical forces and enable the train to derail (see Appendix B).

The roll-over stability calculations were carried out for NSB types 5, 70, 72 and 74 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 calculations show only minor differences between the different types of vehicles.

For NSB Type 74, dynamic simulations have also been carried out in relation to track data from a sample of sections of track. Refer to Appendix B for a detailed overview of the preconditions and limitations relating to these calculations.

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 (see Table 10). 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.

Table 10: Centre of gravity heights used in calculations (source: NSB AS)

	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 report concludes that, despite a slightly higher centre of gravity, NSB Type 74 does not differ significantly from other comparable vehicles that travel on the line in question in terms of roll-over risk.

2.10.3 Recording speed sensors, video and data logs

NSB Type 74 is equipped with a Hasler Teloc data recorder, an ATC recording unit and CCTV monitoring of passenger compartments and the front of the train set. Hasler Teloc records given parameters, including speed, brakes, whistle and GPS position. Its design is robust in order to withstand accidents. The ATC recording unit logs many of the same parameters as Teloc, but records more and more detailed parameters, such as balise information and the values entered in the train's ATC system.

O. J. Dahl AS, which is Hasler Rail AG's Norwegian representative, extracted the data from the train's recording unit on 16 February. The data were handed over to the recording unit manufacturer, Hasler Rail AG, which interpreted it and produced a report that shows the time, speed and controls during train operation.

On 17 February 2012, data from the train's ATC system (Ansaldo STSS) were retrieved using WLANA software at Sundland in Drammen. SSTS is the train set's part of the ATC system, and it is this unit that reads the balises in the ATC system and monitors the train. The AIBN, the supplier Stadler Bussnang AG and a WLANA expert were present. The unit from the train that was involved in the accident was connected to another train, and data were then extracted to a computer. These data correspond to those recorded by the Hasler Teloc recording unit.

The train set's recording speed sensor showed that the train was travelling at a speed of 135 km/h when the brakes were activated. A review of the recording unit for the journey Drammen – Larvik – Nykirke shows that the train was operated in accordance with the line's normal speeds and design. The analyses show that it took approximately 11 seconds from the time the brakes were activated until the train came to a halt. The distance travelled during this time was measured at 340 metres.

NSB AS has chosen to install CCTV monitoring both inside the train and at each end of the train. This is a separate system where the recordings are stored on a hard disk for a certain period of time before they are recorded over. There is no requirement for vehicles to have CCTV monitoring in the direction of travel, but it tends to be very useful in terms of verifying the signal situation in cases of doubt, and documenting near misses and accidents where persons or objects are on or near the tracks. An uninterruptible power supply independent of the train's systems will thus be an advantage, since situations may arise where the train loses power, but the camera can continue filming. By comparison, approximately 40% of all British trains have a front camera with an uninterruptible power supply.

On 20 February 2012, the video from the train was retrieved at Sundland in Drammen, where NSB Type 74 has its maintenance base. Representatives of the AIBN, the supplier Stadler Bussnang AG and the video system supplier Mitron were present. The recordings on the recording units provided no images of the accident itself. According to Mitron, the selected setting is for data to be saved to the hard disk every five minutes. This means that any data in the buffered memory, which has not been saved on the hard disk, must be retrieved using other methods. Video from the front camera was deemed to be the most interesting, and video was retrieved by connecting the recording unit to another train. The video unit was then sent to the company Ibas AS in Kongsvinger, where the video files in the buffered memory were retrieved. It was thus possible to retrieve video from the camera in the front of the train that shows images up to approx. 300 metres before the derailment, but none of the incident itself. The most interesting aspect of recreating the journey in the form of a video recording was to verify that the visibility of speed signs and markers was not obscured. The video recording helped to establish this, regardless of the fact that the last few seconds had been lost. If the buffer interval had been shorter and the power supply uninterruptible, it would have been possible to document more of the accident, but this is not deemed to constitute a significant shortcoming in this investigation.

2.11 Notification, fire and rescue services

2.11.1 The personnel's behaviour after the accident

Immediately after the accident, the driver got up and joined the train inspector in helping the locomotive supervisor in the passenger compartment before he gave notification of the accident and secured the train by means of stop signals. He used his private mobile phone, since the train radio in the driver's cab was broken as a result of the impact against the cliff. The driver called the shift supervisor at DROPS, since he could remember that phone number immediately, and told them to notify the traffic control centre. Each traffic control unit currently has its own emergency phone number with a priority line. This means that the staff on board trains must have the different numbers stored on their phones or otherwise have an overview of which numbers to call. In addition, the NNRA has a short number (1200) from which all calls will be routed to the nearest traffic control centre, but this number is not used much and, in the AIBN's experience, not widely known by train personnel. Drivers do not use this short number either, since they mostly use the train radio in the train. After the call to DROPS, the driver went to check the possibilities for the emergency services to access the scene of the accident. He first went to the front to secure the train with a stop signal, and then went back towards Nykirke station. When he was at the rear of the train, he could see both the fire service and ambulance coming down to the train.

According to the train inspector, the derailment was sudden. He was sitting in the first carriage, facing forward, and was in the process of reporting faults to DROPS by e-mail. He noticed that the train was derailing and ducked under the table. When the train stopped, he went to the front of the train to check on the two people in the driver's cab. They both responded when he called, but the locomotive supervisor also complained of pain in the chest. The train inspector asked the driver to keep an eye on the locomotive supervisor and give notification of the accident, while he went towards the back of the train to check on the two others. The whole time, he was aware that the status of the overhead contact line system could entail a risk. He met the Mitron representative, and found Stadler's representative uninjured outside carriage 4. The train inspector then knew that everybody was accounted for, and fetched emergency equipment from carriage 4. Immediately after the accident, the train inspector could not remember/find the phone number of Drammen traffic control centre, neither the emergency number, the short number nor the ordinary phone number, but he did find the phone number of the local train controller in Tønsberg. He called there and received confirmation that notification of the accident had already been received. He estimates that they waited for the ambulance for approx. 30 minutes, which felt like a long time.

Stadler's representative noticed the accident when he was suddenly thrown out of his seat. He cannot remember any braking. He was not injured, and after the accident he exited the train and went forward along the train, where he met the train inspector. He was told that they had given notification of the accident, and that the train inspector was on his way to the back of the train to find the first aid kit located in the conductor's cabin. They fetched the equipment and made their way to the front of the train to help the injured locomotive supervisor. The Mitron representative also helped.

By coincidence, a farm road leading to the accident site had just been cleared of snow, which made access easier. The traffic controller immediately stated that electricity had been disconnected at the site. When the fire service arrived, it carried out the earthing very swiftly, and the safety at the scene was clarified with no delay to the rescue effort. The emergency services had adequate resources within a time frame of 15 minutes. It has been reported that communication between the emergency service commanders at the scene was good, and injured persons were evacuated quickly. No fire occurred in this accident.

2.11.2 Notification after the accident

Notification of the accident was given by the personnel on board the train immediately after it occurred. Several persons and organisations were notified, some via hand-held train radio (OPH) and some via private mobile phones, since the train radio in the train set was not working. Figure 24 shows the different roles involved in notification immediately after the accident.

The traffic controllers' notification plan contains instructions to consider which of the emergency services (110, 112, 113) to notify first, depending on the type of incident, and they can request that the service first notified notify the others (see Section 2.8.2.3). In this case, the traffic controllers called 112, but due to problems transferring the call between the police operations centres in the Drammen and Vestfold police districts, there was a delay of 10–12 minutes in the notification.

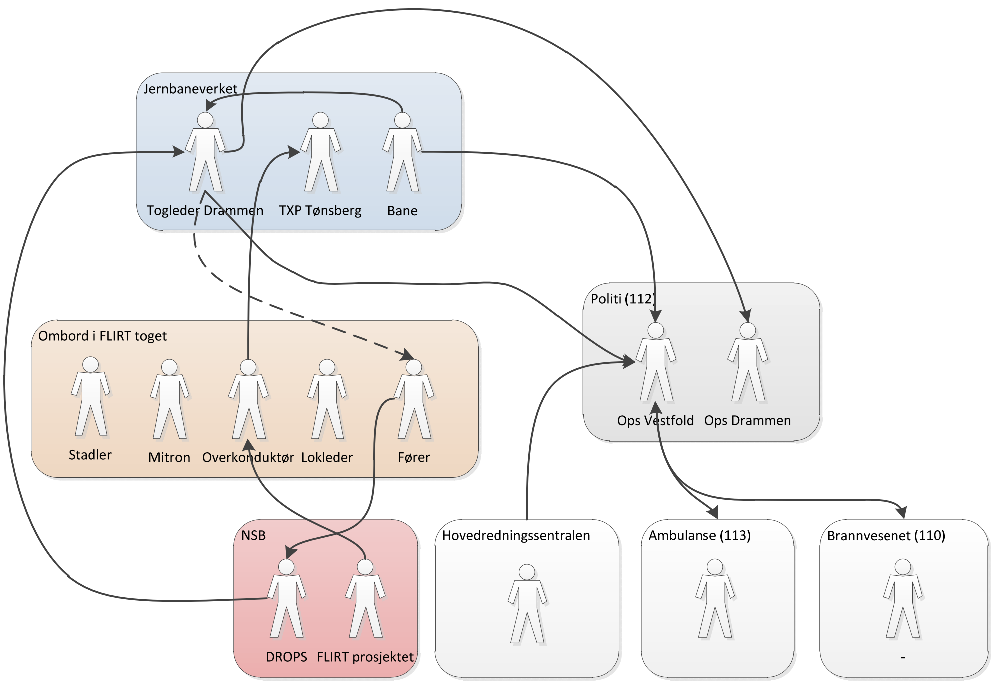


Figure 24: Illustration of the many roles involved in the minutes following the accident.

The NNRA's accident notification instructions state that generally, personnel who are in some way involved in a railway accident shall first notify the traffic control centre, or alternatively call 112 or the Joint Rescue Coordination Centre. In this accident, the train radio on board the train was destroyed, and no one had or could remember the traffic control centre's direct phone number, but notified it via other channels instead. The GSM-R short number (1200) that routes calls directly to the nearest traffic control centre was not used. This number comes in addition to the traffic controllers' ordinary eight-digit numbers, and was created when the GSM-R system was introduced, to enable all operational personnel to contact the traffic control centre via their hand-held train radios (OPH).

The more detailed action points in the traffic controllers' notification instructions do not provide clear guidelines regarding whether 110, 112 or 113 should be notified first (see 2.8.2.3), but leave it up to the traffic controllers to determine this, based on the type of accident in question. The traffic controller in this accident thought that 112 had priority, and therefore called that number. Recently, the NNRA has chosen to focus more on 112, while 110 was formerly thought of as the primary service to notify in the event of fire and major accidents. 110 plays an important role in earthing the overhead contact line and securing the scene of the accident. The instructions for 112 and 113 specify that they must *not* approach the tracks and contact line until the fire service has completed the earthing. The fire service personnel are trained in this and are required to undergo regular certification in the use of the equipment.

Based on the NNRA's audio log, it may seem as if the operator at Vestfold police district thought that the accident involved an ordinary passenger train. At this time, the traffic controller had been in contact with NSB AS's operations centre DROPS and knew how many were on board, but, in the relief at finally getting through, focused more on the problem of describing how to get to the site than on the number of people on board. The traffic controller thereby did not pass the message on, and the police operator did not ask. The initial message from Vestfold police district to Vestfold Emergency Medical Communication Centre (AMK) was therefore to send as many ambulances as possible. Logs from 110 and 112 show that the number of people on board varied from 10 or 15 to six in the first ten to twelve minutes after the accident, when there were actually five people on board.

In this case, it turned out that the 110 communication centre in Drammen had begun using the maps with kilometre points provided by the NNRA via the Directorate for Civil Protection and Emergency Planning in 2011, while 112 only have ordinary maps. However, the NNRA's own maps were not used, since they are deemed to be too time-consuming to use. The resulting situation was that 110 were able to pinpoint the accident site on the basis of the kilometre points given, while neither the police nor the ambulances knew precisely where it was. By coincidence, they saw the fire service passing and followed them. The fire service turned out to be following an NNRA car that guided them all the way to the scene of the accident via a small side road/farm road.

Table 11 lists the different actions taken after the accident. Note that there will be minor inconsistencies between clocks used by the different parties, and the chronology of events may therefore contain errors. The times used in the 110 log are approximately three minutes behind the times in the 112 log. In order for the sequence of actions in the table to be as correct as possible in relation to the actual order in which they took place, three minutes have been added to the times in the 110 log (the original times are kept in brackets).

Table 11: Times and actions

Time	Action/event	Notification from/to	Source
10:31	The derailment indicator at the traffic control centre was activated.		Traffic controller's report
Approx. 10:32	Traffic controller makes an unsuccessful attempt to contact the train via the radio in the train set.		Traffic controller's report
Approx. 10:34	DROPS is notified via a private mobile phone. Asked to notify the traffic control centre.	Driver → DROPS	Witness statement – Driver's report
10:35	The traffic control centre contacts DROPS and receives confirmation that a derailment has taken place. DROPS informs them that there are five people on board.		Traffic controller's report
10:35	The traffic controller calls 112, call received by the police operations centre in Drammen. They transfer the call to Vestfold police district's operations centre, but can't get through. Had to call Vestfold police district's switchboard, which transferred the call to 112, with no reply. Called again and was put through to the right person at 10.47.	Traffic controller → 112	Traffic controller's report
10:44	Time of accident according to 112.		112 log
10:44	The train inspector on board the train notifies of the accident, given confirmation that notification has been received.	Train inspector → Local traffic controller, Tønsberg	The NNRA's audio log
10:47	The traffic controller gets through to 112 to notify of the incident. Problems explaining where Nykirke station is.	Traffic controller → police operations centre, Vestfold	The NNRA
10:48	The police records the first notification of the accident.		112 log
Approx. 10:48 (10:45*)	The police notifies 110 of the accident, 110 then notifies AMK Vestfold, which has not been notified.	110→ AMK Vestfold	110 log
Approx. 10:48 (10:45*)	The 110 communication centre immediately contacts the crew commander at Kopstad fire station to give advance notification, and they agree that a 'full alarm three stations' is warranted.		110 log
Approx. 10:49 (10:46*)	Contacts the Vestfold police to check whether they have been notified of the incident and status. The incident is confirmed, but they have no position for the incident. They agree that the 110 communication centre will contact the traffic controllers.	110 → Police	110 log
Approx. 10:49	The train inspector responds and gives the project the exact position and status.	Project → Train inspector	Witness statement – Train inspector
10:50	AMK notified – sends all available personnel.	Police → 113	112 log

Time	Action/event	Notification from/to	Source
Approx. 10:51 (10:48*)	Contacts the traffic controller in Drammen and receives a little information about the accident site. The position given is the 'cutting' near Nykirke on the way to Holmestrand. The 110 operator asks if they can get the position in the railway kilometre points, but the operator who has the maps are engaged. It is stated that there is no road to the site. Reports that at least two persons are seriously injured, one of whom is the train driver. The train is said to have a delegation of 10–15 people on board.	110 → traffic controller	110 log
10:52	Car B30 drives to the level crossing at Nykirke.		112 log
10:53	All-units call from 110: Test train 2 damaged, 10–15 people on board. Isolated location. Personnel to report at Nykirke station. 110 has special vehicles for personnel transport.	110 → 112, AMK	112 log
Approx. 10:53 (10:50*)	The 110 communication centre arranges a teleconference with Vestfold AMK and the police to update them both on the status report from the traffic controller. There is supposedly a delegation of 10–15 people on board, two seriously injured, one of whom is said to be the train driver. The 110 communication centre proposes Nykirke as a muster point.	110 → AMK, police	110 log
Approx. 10:50	NNRA personnel reports to the traffic controller, put in contact with the rescue services. Guides all rescue personnel to the scene of the accident.		The NNRA
10:56	The Joint Rescue Coordination Centre (JRCC) has been notified, sends a Sea King helicopter.	Police → JRCC	112 log
Approx. 10:59 (10:56*)	Contacts the traffic control centre and electric power centre in Drammen for an up-to-date position and confirmation that power has been disconnected. The electric power centre confirms that power has been disconnected between Skoppum and Holmestrand. They also confirm that earthing equipment is on its way. The 110 communication centre state that they are bringing earthing equipment and ARGO. After making another request for the position, the 110 operator is given a kilometre reference of 92.57 km. At this time, the incident is correctly placed by the 110 communications centre. It is confirmed that the train driver is seriously injured and that there are a total of six people on board the train.	110 → Traffic controller, Drammen electric power centre	110 log
11:02	The police drives to Fesil, where there is a new railway tunnel opening.		112 log
Approx. 11:04 (11:01*)	110 contacts AMK Vestfold to update the incident status and confirm the position.	110 → AMK	110 log
11:06	The police enters the railway line at the NNRA's facility near Sand Camping.		112 log
Approx. 11:07 (11:04*)	Contacts the Vestfold police to update with the same information as for AMK.	110 → Police	110 log

Time	Action/event	Notification from/to	Source
11:07	Personnel enter the railway line to locate the incident. Drammen traffic control centre notified, all trains between Skoppum and Holmestrand have been stopped. Power has been disconnected.		112 log
11:07	The 110 communications centre notification that there are six persons on board the train. The train driver is said to be seriously injured and bleeding heavily, the second injured person complaining of back injuries, condition unknown for the other four. The accident is said to have happened between kilometre points 92 and 93 from Oslo. Very isolated location.	110 → Police	112 log
Approx. 11:07 (11:04*)	The first unit from the fire service reports status 'arrived'.		110 log
11:13	The police are in Bruserudveien, the fire service is also there.		112 log
11:14	The Sea King is in the area.		112 log
11:14	The Sea King is about to land.		112 log
11:18	Ambulance on site at Bruserudveien 305.		112 log
11:26	Situation report from the incident commander. All rescue units are on the scene.		112 log
11:38	All out of the train, according to medical personnel.		112 log
11:53	All taken to hospital.		112 log

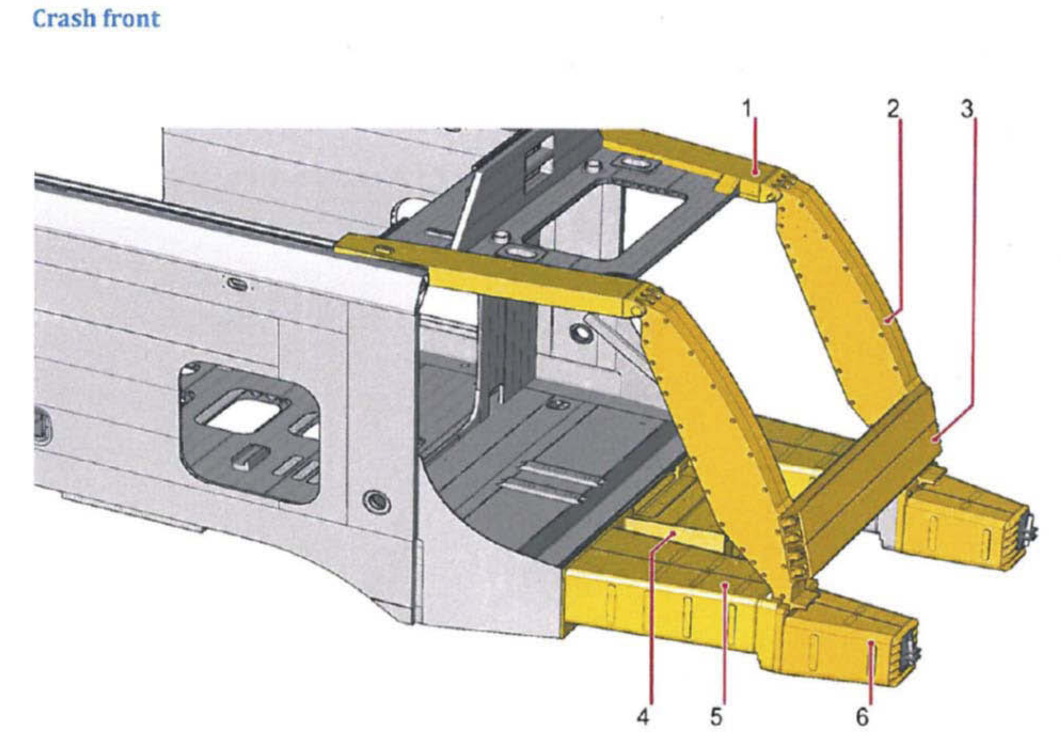
**The original times in the 110 log are approximately three minutes behind the times in the 112 log.*

2.12 Survival aspects

On of the aspects for consideration in a safety investigation is to what extent vehicle characteristics put persons on board at increased risk in an accident situation by having a poor design. For example, glass can splinter into sharp objects instead of crumbling. In this accident, the train set was exposed to significant stress, and it is natural that damage occurred. However, the vehicle cannot be said to have performed worse than expected.

International and/or European standards and test procedures are in place for elements with a bearing on the safety of train personnel and passengers. According to the manufacturer Stadler, these standards and procedures were the basis for any changes and additions in the delivery project. Stadler would not have accepted any changes that would have resulted in reduced safety.

The driver's cab in NSB Type 74 has extra reinforcement intended to protect the driver in the event of impact (Figure 25 and Figure 26). This probably helped to reduce the extent of injuries to the two people who were in the cab when the train hit the cliff. The driver has also pointed out in interviews that the train appears to be very strong and robust. The locomotive supervisor agrees, and is glad they were in precisely this safe train set which has a very safe driver's cab, among other things.



1	Kollisjonsramme	4	Åpent rom for kobell
2	Bevegelig A stolpe	5	Absorberingsbokser
3	Forsterkning kollisjonsbjelke	6	Buffer med antiklatrefunksjon

Figure 25: The front of the train is reinforced with a collision frame (source: NSB AS).

Figure 26: The front of the train with reinforcements visible (photo: the AIBN).

The photos below illustrate how much damage was done to the driver's cab in the incident.

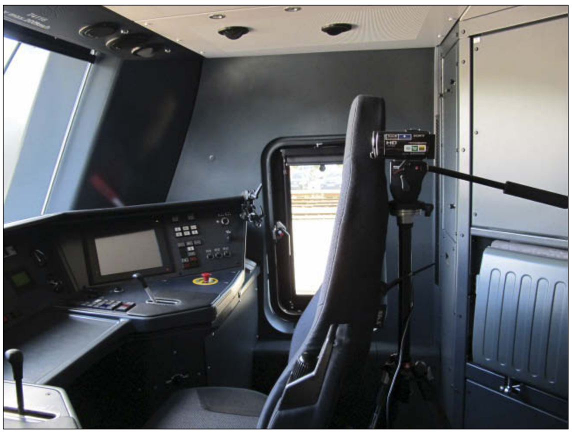


Figure 27: Normal driver's cab. The extra seat is visible behind the driver's seat (photo: the AIBN).

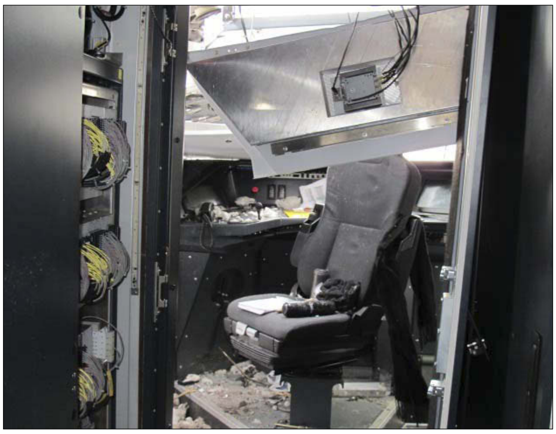


Figure 28: The driver's cab after the incident (photo: the AIBN).

The person in the fourth carriage, which rolled over, was in the compact conductor's cabin, from which he could monitor the train's systems during the journey. The size of the room limited the possibility of being thrown around, which very probably contributed to him not suffering any injuries at all. Figure 29 shows a similar conductor's cabin.

Figure 29: Conductor's cabin in NSB Type 74 (photo: the AIBN).

Figure 30: The room where the Stadler representative was (photo: the AIB).

There was extensive damage to the side of compartments and passenger areas closest to the cliff. Also, some fixtures and fittings came loose from ceilings as well as from technical cabinets. As is known, there were no passengers or luggage in the train. Had there been, the situation would have been considerably worse.

Figure 31: Normal compartment (photo: the AIBN).

Figure 32: Compartment after the incident (photo: the AIBN).

Figure 33: Normal compartment (photo: the AIBN).

Figure 34: Compartment after the incident (photo: the AIBN).

Figure 35: Normal compartment (photo: the AIBN).

Figure 36: Compartment after the incident (photo: the AIBN).

Figure 37: Normal compartment (photo: the AIBN).

Figure 38: Compartment after the incident (photo: the AIBN).

Figure 39: Normal compartment (photo: the AIBN).

Figure 40: Compartment after the incident (photo: the AIBN).

2.13 Other information

2.13.1 Other incidents of a similar nature

On 9 June 2012, a passenger train passed a curve near Sokna on the Bergen line at too great a speed, approximately 120 km/h. The speed prescribed by signs for the curve in question is 70 + 5 km/h. The speed was so great that water from the dishwasher flooded the floor, and items fell down from the tables/counter in the café car. One passenger was hit by some luggage, but no other injuries of significance are known in connection with this incident.

The AIBN's preliminary investigation concluded that the driver had overlooked the speed reduction sign. The driver only became aware of the speed reduction on seeing the marker from which the reduced speed limit applied, which resulted in the train travelling much too fast through the curve. The train in question was operated with a locomotive and passenger carriages.

This shows that the incident at Nykirke was not unique, but that speed reduction signs have also been overlooked elsewhere. The outcome, on the other hand, will depend greatly on the speed range in question and how great the reduction of speed is.

3. ANALYSIS

Through its investigations, the AIBN has established the chain of events with pertaining safety problems such as non-conformity and a lack of barriers. The purpose of this section is to shed light on the findings made.

The preliminary investigations found that a combination of several circumstances was behind the accident. The goal of the further work has been to identify barriers that could have prevented the accident. This covers both operational and organisational matters relating to the operation of trains, as well as technical barriers in the infrastructure.

3.1 Establishing the chain of events

The investigation has established the chain of events. The preceding sections describe the events in more detail, but they can be briefly summarised as follows. On Wednesday 15 February 2012 at 10.30, northbound train 12926 derailed at Nykirke station on the Vestfold line. There were personal injuries and significant damage to the train and the railway infrastructure.

As part of the preparation process for NSB AS's new train sets, NSB Type 74 was undergoing continuous on-track testing on the Vestfold line. The purpose of the journey on the day in question was burn-in driving. This was combined with function testing of the train's passenger information system and providing user experience of the train for personnel who had been trained and checked out for the train type in question.

When the train approached Nykirke station on the return journey to Drammen, the driver reduced traction power and let the train roll towards the station. The train's recording unit shows that the speed was approx. 130 km/h, which corresponds to the line speed on the section. Due to a slight downhill gradient on the line, the speed increased from approx. 130 km/h to approx. 135 km/h. On entering Nykirke station, the driver overlooked the sign that notified of the reduction of speed from 130 to 70 km/h. It was only when the train arrived at the point from which the reduction of speed applied that he became aware that the speed was too high. The driver started braking, but did not initiate emergency braking. All five carriages in the train derailed and hit the cliff on the left-hand side of the tracks. The train set was split into three in the accident, and carriage number four rolled over to the right in the direction of travel (Figure 11). Of the five people on board the train, four were deemed to have suffered minor injuries, while one was seriously injured.

3.2 Non-conformity analysis

Non-conformity with applicable rules, standards, procedures and norms can contribute to the occurrence of undesirable incidents. This section discusses the various non-conformities identified by the investigations after the incident.

The speed sign stating the speed on the departure route from Nykirke station was missing. This sign would have repeated the line speed for the section of track the train was heading onto, and made it clear to the driver by how much the train was overspeeding as it approached the first curve. The sign is significantly larger than the speed reduction marker (see Figure 17 and Figure 16), and might have been seen at an earlier time. In the AIBN's opinion, it is not certain that a repetition of the speed sign at this time would have helped, but it might have given the driver an indication of the excess speed so that he would have activated the emergency brake, thereby achieving a greater reduction of speed. It is difficult to determine whether this would have been sufficient to prevent the accident.

If we assume that the repeater sign was located at the northern end of points 1, and that it is possible for the driver to see this sign approx. 100 metres before the main departure signal/speed reduction marker, the distance from the place where the sign is visible to the derailment site would be approx. 250 metres. The question is whether this would be sufficient for the driver to have time to perceive by how much the train was overspeeding, initiate emergency braking and be able to reduce the speed of the train sufficiently. General calculations given in Section 2.10.2.1 show that vehicles whose centres of gravity are at a height corresponding to that of NSB Type 74 would not have derailed if the speed had been reduced to approx. 115 km/h. This reduction of speed is contingent on several uncertain factors:

1) The driver would have had to spot the speed sign as soon as it was visible. The sign is considerably bigger than the speed reduction marker (Figure 16 and Figure 17). The distance from the place where the sign would have been visible to the driver (due to overhead contact line masts and other signs) to the derailment site is approx. 250 metres.

2) The driver would have to be aware of his own speed and deem the excess speed to be so great that emergency braking was necessary. At a speed of 135 km/h, this would give the driver approx. seven seconds to notice and assess the excess speed and activate the brakes. The brake activation time and the time it takes to reduce the speed of the train by a minimum of 20 km/h comes in addition to this. When making this assessment, it is important to bear in mind the fact that the thought that a train could roll over was highly unusual to drivers until this accident. There have not been any previous cases of passenger trains rolling over due to overspeeding in Norway, and there are few examples from abroad. The consequences of travelling through curves at too high a speed have been considered to be limited to objects falling on the floor and a less comfortable ride through the curve, and only in extreme cases derailment. Generally speaking, it can be said that the normal course of action when the train is travelling too fast in relation to the line speed is often to let the train roll through the curve, or over track irregularities, without applying brakes or tractive power. Applying the brakes would make the train stiffer, which is deemed to make the train less able to tackle track irregularities and curves.

3) The driver would have to initiate emergency braking immediately, and not just use the service brake.

In the AIBN's assessment, it is likely that a sufficient reduction of speed could have been achieved, but that it would require an optimal course of action in a situation that is not part of the driver's ordinary training.

The driver had not received a test plan for the trip, but had been informed that the purpose was burn-in, and that the train's passenger information system was to be tested. This would not normally affect the train operation, since it corresponded to the normal driving pattern for intercity trains with stops and starts at the relevant stations.

As mentioned, there are a number of sections with similarly large reductions of speed that can therefore be assumed to be a known risk factor in the Norwegian railway network. The AIBN chooses to follow up this problem by making a safety recommendation.

The driver had only driven this type of train a few times before. The AIBN feels that the good driving properties of NSB Type 74 may have contributed to giving the driver a poorer perception of the train's speed compared to other train types.

The train's speed recording unit shows minor speed variations, both over and under the line speed given. This can probably be ascribed to the fact that the driver did not know the type of vehicle, the line and the track design as regards speed and driving style very well. The new Train Driver Regulations introduced new requirements for follow-up and control of personnel's knowledge of the line.

The NNRA's traffic control centre chose to contact 112 to give notification of the accident. This does not represent a non-conformity with the applicable procedures, but the procedures provide no absolute guidelines as to which emergency service should have priority for first notification. This means that the traffic controllers could have chosen to call 110 or 113 when 112 failed to respond within a reasonable period of time.

According to the Notification and Reporting Regulations, the nearest traffic control unit should be the first to be notified of accidents. Since the train radio on the train was destroyed in the derailment, the personnel on board the train had problems finding/remembering the right phone number for the traffic control centre on the hand-held train radio (OPH). The short number for hand-held train radios (OPH) that route the operational personnel's call directly to the nearest traffic control centre was not used. As a result, NSB AS's operations centre DROPS was called instead, and it in turn notified the traffic controllers. This calls will thus bypass the NNRA's logging and speech recording systems, which is unfortunate for the subsequent investigation of the accident.

3.3 Technical and organisational matters

The causes of an accident are often complex, and the AIBN has chosen to divide them into immediate causes and organisational factors. The accident occurred because the train was entering the curve too fast, and the train rolled over and derailed. The AIBN has found that the driver overlooked a notification of speed reduction from 130 to 70 km/h, and braking was initiated too late. It has not been established what distracted the driver's attention for the four or five seconds during which the speed sign was visible.

Both the driver and locomotive supervisor have emphasised in interviews that the journey was calm and quiet, with no stress or distracting elements. It has been considered whether the driver might have been distracted by inquiries from the project, by test personnel on board or by information from the train systems, but the AIBN has not found this to be the case. What the AIBN has looked more closely at, on the other hand, are circumstances that may arise as a result of an insufficient mental workload and expectations.

It is not an uncommon finding in investigations of rail, aviation, marine and road traffic accidents that operational personnel overlook easily visible information. This can often be explained by the phenomenon of inattentional blindness, which has to do with the fact that people have a very limited capacity to perceive what is going on around them. Much of the information must be subconsciously filtered out – you become blind to much of the information in your surroundings. One of the factors that might trigger this is an insufficient mental workload, i.e. reduced alertness and ability to react due to a feeling of control in the situation, often related to tasks that require monitoring. When such tasks are performed, there is little to activate an individual. This, together with the fact that the driver did not have the line fresh in his memory, could have influenced the driver's expectations concerning where and when he needed to look for critical information such as speed signs. The comfort and perceived running properties of the type of train in question may also have contributed to a reduction in his alertness, leading to the sign being overlooked. In summary, this helps to explain why the driver might have been less alert than during an ordinary scheduled service, since this was purely a transport journey back to Drammen.

The possibility has been considered that the driver was receiving an unnecessarily large amount of information from the error information system in the driver's cab during the journey. There is nothing to indicate that this was the case, although the process of optimising the information system and proofreading the error messages from a linguistic perspective was not complete.

The train manufacturer's two representatives both observed the train systems via their own computers, and their contact with the two persons in the driver's cab was minimal. Therefore, the AIBN finds no grounds for claiming that distractions caused by other persons on board had a bearing on the course of events.

The AIBN has considered the design of the curve and modifications on the line leading to the curve. No faults have been found that are deemed to have had a bearing on the course of events.

The AIBN believes that it is of material importance to note that this accident could also have happened to other types of train if they had been travelling at the same excessive speed. Calculations show that all the comparable train types used on the line would have derailed and rolled over at this excessive speed.

NSB AS implemented a reorganisation in June 2008 whereby it established two business units (business unit East and business unit National), and the operating licence was transferred to NSB AS. Responsibility for the locomotive staff and some responsibility from DROPS was transferred to the locomotive supervisors for each line.

According to NSB AS's traffic safety entity, this reorganisation had not been fully implemented in the operational parts of the organisation. Among other things, this meant that the testing and driver training for NSB Type 74 took place in accordance with the old organisation model. The same was true of the extended training for locomotive supervisors at DROPS, which was carried out in accordance with the old course model.

However, it is the AIBN's opinion that this has had no effect on the final outcome of the investigation. According to NSB AS's documents, the driver was qualified to operate the train on the Vestfold line, regardless of the company's form of organisation. The drivers had clarified the division of responsibility for the operation of the train between them, and the same applied to the procurement project that organised the rotation of train sets for burn-in and that, together with the supplier, staffed the train during on-track testing. The personnel carried out their duties as established for the on-track testing of NSB Type 74.

3.4 Barrier analysis

Barriers are used both to reduce the probability of undesirable incidents and to eliminate or limit the consequences of such incidents. This section reviews the relevant barriers in relation to this incident.

The driver's knowledge of the line is an important barrier against excessive speed. A driver who knows the line will often know what the speed limit is. The requirements concerning knowledge of the line were to a great extent based on the driver's own assessment of what was 'sufficient knowledge of the line'. The driver considered himself to have sufficient knowledge of the line to operate trains on it, but did not describe himself as having detailed local knowledge.

In the AIBN's opinion, NSB AS lacked clear criteria by which to measure knowledge of the line, and did not have any control systems to identify such knowledge. When such assessments were left to the drivers, there was a risk of differences in interpretation and practice, which, as this accidents proves, can have serious consequences.

According to the Train Operation Regulations' chapter on signal signs etc., there shall be a speed signal at the departure train route to indicate the departure speed from the station. This sign was missing at Nykirke station, and so there was no reminder of the reduction in speed. A speed sign is deemed to be a weak barrier, as its effect depends completely on the driver perceiving it correctly and taking the required action at the right time. When the driver overlooked the speed sign notifying of the reduction of speed from 130 to 70 km/h, there were no technical systems to detect this, intervene and reduce the speed. In the AIBN's opinion, the signal might have caused the driver to react and brake somewhat earlier, but whether this would have reduced the speed enough for it to be possible to limit or prevent the accident depends on several uncertain factors (see Section 3.2).

The new Train Driver Regulations introduced new requirements for follow-up and control of personnel's knowledge of the line. The AIBN has expectations regarding the effect of the change in requirements, and has therefore chosen not to submit a safety recommendation relating to knowledge of the line so soon after the change in regulations. It is not deemed expedient until the results of the change can be determined.

It was not the locomotive supervisor in the driver's cab's job to monitor the operation of the train. The driver had been authorised and checked out for the type of train in question, and the locomotive supervisor was there to provide technical support relating to the vehicle as required. His focus was therefore not on monitoring the driver's driving pattern and the signs along the line, and in any case this would be impossible from the extra seat behind the driver.

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 classifications, the procedure is for the ATC system to be set to the maximum speed permitted on the route as a whole. This is done in order to avoid changing the speed settings during the journey. For the journey from Larvik to Drammen, the maximum permitted speed is 200 km/h, although long sections of the track have a lower permitted speed. If the ATC had been set at a maximum permitted speed of 130 km/h, this would normally have triggered a warning light and an audible warning to the driver once the speed reached 135 km/h on this section of the line. This was of no significance at Nykirke station, since the balises are coded at 130 km/h. This coding would generate a warning in the train's ATC system. According to the NNRA, this speed coding is not common, since the balises are normally coded at speeds well above 200 km/h.

ATC monitoring of the maximum permitted speed is a marginal barrier, but the AIBN feels that one should consider whether it would be expedient to use this monitoring option on PATC sections.

A review of the potential barriers shows that there are no *technical* barriers relating to the operation of trains that intervene if a driver drives a train at excessive speeds on a PATC section. In the AIBN's opinion, the incident at Nykirke in February 2011 proves that there are sections of the Norwegian railway network that lack sufficient barriers to prevent accidents. The driver's awareness of a single sign, in addition to knowledge of the line, is not deemed to be sufficient on these challenging sections.

Continuous speed monitoring would have detected this incident, since the system would have detected excessive speed in the area where the train's speed should normally decrease. The system would then have intervened and slowed the train down to the correct speed. If we compare the situation with other countries, this incident could not have taken place in e.g. Sweden, where speed monitoring is mostly installed on all lines from the outset.

The variations in speed are often smaller on the Norwegian railway network, and the speeds are also lower, which means that the consequences of excessive speed in curves are not as serious as in this case. There are examples of excessive speed in curves having been uncomfortable for passengers, but no trains have derailed. The NNRA estimates that there are approx. 30 locations with similarly large reductions in speed, in corresponding speed ranges, and in combination with a curve. However, these places do not automatically pose a similar risk. Several factors influence the risk, including the design of the curve, the height of the vehicle's centre of gravity and the curvature towards the point where the speed is reduced. The AIBN feels that the risk in these places must be mapped with a view to introducing extra barriers where needed. This information must also be communicated to the railway undertakings to ensure that the risk element is sufficiently well known. By comparison, the regulations require the NNRA to establish speed monitoring when temporary speed reductions are introduced. It should therefore, in the AIBN's opinion, be possible to introduce it in the approximately 30 places in Norway where there are permanent large reductions in speed that could result in consequences of this type.

3.5 Consequence assessment

Of the five people on board the train, four were deemed to have suffered minor injuries, while one was seriously injured. Many factors would have been different in a normal train operation situation with passengers, but, on a general basis, the AIBN assumes that a corresponding derailment at this speed would very likely have killed and injured a large number of people.

The derailment caused a delay of about a month to the temporary approval and placing in service of NSB Type 74. The train set, worth approx. NOK 80 million, was a write-off and was condemned. The Vestfold line suffered relatively extensive damage, and the costs incurred in restoring the infrastructure are estimated to be in the neighbourhood of NOK 4.2 million. In addition, the line was closed until Thursday 23 February at 19.00 due to the investigation work, recovery of the train and repairs to the infrastructure.

3.6 Notification of the accident and the rescue services

The NNRA's traffic control centres each currently has its own emergency phone number with a priority line. There is also a four-digit short number (1200) that the hand-held train radio (OPH) will route directly to the nearest traffic control centre. If the radio in the train set is damaged in an accident, the staff on board the train must know the GSM-R short number for the hand-held train radio (OPH), or have saved the traffic control centres' phone numbers (emergency numbers/ordinary phone numbers) on their phones (private mobile phones or hand-held train radios (OPH)) in order to be able to give notification of the accident. In the AIBN's experience, the short number is not sufficiently well known among some railway undertakings, since the driver uses pre-stored numbers in the train radio and other members of staff rarely or never need to contact the traffic controllers. It is the AIBN's opinion that in an emergency situation where the head conductor acts as incident commander, and both the driver and the train set's radio may be unavailable, it will be of great importance for the head conductor to be able to contact the traffic control centre directly. At present, there is no requirement in place for the on-board staff to have access to hand-held train radios (OPH). It is left up to the companies to consider this in relation to their emergency response plans. If this number had been known, that would have eliminated the need to know several different phone numbers, depending on which traffic control centre is nearest, and the notification would go directly to the traffic controllers.

The AIBN finds that there are two matters relating to the notification of the accident that gives cause for serious concern:

1) It took 12 minutes for the traffic controller to get through to the right entity at 112.

2) It was very difficult to explain to the 112 operator where Nykirke station is, since it is in an isolated location and is not a station for passengers in the traditional sense, but a crossing station.

The NNRA's instructions for notification about serious accidents begin by stating that one must contact the nearest traffic control centre (traffic controller), which will in turn notify 112 or the Joint Rescue Coordination Centre. The more specific actions described in the notification procedure amend this and leave it up to the traffic controllers to determine which emergency service to notify, depending on the type of incident. In this case, the 112 call was routed to Buskerud, since that is the nearest 112 communication centre to the traffic control centre in Drammen. When 112 transferred the call to Vestfold operations centre, which was the appropriate authority in charge of the area, the traffic controller was put in a unprioritised queue. This delayed notification. Buskerud 112 communication centre did not check whether the traffic controller's call got through to the Vestfold central. It took a total of 12 minutes before the traffic controller got through to 112, which the AIBN feels is too long.

The traffic controller knew the number of persons on board when 112 was reached, but the 112 operator did not ask, and in a stressful situation focus turned to the problem of giving directions. As a result, the number of people on board was not clear when 112 notified the other emergency services. In the AIBN's opinion, this information may be of importance to ensuring that the right amount of resources are allocated to the rescue efforts.

Many 110 communication centres have implemented the NNRA's maps. The 112 centres have not done this, nor will they do so within a reasonable period of time (see planned measures in Section 5.2.1). In the AIBN's opinion, the NNRA should consider whether 110 is not better equipped to pinpoint the geographical location of an accident with a view to giving directions to other emergency services. When this incident took place, the 110 communication centre in Drammen had begun using the NNRA's maps and could therefore quickly determine the map references of the accident site, which are needed e.g. by rescue helicopters. It is the AIBN's opinion that the NNRA should check which of the 110 centres are using the maps, and the police should also have this information.

In addition to having maps, 110 also plays a crucial role in securing the scene of the accident by earthing the overhead contact line system, which indicates that it is an advantage if they can talk directly to the NNRA's traffic controller in charge. Even if 112 and 113 are told by NNRA personnel that the electricity has been disconnected, their instructions state that they are not to approach the tracks and the overhead contact line system until the fire service has completed the earthing. The fire service personnel are required to practise this task regularly.

The accident at Nykirke shows that a 112 call can end up in an unprioritised telephone queue when transferred between two centres, while 110 generally have more capacity for calls, since they often receive fewer calls than 112. Since the geographical location of the traffic controllers will differ from that of the accident, the nearest emergency service notified will nearly always have to transfer the call to another entity closer to the site of the accident.

Regardless of which emergency service should be the NNRA's priority recipient of notifications, the AIBN feels that 112 should review their procedures for transferring phone calls to ensure that contact with the caller is not broken before contact with the correct centre has been established. It is also important that such calls are not placed in an unprioritised telephone queue on transfer. According to the 110 communications centre in Drammen, work is under way to establish priority lines between different 110 centres, but they have never known it to take long for another 110 centre to answer a call. By comparison, it is common practice for Norwegian 113 emergency communications centres to stay in contact with the caller and listen in until the call is picked up by the next 113 centre.

In most cases it is reasonably unproblematic to explain to the emergency services where an accident has happened, but for this incident problems arose. The NNRA's maps were not used, partly because they had only recently been made available and partly because they are seen as time-consuming in a notification situation. The accident site is in an isolated location, but personnel from the NNRA's infrastructure management department gave valuable help in guiding the emergency services' vehicles to the scene of the accident. By coincidence, snow had also been cleared from a farm road leading to the scene a few days earlier.

It is the AIBN's opinion that several aspects of the rescue work were satisfactory. Safety on the scene was quickly clarified in that traffic control immediately ensured that overhead contact line power was disconnected and the fire service earthed the site. The rescue services were located relatively close to the accident site, and once they found their way there with the help of people with local knowledge, work on the scene was well organised and the injured persons were quickly evacuated.

4. CONCLUSION

The AIBN has carried out a safety investigation to shed light on how insufficiently strong barriers can result in an accident on this scale. The investigation has shown that there are no technical barriers that can detect a train's failure to initiate speed reduction on time on a section with PATC (partial speed monitoring).

Based on the AIBN's investigations, the immediate cause of the accident is deemed to be that the train was travelling at an excessive speed on the section of track in question. The driver had overlooked a speed reduction notification to reduce the speed from 130 to 70 km/h, and braking was initiated too late. It has not been finally determined what caused the driver to overlook the speed reduction signal. In the AIBN's assessment, it is likely that a sufficient reduction of speed could have been achieved by emergency braking, but that it would require an optimal course of action in a situation in which the final outcome was regarded as improbable until the accident, and that is not part of the driver's ordinary training.

The AIBN has considered potential sources of distraction, but found none that can with certainty be linked to the driver's having overlooking the sign. It has been considered whether the driver might have been distracted by inquiries from the project or test personnel on board, or by information from the train systems, but the AIBN has found noting to support this theory. In order to avoid similar accidents, it is necessary to focus on places with similar risk potentials. It is the AIBN's opinion that in the absence of FATC (full speed monitoring), the NNRA must look into the possibilities for introducing adequate and independent barriers where necessary.

DATC has no speed monitoring. When a train is to drive a stretch of tracks with varying speed classifications, the procedure is for the ATC system to be set to the maximum speed permitted on the route as a whole, even if most of the route has a lower maximum permitted speed. The ATC's initial action would be to trigger a warning light and an audible warning to the driver if the speed exceeds the maximum permitted speed that has been set. In the AIBN's opinion, it should be considered whether it would be expedient to use this monitoring opportunity in PATC areas.

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 AIBN's opinion, this 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 NNRA has a direct phone number (1200) to the traffic control centres on the GSM-R network that staff on board trains can call from their hand-held train radios (OPH) and be routed to the nearest traffic control centre, similar to the emergency services' system. This means that it is not necessary to think about different numbers depending on which is the nearest traffic control centre. In the AIBN's experience, this short number is not widely known in some railway undertakings.

In the AIBN's opinion, the NNRA should also consider which of the emergency services to notify first about accidents, on the basis of their roles on the scene, and their ability to translate the railway's kilometre points into ordinary map references. It will also be of material importance for the NNRA's traffic control centres to establish good working channels with their local emergency services in order to prevent unnecessary delays and misunderstandings.

The new Train Driver Regulations introduced new requirements for follow-up and control of personnel's knowledge of the line. The AIBN has expectations regarding the effect of the change in requirements, and has chosen not to submit a safety recommendation relating to knowledge of the line so soon after the change in regulations. It is not deemed expedient to do so until the results of the change can be determined.

NSB AS's restructuring in 2011 had not been implemented into the organisation's operational entities. However, it is the AIBN's opinion that this has no effect on the final outcome of the investigation. According to NSB AS's documents, the driver was qualified to operate the train on the Vestfold line, regardless of the company's form of organisation. The drivers had clarified the division of responsibility for the operation of the train between them, and the personnel carried out their duties as established for the on-track testing of NSB Type 74.

5. PLANNED AND IMPLEMENTED MEASURES

5.1 Implemented measures

5.1.1 Norwegian State Railways (NSB AS)

NSB AS has informed the AIBN that its internal investigation of the accident has identified several areas in which changes have been implemented.

NSB AS identified four urgent measures:

- *An immediate review is to be initiated of governing documents and procedures relating to train path booking, personnel selection and allocation of service for on-track testing and trials in the NSB Passenger Train Division.*

  It must be ensured that the trains are staffed in a manner that ensures that the entity responsible for the operation of trains during the on-track testing and trial period has full control.

- *An immediate review is to be initiated of the knowledge of the line authorisation awarded to train driver personnel during on-track testing and trials for Type 74 in the NSB Passenger Train Division in accordance with requirements.*

  Satisfactory knowledge of the line at all times must be ensured.

- *An immediate review is to be initiated of governing documents and compliance with procedures relating to access to the driver's cab during on-track testing and trials in the NSB Passenger Train Division.*

  It must be ensured that only authorised/approved personnel are present in the driver's cab during train operation in the testing and trial period, including during extended compulsory consultation intended to optimise train drivers' working conditions.

- *An immediate review is to be initiated of responsibilities and authority in the interface between 1) the procurement project, 2) DROPS, 3) the rolling stock department and 4) the line organisation in charge of train operations.*

  The review is carried out with a view to ensuring that the transport management, management in charge, the project and all personnel on board trains are familiar with the responsibility and authority interfaces relating to the staffing and operation of trains during the on-track testing and trial period.

Other measures:

- *A review of governing documents, procedures, tools and functional descriptions (……) shows that the governing documents must be amended in relation to the overall division of responsibility and authority described in LD-00006 Chapter 4.3.*

- *The process leading up to the final approval of governing documents and their approval through incorporation into LOS is being reviewed in order to ensure that the necessary quality assurance of the documents is carried out. The critical interfaces/deliveries in the process must be reflected in the document management procedures in force at all times in the NSB Passenger Train Division.*

- *A review is to be initiated of the lines where the NSB Passenger Train Division operates in order to identify any speed reductions similar to that at Nykirke and check whether the current overall risk assessments for operations address this risk element.*

- *Representatives of the NSB Passenger Train Division will initiate a dialogue with the NNRA to look into the possibility of introducing balise-based speed reduction control for speed reductions in excess of a defined value.*

5.1.2 The Norwegian National Rail Administration

5.1.2.1 *Speed reduction*

The NNRA has changed its technical regulations with effect from 1 July 2012 (https://trv.jbv.no/wiki/Hovedside) as regards the use of signal 68 A 'Reduced speed' (Figure 16). Large speed reductions on sections without FATC will now be done by reducing the speed gradually in several steps:

Area of application
Indicates the maximum speed permitted on the line and on the main track. The driving speed should be reduced to the speed stated on the signal.
The maximum permitted speed (km/h) is the number stated on the signal multiplied by 10. A small 5 on the top right-hand corner in addition to the larger number means that the speed is 5 km/h higher.

Placement
The sign shall be placed at a sufficient distance before the point from which the reduced speed applies as to ensure that the speed can be reduced accordingly; see Signal/Prosjektering/ATC/Vedlegg a: Målavstandstabeller.

The following applies to sections without speed monitoring:
For speed reductions of 50 km/h or more from a speed of 100 km/h or more, the speed must be reduced in two steps or a repeater sign must be put up.

- *Repeater signs: Repeater signs are placed 100–200 metres after the speed sign.*
- *Gradual reduction: Half of the total speed reduction is to be carried out in each step.*

As a rule, the sign shall be placed on the right-hand side of the track on one of the following mountings:

- *A post approx. three metres high*
- *light signal*
- *gantry*

5.1.2.2 *Signage*

According to the NNRA, the line analysis has not been changed after the incident, but an attempt has been made to obtain an overview of similar signage shortcomings elsewhere in the infrastructure district with a view to drawing up an overall improvement plan. It has been discovered that such signs are also missing at Kobbervik and Eriksrud stations, but the work has not been completed. The infrastructure district is therefore preparing a signage plan only for Nykirke. In parallel with this work, preparations are under way to put up signs, and an S circular is being drafted and submitted for internal approval.

The NNRA stated in S circular 180-2012 that the following speed signals have been put up since 4 January 2013:

- Signal 68B 'Increased speed' has been put up at kilometre point 92.205 for trains travelling towards Holmestrand. The signal shows the number 7 (70 km/h).
- Signal 68D 'Marker' has been put up at kilometre point 92.943 for trains travelling towards Holmestrand.
- Signal 68A 'Reduced speed' has been put up at kilometre point 93.733 for trains travelling towards Holmestrand. The signal shows the number 10 (100 km/h).

Speed signal moved:

Signal 68A 'Reduced speed' has been moved from kilometre point 93.341 to kilometre point 93.843 for trains travelling towards Holmestrand. The signal shows the number 7 (70 km/h).

5.1.2.3 *Notification*

After the accident, both the National Police Directorate (POD) and the NNRA saw the need for cooperation on matters relating to accident notification, and a meeting was held between the National Police Directorate, the Directorate for Civil Protection and Emergency Planning and the NNRA on 16 May 2012. The parties agreed on the following:

- The police shall be the first service to receive notification of accidents (the police will notify the other emergency services).
- The NNRA will send POD a map showing the railway network in Norway so that POD can enter the direct telephone number of the respective operations centre for the accident site. This is the number that the traffic controllers are to use. (At present, there is a weakness in the system relating to transferred calls when the NNRA calls 112, since it is not possible to prioritise calls that are transferred if an accident has taken place in a geographical area that is the responsibility of another operations centre than the one receiving the initial notification. The transferred call ends up in an unprioritised telephone queue.)

Since the accident, the NNRA traffic managers have emphasised that their staff should focus on using the electronic maps to make it easier to give directions.

The NNRA has set aside a training day for all operational personnel in traffic, and it was held in October/November. One of the training day topics was emergency response and how to act in the event of an accident/mishap and near misses. In order to ensure that the staff have a good overview of the duties of the NNRA when accidents or mishaps occur, instructions STY601061 *'Instruks for varsling av ulykker/uhell '* ('Notification instructions for accidents/mishaps' – in Norwegian only) were reviewed, as was the use of the electronic maps. This was done in order to ensure that all personnel have a good knowledge of these things for use in future emergencies.

5.2 Planned measures that have not been implemented

5.2.1 The Norwegian National Rail Administration

According to the NNRA, the National Police Directorate (POD) are currently in the process of indicating police district boundaries on the map received from the NNRA. However, the POD has notified the NNRA that the work will take time, largely due to follow-up cases relating to the 22 July Commission's report.

The POD has also promised to see to it that an option of prioritising notifications received, similar to the 112 system, is facilitated for the operations centres that could be involved. However, this will be a challenge for the POD, since both old and new technology is in use.

The POD has informed the NNRA that it is currently not possible to implement map coordinates from the railway kilometre points. This is because the police's map solutions are based on a different system from the solution used by 110. The POD will therefore have the National Police Computing and Material Service look into whether/how this problem can be solved.

The NNRA is working to update its emergency response plans, specifically instructions STY601061 *'Instruks for varsling av ulykker/uhell'* ('Notification instructions for accidents/mishaps' – in Norwegian only) and the notification forms for the traffic control centres. Some centres have already started using the direct number for the police operations centre in charge of each accident.

6. SAFETY RECOMMENDATIONS

The Accident Investigation Board Norway proposes the following safety recommendations.[1]

Safety recommendation RW no 2013/02T

At the end of the passing tracks at Nykirke station, the line speed is reduced from 130 km/h to 70 km/h before a curved section. The speed at which the train was travelling was too high to manage the curve, and all the train's five carriages derailed and hit the cliff on the left-hand side of the tracks. Most of the Norwegian railway network is not equipped with a speed monitoring system capable of intervening if a train exceeds the line speed.

The Accident Investigation Board Norway recommends that the Norwegian Railway Authority instruct the National Rail Administration to identify the places where large reductions in speed could pose a danger in connection with curves, and to implement sufficient barriers to improve safety in connection with large reductions in speed.

Accident Investigation Board Norway

Lillestrøm, 12 February 2013

[1] The investigation report is submitted to the Ministry of Transport and Communications, which will take the necessary steps to ensure that due consideration is given to the safety recommendations, cf. Regulations of 31 March 2006 No 378 relating to official investigations into railway accidents and serious railway incidents etc. (the Railway Investigation Regulations) Section 16.

REFERENCES

[1] Ursin, H and Zahl-Begnum, O. H. (1993). *Biologisk psykologi*. Oslo, Tanum-Norli

[2] '*ERTMS – orientering om regjeringens beslutning*, letter to the Norwegian National Rail Administration from the Ministry of Transport and Communications, 26 November 2012

[3] *'PR-00109 Strekningskunnskap for togpersonalet i NSBs tog under togframføring og på stasjon'*, rev. 4, dated 3 June 2011

[4] *"VK-00322 Strekningskompetanse Regiontog Skien – Drammen",* rev. 2, dated 25 January 2012

APPENDICES

VEDLEGG A – UNDERSØKELSER AV BOGGIER

1. UNDERSØKELSER AV BOGGIER

1.1 Metode

Undersøkelsen ble utført som en visuell inspeksjon av boggiene etter at disse var flyttet fra havaristedet og plassert på gulvplanet i hall E på Sundland verkstedområde. Inspeksjon av boggiene foregikk den 23. og 24. februar 2012.

Inspeksjonen ble utført uten å demontere komponenter. Tilstanden på boggiene ble dokumentert ved fotos og det ble ført protokoll over observerte skader. Hjulprofilene for hjulene i boggi betegnet MB7 (første boggi i togets fartsretning) ble besluttet oppmålt. Hjulprofilene på de øvrige boggiene ble under besiktigelsene den 23. og 24. februar vurdert visuelt til ikke å avvike signifikant fra profilene for MB7.

Oppmåling av hjulprofilene i boggi MB7 (akselposisjon 14 og 13) ble foretatt av representant for Stadler. Resultatene ble oversendt til SHT i epost datert 08.03.12.

Både de enkelte skadene og det samlede skadebildet ble vurdert med sikte på å avgjøre om de observerte skadene var følgeskader eller ikke.

1.2 Konklusjon

Ved gjennomgang og vurdering av skadene på boggiene ble det ikke funnet skader eller feil som kan antas å ha vært til stede før avsporingen. Alle de observerte skadene kan forklares som en følge av togets bevegelser etter avsporingen, eller som følge av demontering og transport av boggiene fra ulykkesstedet til verkstedet Sundland.

1.3 Begrensninger/usikkerhet

For drivakslene hindrer drevkasse, elastiske koplinger og kraftoverføring inspeksjon av hele akselen. Eventuelle initiale feil i disse ville imidlertid gitt andre observerbare feil. Slike ble ikke funnet.

For noen av de observerbare skadene kan det ikke med sikkerhet avgjøres om skaden skyldes avsporingen eller den senere demonteringen av boggiene og transporten til verkstedet. Dette er uansett sekundært for oppdraget, men må tas med i betraktningen dersom skadebildet på boggiene skal nyttes til å tolke hendelsesrekkefølgen.

1.4 Besiktigelsesprotokoll

Observerte skader er listet pr boggi med referanse til standard boggibetegnelse og akselposisjonsbetegnelse. Det skilles mellom skader på venstre og høyre side i togets fartsretning. Ved avsporingen gikk toget med boggi MB7 som ledende boggi og akselposisjon 14 som ledende aksel. Toget sporet av mot venstre i fartsretningen.

1.4.1 Boggi nr. 64-022 MB 7 første boggi i fartsretning

1.4.1.1 *Generelt:*

- Skrapeskader på boggivange venstre side etter kontakt med terreng.
- På høyre side er det skader på demperne.
- Alle 4 sikringswire mellom bolster og boggiramme er slitt av
- Begge luftbelger ser intakte ut
- Fremre venstre og bakre høyre sideanslag for boggien er skadet (knust)
- Bruddstykke X5 kan passe i posisjonen for bakre høyre sideanslag
- Fremre venstre og bakre høyre lenk arm til torsjonsstag har skader på øvre oppheng
- Begge banemotorene er tilsynelatende uskadet

1.4.1.2 *Akselposisjon 14:*

- Hjulskivene har sår etter kontakt med terreng (spesielt på flensen)
- Aksel og akselhylse med elastiske elementer tilsynelatende uskadet
- Drevkassen ok
- Bremseskiver, klosser og holdere ok på begge sider
- Akselkasselokk på venstre side er slått av
- Pusseklosser ok på begge hjul

1.4.1.3 *Akselposisjon 13*

- Vestre hjul: slagmerker etter kontakt med terreng
- Høyre hjul: bare mindre skader
- Akselhylse har brudd ved den venstre elastiske koplingen.
- Venstre elastiske kobling har merker etter kontakt sannsynligvis med en skinne.
- Ingen observerbare skader på aksel inne i hylsen, observert gjennom sprekkene i hylsen. Ikke demontert for videre undersøkelse
- Drevkassen har mindre lakkskader
- Bremseskiver, klosser og holdere ok på begge hjul
- Pusseklosser ok på begge hjul

Figur 1: Boggi nr. 64-022 MB 7.

1.4.2 Boggi nr. 62-023 JTB 6 andre boggi i fartsretning

1.4.2.1 *Generelt:*

- Moderate skrapeskader på boggivange venstre side.
- Slitasjeskader og lakkskader etter kontakt med pukk i underkant på venstre side.
- Sikkerhetswire er slitt av i posisjon venstre fremme og høyre bak
- Mindre merker i sideanslag begge sider
- Bakre venstre luftbelg har klemskade, de øvrige er tilsynelatende intakt
- Magnetskinnebrems venstre side har store lakkskader etter kontakt med pukk

1.4.2.2 *Akselposisjon 12*

- Små lakkskader på aksel
- Moderate til små skader på hjulbanen begge hjul
- Bremseskiver ok på begge hjul
- Mangler bremsekloss på venstre hjul innside, men ingen slitasjemerker på klossholder.
- Nedre ytre feste for bremsesylinder er knekt etter kontakt med terreng.

1.4.2.3 *Akselposisjon 11*

- Aksel tilsynelatende uskadet
- Moderate til små skader på begge hjul
- Bremseskiver ok på begge hjul
- Ytre bremseklossholder (og kloss) borte på venstre side
- Bremseklosser ok på høyre side og indre venstre side ok.

Figur 2: Boggi nr. 62-023 JTB 6.

1.4.3 Boggi nr. 62-022 JTB 5 tredje boggi i fartsretningen

1.4.3.1 *Generelt:*

- Moderate skrapeskader på boggivange venstre side
- Alle 4 sikringswire er slitt av
- Sideanslag for boggi knust eller skadet på begge sider, men mest på høyre
- Bakre venstre topp på luftbelger er borte
- Bakre høyre topp på luftbelg er revet løs fra vognkassen
- Alle støtdempere er skadet
- Fremre feste for magnetskinnebrems venstre side er deformert
- Lakkskader på magnetskinnebremsene, mest på venstre side

1.4.3.2 *Akselposisjon 10*

- Aksel tilsynelatende uskadet
- Moderate skader på løpebane og flens på begge hjul
- Bremseskiver klosser og holdere ok på begge sider.
- Akselkasselokk på venstre side er slått av

1.4.3.3 *Akselposisjon 9*

- Aksel tilsynelatende uskadet
- Grove slagskader på venstre hjul, ytterkant
- Moderate skader på høyre hjul
- Bremseskiver, klosser og klossholdere ok på begge hjul
- Løftesikring venstre side brukket og bøyd
- Slitasjemerker etter kontakt med terreng/pukk under akselkasse venstre side

Figur 3: Boggi nr. 62-022 JTB 5.

1.4.4 Boggi nr. 64-023 MB 4

1.4.4.1 *Generelt:*

- Skrapeskader på boggivange venstre side
- Mindre kontaktskader på høyre side
- Høyre belg for luftfjæring ute av posisjon, men tilsynelatende hel
- Venstre belg tilsynelatende ok
- Dempere mellom bolster og boggiramme deformert på venstre side, ødelagt på høyre side
- Fremre venstre sikringswire ok, de øvrige 3 er slitt av
- Fremre sideanslag på begge sider er knust og borte
- Bakre sideanslag på venstre side er knust og delvis borte
- Bakre sideanslag høyre side er skadet
- Bakre lenkarm høyre side har bare lakkskader, de øvrige 3 er slitt løs fra festene
- Bolsteret ligger skjevt, heller mot venstre side og er trykket forover på høyre side

1.4.4.2 *Akselposisjon 8:*

- Aksel, akselhylse og elastiske koplinger er tilsynelatende uskadet
- Drevkassen har lakkskader på undersiden
- Mindre skader på hjul begge sider
- Bremseskiver, klosser og klossholdere ok på begge hjul
- Pusseklosser ok på begge hjul
- Understykke for akselkasse mangler på venstre side
- Akselkasselokk borte på venstre side
- Løftesikring slitt av og deformert på begge sider
- Banemotor tilsynelatende uskadet

1.4.4.3 *Akselposisjon 7:*

- Aksel, akselhylse og elastiske koplinger er tilsynelatende uskadet
- Drevkassen tilsynelatende uskadet
- Mindre skader på hjul begge sider
- Bremseskiver, klosser og klossholdere ok på begge hjul
- Pusseklosser ok på begge hjul
- Løftesikring venstre side defekt
- Akselkasselokk høyre side er skadet
- banemotor tilsynelatende uskadet men kabler og rørforbindelse til vogn er slitt av
- kjøleluft inntak er deformert

Figur 4: Boggi nr.64-023 MB4.

1.4.5 Boggi nr. 60-008 TB3

1.4.5.1 *Generelt:*

- Moderate skrapeskader på boggivange, venstre side
- Bolster flyttet bakover på venstre side og forskjøvet mot høyre
- Venstre belg ute av posisjon, høyre ok
- Alle 4 sikringswire er slitt av
- Bakre venstre sideanslag knust, feste deformert
- Bakre høyre sideanslag har mindre kontaktskade
- Fremre høyre sideanslag er uskadet
- Fremre venstre sideanslag er knust og borte, festet er deformert
- Alle 4 lenk armer er intakte
- Skrapeskader på magnetskinnebrems venstre side

1.4.5.2 *Akselposisjon 6:*

- Mindre lakkskader på aksel
- Minimale skader på begge hjul
- Indre bremsekloss på begge hjul er borte, ingen slitasjemerke på holderne
- Bremseskiver, klossholdere og øvrige klosser er ok
- Skader på akselkasselokk venstre side

1.4.5.3 *Akselposisjon 5:*

- Aksel tilsynelatende uskadet
- Indre bremsekloss høyre side mangler, ingen slitasjemerke på holderne
- Bremseskiver, klossholdere og øvrige klosser er ok
- Minimale skader på begge hjul

Figur 5: Boggi nr. 60-008 TB3.

1.4.6 Boggi nr. 62-024 JTB 2

1.4.6.1 *Generelt:*

- Skrapeskader på boggivange venstre side etter kontakt med terreng
- Høyre side er stort sett uskadet
- Magnetskinnebrems på venstre side har hatt kontakt med pukk
- Fremre feste for torsjonsstag synes revet løst på begge sider
- Bakre feste for torsjonsstag synes revet løs på venstre side, høyre side virker demontert under berging
- Alle 4 sikringswire er slitt av
- Samtlige luftbelger var demontert eller falt av

1.4.6.2 *Akselposisjon 4:*

- Moderate (lakk-)skader på aksel
- Moderate skader på hjulene på begge sider
- Ytre venstre bremsekloss mangler, ingen slitasjemerker på klossholder
- Bremseskiver, klosser og klossholdere for øvrig var ok
- Akselkasselokk på venstre side er revet av

1.4.6.3 *Akselposisjon 3:*

- Mindre ripe- og lakkskader på aksel
- Store slagskader på venstre hjul utside
- Små skader på høyre hjul
- Bremseskiver, klosser og klossholdere ok på begge sider.

Figur 6: Boggi nr. 62-024 JTB 2.

1.4.7 Boggi nr. 64-025 MB 1 bakerste boggi

1.4.7.1 *Generelt:*

- Skrapeskader på boggivange venstre side
- Begge luftbelger tilsynelatende ok
- Fremre venstre sikringswire er intakt
- Øvrige 3 sikringswire er slitt av
- Fremre venstre sideanslag knust
- Fremre høyre sideanslag knust og borte
- Bakre sideanslag skadet begge sider
- Fremre lenkarmer har skader øverst begge sider
- Bakre lenkarmer har bare mindre skader øverst begge sider
- Feste for skinnerydder deformert på venstre side

1.4.7.2 *Akselposisjon 2:*

- Aksel, akselhylse og elastiske koplinger tilsynelatende ok
- Drevkasse tilsynelatende ok
- Venstre hjul har små skader, høyrehjul har minimale skader
- Bremseskiver, klossholdere og klosser på begge hjul
- Pusseklosser ok
- Mindre slitemerker under venstre akselkasse
- Banemotor tilsynelatende uskadet

1.4.7.3 *Akselposisjon 1:*

- Aksel, akselhylse og elastiske koplinger tilsynelatende ok
- Drevkasse tilsynelatende ok
- Begge hjul har minimale skader
- Bremseskiver, klossholdere og klosser på begge hjul
- Mindre slitemerker under venstre akselkasse
- Banemotor tilsynelatende uskadet

Figur 7: Boggi nr. 64-025 MB 1.

1.5 Sammenstilling av noen av de observerte skadene

	Akselpoisjon	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Venstre side	Hjul	minimale skader	små skader	Store slagskader	moderate skader	minimale skader	minimale skader	mindre skader	mindre skader	Grove slagmerker	moderate skader	Små skader	moderate skader	Slagmerker	skadet
	Lenker	mindre skader	skader øverst	slitt løs	slitt løs	intakt	intakt	lakkskader	slitt løs					ok	skadet øverst
	Wire	slitt av	intakt	slitt av	slitt av	slitt av	slitt av	slitt av	ok	slitt av	slitt av	ok	slitt av	slitt av	slitt av
	Sideanslag	skadet	knust			knust, feste deformert	knust, feste deformert	knust, delvis borte	knust, delvis borte	skadet	skadet			ok	knust
	Boggivange	Skrapeskader		Skrapeskader		moderate skrapeskader		Skrapeskader		Moderate skrapeskader		Moderate skrapeskader		Skrapeskader	
	Boggi	MB 1		JTB 2		TB 3		MB 4		JTB 5		JTB 6		MB 7	
Høyre side	Boggivange	stort sett uskadet		stort sett uskadet		stort sett uskadet		små skader		små skader		små skader		Skader på dempere	
	Sideanslag	skadet	knust og borte			Mindre kontaktskad	uskadet	skadet	knust, delvis borte	mer skadet	mer skadet			knust	ok
	Wire	slitt av	slitt av	slitt av	slitt av	slitt av	slitt av	slitt av	slitt av	slitt av	slitt av	slitt av	ok	slitt av	slitt av
	Lenker	mindre skader	skader øverst	demontert	slitt løs	intakt	intakt	slitt løs	slitt løs					skadet øverst	ok
	Hjul	minimale skader	minimale skader	små skader	moderate skader	minimale skader	minimale skader	mindre skader	mindre skader	moderate skader	moderate skader	små skader	moderate skader	mindre skader	skadet

1.6 Referanse til øvrig dokumentasjon

I forbindelse med arbeidet har man også gjennomgått og støttet seg på følgende dokumenter:

«Rules for representation, NSB coach designation»; Stadler/NSB: gir en oversikt over betegnelser for vogner, boggier og akselposisjoner.

Tekniske tegninger mottatt i epost fra Stadler datert 29.februar 2012:

- BU_1196331 Motordregestell MDG1
- BU_1314340 Motordregestell MDG4
- BU_1248457 Laufdregestell
- BU_1248457 Jacobdregestell JDG2+6
- BU_1182091 Jacobdregestell JDG5

Beskrivelser av boggiene mottatt i epost fra Stadler 08. mars 2012:

- NSB Dok.nr: A-61071-VD-02090; Rev. 1: Product description Motor bogie
- NSB Dok.nr: A-61071-VD-02091; Rev. 1: Product description Trailer bogie
- NSB Dok.nr: A-61071-VD-02092; Rev. 1: Product description Jacobs trailer bogie

Måleresultater fra hjulmåling mottatt i epost fra Stadler085. mars 2012:

- NSB train5-MB7 64-022-wheel measurement summary
- NSB train5-MB7 64-022 wheel measurement detailed

Vältningsberäkningar för NSB fordon Typ 74, 70, 72 och 5

Dokumentbeteckning	:	TS4631-0000-2-RES utgåva 2 , UN
Datum	:	2012-04-13

C.bl.06-5

Sammanfattning

NSB har gett Interfleet Technology i uppdrag att beräkna de hjulomlastningar som uppträder vid exceptionella spårplansaccelerationer för olika fordonstyper.

Vältningsberäkningar har genomförts för fyra olika fordon; NSB typ 74, 70, 72 och 5. Beräkningarna är gjorda med fordonsdynamiska simuleringar, och fordonsmodeller har tagits fram med hjälp av fordonsdata erhållna från NSB och Stadler. Fokus har varit på att ge en korrekt beskrivning av de kvasistatiska värdena utifrån givna förutsättningar, och fordonsmodellernas komplexitet har anpassats för detta. Beräkningarna visar att de olika fordonstyperna har i princip likvärdiga marginaler mot vältning om man enbart ser till de kvasistatiska värdena.

Utöver de kvasistatiska vältningsberäkningarna har även dynamiska simuleringar genomförts för typ 74 med hjälp av uppmätta spårdata. Dessa beräkningar ställer betydligt högre krav på modelleringen de ingående fordonskomponenterna, varför onoggrannheten är betydligt större i dessa resultat. Längden på de spåravsnitt som har simulerats har dessutom varit mycket begränsad, varför det är svårt att göra några generella uttalande om dynamikens inverkan på vältningsrisken. Simuleringarna indikerar att det är möjligt att kortvarigt helt avlasta en boggi utan att fordonet välter.

Slutligen redovisas kvasistatiska spårkrafter, ΣY, Y/Q och Y för typ 74 som funktion av spårplansacceleration. Även i detta fall bör resultaten användas med försiktighet på grund av begränsningarna i den använda fordonsmodellen.

Titel	:	Vältningsberäkningar för NSB fordon Typ 74, 70, 72 och 5
Dokumentbeteckning	:	TS4631-0000-2-RES utgåva 2
Utgåva	:	2
Datum	:	2012-04-13

Ändringshistorik

Utgåva	Ändringsbeskrivning	Datum
1	Första utgåva	2012-03-30
2	Andra utgåva. Fel rättade, infört Figur 9 och Figur 14	2012-04-13

C.bl.06-5

INNEHÅLL

C.bl.06-5

1. Inledning

NSB har gett Interfleet Technology i uppdrag att beräkna de hjulomlastningar som uppträder vid exceptionella spårplansaccelerationer för ett antal fordonstyper.

1.1 Uppdrag

Uppdraget är att beräkna vid vilken spårplansacceleration något fordon når vältningsgränsen. Beräkningarna görs i första hand vid ideala förhållanden, d.v.s. utan ytterligare dynamik p.g.a. spårfel eller ändring i spårgeometri. Fyra fordonstyper, motorvagnståg typ 74, typ 70, typ 72 samt personvagn typ 5 skall undersökas.

För typ 74 görs även en bedömning av dynamikens inverkan på vältningskriteriet.

För typ 74 skall dessutom de uppträdande kvasistatiska spårkrafterna vid dessa extrema förhållanden beräknas.

2. Bedömningskriterier

Bedömningskriterier för säkerheten mot vältning finns i TSD Höghastighet Rullande materiel [1] och EN 14067-6 [2] i samband med sidovindar, och i UIC 518-1 [3] i samband med godkännande av fordon för höga spårplansaccelerationer. I båda fallen är det, av naturlig orsak, graden av hjulavlastning på de innerhjulen i en kurva som avgör benägenheten för vältning.

I TSD och EN 14067-6 är bedömningskriteriet:

$\Sigma Q_{\_boggi\_inner}/Q0 \leq 0.9$

I UIC 518-1 är bedömningskriteriet:

$\eta = [\Sigma Q_{\_boggi\_ytter} - \Sigma Q_{\_boggi\_inner}]/[\ \Sigma Q_{\_boggi\_ytter} + \Sigma Q_{\_boggi\_inner}] \leq 1.0$

I båda kriterierna är krafterna på hjulen lågpassfiltrerade med en brytfrekvens på 1.5 Hz.

I denna rapport redovisas η som funktion av spårplansacceleration och hastighet.

3. Förutsättningar

3.1 Simuleringsverktyg

Vältningsberäkningarna har gjorts med hjälp av fordonsdynamiska simuleringar i simuleringsverktyget Gensys [4]. Tredimensionella modeller av de fyra olika fordonstyperna har tagits fram, där de olika fordonsdelarna, hjulaxlar, boggier och vagnskorgar, beskrivs som stela kroppar. Dessa är förbundna med fjädrar och dämpelement för att motsvara den verkliga vagnen. Dessa modeller används sedan för att göra tidssimuleringar på några km långa spåravsnitt. Dessa är såväl ideala som baserade på uppmätningar av verkliga spår. De beräknade vertikalkrafterna mellan hjul och räl har utvärderats enligt bedömningskriterierna ovan.

3.2 Fordonsdata

Indata har för fordonstyperna har erhållits av NSB och för typ 74 även från tillverkaren Stadler. Typ 74 har den mest kompletta fordonsdynamiska modellen. För övriga fordonstyper har denna grundmodell modifierats med avseende på fordonskonfiguration, massor, tyngdpunktslägen, primär- och sekundärstyvheter och sekundärstopp.

Vagnskorgarnas tyngdpunktslägen i vertikal riktning har erhållits från NSB och Stadler. Tyngdpunktsläget i lateral riktning har för samtliga fordon antagits vara centrerat. För typ 5 FR5-1 vagnen är detta sannolikt inte korrekt. Layouten för denna vagn tyder på att tyngdpunkten har en signifikant förskjutning i lateral riktning.

Tyngdpunktsläget i longitudinell riktning har antagits ligga mitt i mellan boggierna för typ 70 och typ 5 medan de, för typ 74, beräknats med hjälp av överlämnad information från Stadler. För typ 72 har tyngdpunktsläget i longitudinell riktning i ändvagnarna antagits vara snarlikt motsvarande vagnar i typ 74 medan det för mellanvagnarna antagits ligga centrerat mellan boggierna.

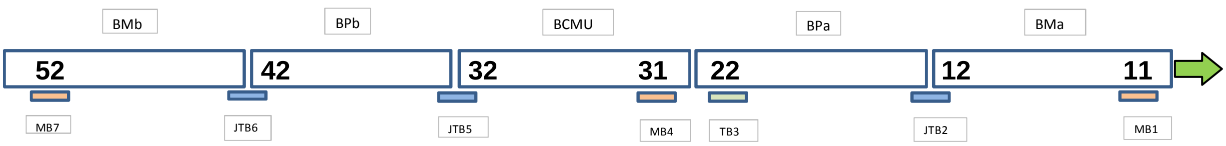
Fordonskopplen mellan vagnarna är modellerade på ett förenklat sätt med enbart ett bussningselement. För de vagnsändar som inte är förenade med jacobsboggier kan denna förenkling påverka de simulerade spårkrafterna i lateral led. Detta gäller i synnerhet för Typ 70, vilken har olika boggiavstånd för BFM och B-vagnarna. Däremot påverkas vertikalkrafterna i betydligt mindre omfattning, varför förenklingen inte bedöms påverka slutsatserna av vältningssimuleringarna. För typ 70 och typ 5 har beräkningar gjorts även utan koppel och detta bekräftar denna slutsats.

Utformning och modellering av de laterala och vertikala sekundära stoppen inverkar på resultaten vid dessa höga spårplansaccelerationer. Osäkerheter i beskrivningen av dessa stopp ger en osäkerhet i framförallt de dynamiska beräkningarna.

3.3 Fordonskonfigurationer

3.3.1 Motorvagn typ 74

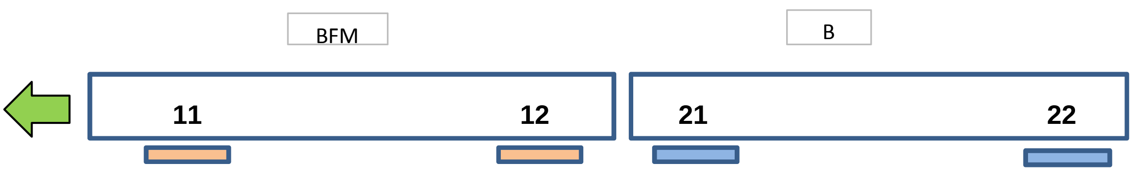
För typ 74 har ett helt 5-vagnars tågsätt simulerats. Fordonet har både jacobsboggier och konventionella boggier, även som mittboggier. Den använda fordonskonfigurationen visas i Figur 1.



Figur 1. Simulerad fordonskonfiguration för NSB Typ 74. Den i rapporten använda bogginumreringen och färdriktningen framgår av figuren.

3.3.2 Motorvagn typ 70

För typ 70 har endast de två främsta vagnarna, BFM och B, beräknats. Övriga vagnar inklusive manövervagnen bedöms vara likvärdiga eller bättre med avseende på vältning. Den använda fordonskonfigurationen visas i Figur 2.



Figur 2. Simulerad fordonskonfiguration för NSB Typ 70. Den i rapporten använda bogginumreringen och färdriktningen framgår av figuren.

3.3.3 Motorvagn typ 72

Typ 72 har en annan typ av löpverk än övriga fordonstyper, med enkelaxliga boggier sammanbundna parvis med länkar. I simuleringsmodellen har två enkelaxliga boggier i leden

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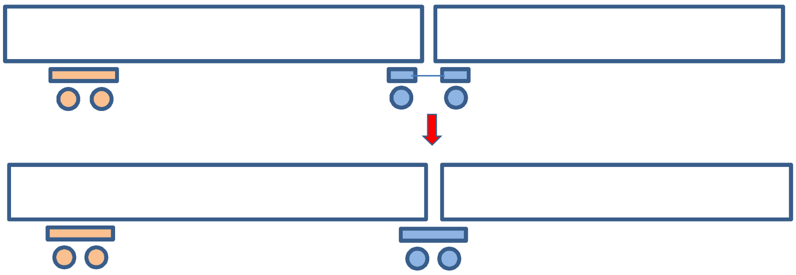
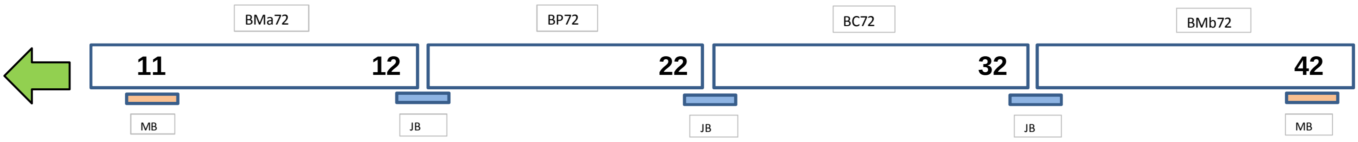
mellan vagnarna ersatts av en jakobsboggi, se Figur 3 nedan. Ur vältningsaspekten bör detta vara en acceptabel förenkling.



Figur 3. Två enkelaxliga boggier har modellerats som en jacobsboggi.

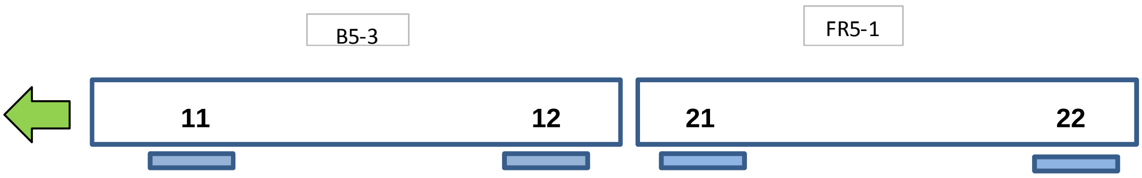
För typ 72 har ett fyravagnars tågsätt använts vid simuleringarna, se Figur 4.



Figur 4. Simulerad fordonskonfiguration för NSB Typ 72. Den i rapporten använda bogginumreringen och färdriktningen framgår av figuren.

3.3.4 Personvagn typ 5

För typ 5 har endast två vagnar, B5-3 och FR5-1, modellerats. Övriga vagnar bedöms vara likvärdiga eller bättre i detta hänseende. Den använda fordonskonfigurationen visas i Figur 5.



Figur 5. Simulerad fordonskonfiguration för NSB Typ 5. Den i rapporten använda bogginumreringen och färdriktningen framgår av figuren.

3.4 Lastfall

Två lastfall har studerats för samtliga fordon:

- Tara (tomlast)
- Last motsvarande fullt antal sittande + 4 stående/m^2

3.5 Spårdata

De kvasistatiska beräkningarna har gjorts på ett idealt spår utan spårlägesfel, i en högerkurva med kurvradie 250 meter och 140 mm rälsförhöjning. Simuleringarna har startat på rakspår, men fordonen har efter den inledande övergångskurvan befunnit sig i en konstant cirkulärdel tills simuleringarna har avslutats.

För bedömningen av de dynamiska effekterna har simuleringar gjorts på två banavsnitt på Dovrebanan respektive på Sörlandsbanan. Dessa banavsnitt har valts som exempel på avsnitt med snäva kurvor och förhållandevis dåligt spårläge eller/och svår spårgeometri. Simuleringarna ger alltså information om både inverkan av spårgeometri, såsom övergångskurvornas utformning, och av lokala spårfel.

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Banavsnitt 1: Dovrebanan mellan km 170.5 och 173.5 har ett antal kurvor med c:a 250 m radie och förhållandevis dåligt spårläge (inklusive geometrifel eller fel med stor våglängd).

Banavsnitt 2: Sörlandsbanan mellan km 128 och 130 har ett antal kurvor med c:a 300 m's radie inklusive några med kort utsträckning. Spårkvaliteten på detta avsnitt förefaller något bättre än på avsnitt 1.

I Bilaga 1 visas kurvaturen för de valda avsnitten.

3.6 Hjul/räl-kontakt

Rälprofilen har vid samtliga simuleringar varit 54E3 (S54) med lutning 1:20, och hjulprofilen har varit P8 med flänstjocklek 30 mm. Kontaktmodellen, vilken beräknar krafterna mellan hjul och räl i varje tidpunkt, har varit av en typ som normalt används för spårkraftsberäkningar[1]. De aktuella beräkningarna har antagit enpunktskontakt, d.v.s. med enbart en kontaktyta åt gången mellan hjul och räl.

Vid samtliga beräkningar har friktionskoefficienten μ=0.3 använts.

3.7 Simuleringsfall

Grundsimuleringarna har gjorts kvasistatiskt på idealt spår i en mycket lång kurva, med radien 250 m och rälsförhöjningen 140 mm. Genom att öka hastigheten gradvis i kurvan ökas också spårplansaccelerationen successivt. Beräkningen avbryts då det ledande hjulparet får 100 % hjulavlastning på innerhjulet. Detta innebär att beräkningarna, med något undantag, inte resulterar i faktisk vältning.

De dynamiska simuleringarna har gjorts på de två banavsnitt, som beskrivs ovan. Hastigheten har anpassats till spårplansaccelerationerna 2.0 m/s^2 och 3.0 m/s^2 i de snävaste kurvorna på den studerade sträckan. På banavsnitt 1 har dessutom hastighet motsvarande spårplans-accelerationerna 3.7 m/s^2 och 4.0 m/s^2 simulerats. De dynamiska värdena beräknas som de maximala (absoluta) värden minskat med de tillhörande ideala värden, som den aktuella kurvgeometrin skulle resultera i.

Förutom simuleringar med varierande spårplansacceleration med fordon med nominella fordonsdata har känsligheten för tyngdpunktens vertikala läge, som alltid är behäftad med en signifikant osäkerhet, studerats för typ 74.

4. Resultat

4.1 Kvasistatisk vältningsberäkning

Fordonen har simulerats i en lång kurva med kurvradie 250 m och rälsförhöjningen 140 mm. Hastigheten har ökats successivt från 80 km/h tills att första boggin uppnådde η=1, varvid simuleringen avbrutits. Ett exempel på resultat från en sådan simulering visas i Figur 6. I det vänstra diagrammet visas η som funktion av spårplansaccelerationen a_y. Varje boggi redovisas som en separat kurva, och respektive bogginummer enligt avsnitt 3.3 framgår av förklaringarna till vänster om diagrammen. I det högra diagrammet visas samma information men med hastighet på x-axeln. Beräkningarna för de fyra olika fordonen visas i Bilaga 2 till Bilaga 5.

Resultaten sammanfattas från diagrammen genom att ge spannet mellan spårplans-accelerationen då den sämsta och den bästa boggin når η-värdet 0.9 motsvarande 90 % avlastning redovisas. Dessa värden är indikerade med lodräta streck i Figur 6.

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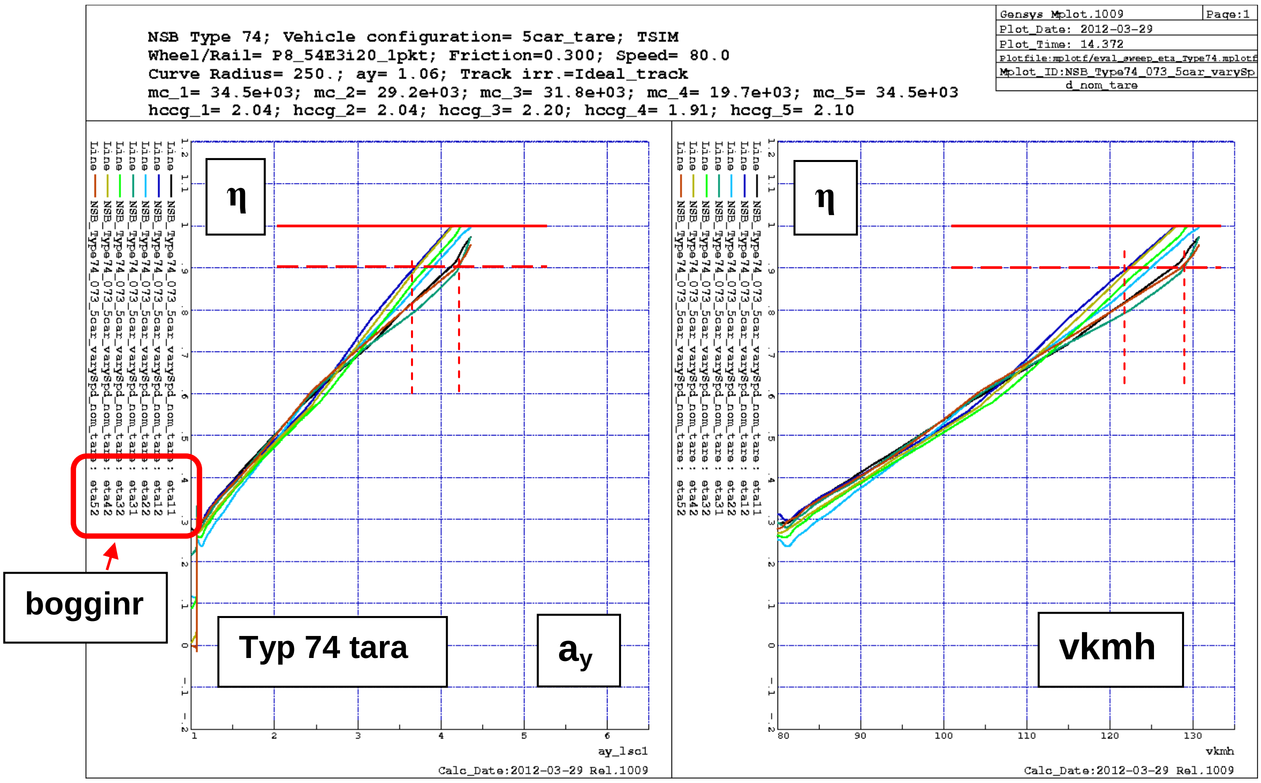
[1] wr_coupl_pe3. Kontaktmodellen finns beskriven på Gensys hemsida, www.gensys.se.



Figur 6. Diagram av η per boggi som funktion av spårplansacceleration (vänster diagram) och hastighet (höger diagram) för typ 74, tara. Gränsvärdet η=1.0, d.v.s. total hjulavlastning, samt η=0.9, vilket har använts i de redovisade tabellerna, är inritade i diagrammen. De vertikala strecken visar spannet mellan sämsta och bästa boggi vid η=0.9.

I Tabell 1 redovisas resultaten för η-värdet 0.9 som funktion av spårplansaccelerationen [m/s^2] för de fyra fordonstyperna.

Tabell 1. Sammanfattning över spårplansaccelerationer då η når 0.9 för samtliga fordon.

	tara		**sittande + 4 stående/m^2**	
	$\eta_{0.9}$ sämsta boggi	$\eta_{0.9}$ bästa boggi	$\eta_{0.9}$ sämsta boggi	$\eta_{0.9}$ bästa boggi
Typ 74	3.68	4.20	3.70	4.00
Typ 72	3.62	4.70	3.59	4.42
Typ 70 *	3.76	5.40	3.59	5.00
Typ 5 *	3.65	4.20	3.54	4.00

** För typ 70 och typ 5 redovisas värdena för de separata vagnarna, d.v.s. då inverkan av kopplet tagits bort.*

Motsvarande värden som funktion av hastighet [km/h] i den aktuella kurvan, med kurvradie 250 m och rälsförhöjning 140 mm, visas i Tabell 2.

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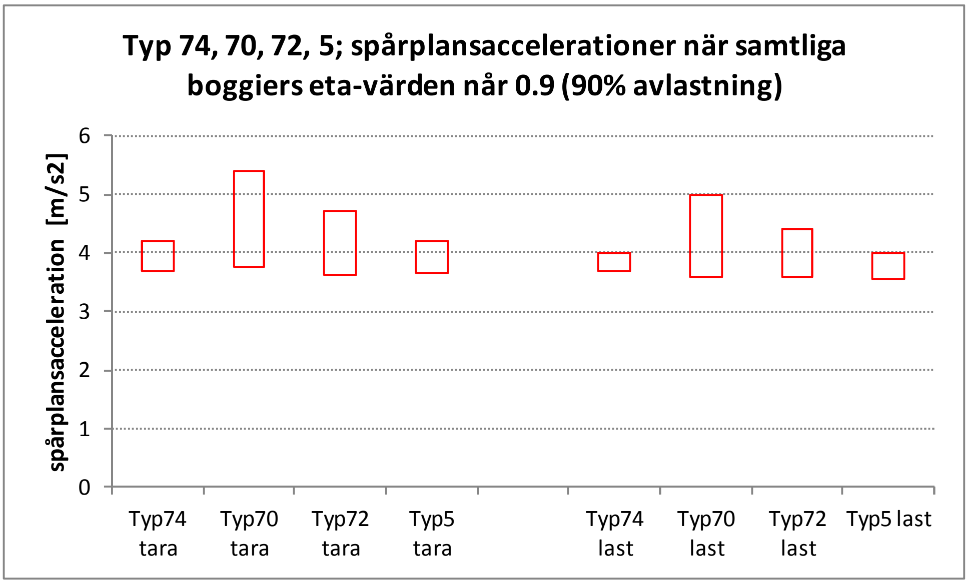
Tabell 2. Sammanfattning av fordonshastigheter i den aktuella kurvan (R=250 m, h_a=140mm) när η når 0.9 för samtliga fordon.

	tara		sittande + 4 stående/m²	
	$\eta_{0.9}$ sämsta boggi	$\eta_{0.9}$ bästa boggi	$\eta_{0.9}$ sämsta boggi	$\eta_{0.9}$ bästa boggi
Typ 74	122	129	122	126
Typ 72	121	135	121	131
Typ 70 *	123	144	121	138
Typ 5 *	122	129	120	127

** För typ 70 och typ 5 redovisas värdena för de separata vagnarna, d.v.s. då inverkan av kopplet tagits bort.*

Resultaten enligt Tabell 1 åskådliggörs schematiskt i Figur 7.



Figur 7. Översiktligt diagram av spårplansaccelerationen då η = 0.9 för de studerade fordonstyperna.

Som framgår av figuren skiljer sig inte de sämsta värdena för de olika fordonstyperna nämnvärt. En förklaring är att man vid dessa höga sidoaccelerationer ligger i hård kontakt med både lateral- och vertikalstoppen hos vagnskorgarna, vilket är det som begränsar rörelsen. Individuella skillnader i löpverken har därför mindre betydelse. Att de bästa värdena för typ 70 och 72 blir högre än för de andra fordonstyperna beror till stor del på den förhållandevis låga tyngdpunkten i ändvagnarna för dessa fordon.

4.2 Tyngdpunktens inverkan

För typ 74 har en studie av inverkan av tyngdpunktens höjd gjorts. Tyngdpunkternas höjder har varierats ± 200 mm från de nominella höjderna enligt Stadler.

I Figur 8 visas spannen i spårplansacceleration [m/s^2] för η = 0.9, dels för den nominella tyngpunktshöjden och dels för en ökning respektive minskning med 200 mm. Värdena avser typ 74 tara och lastad.

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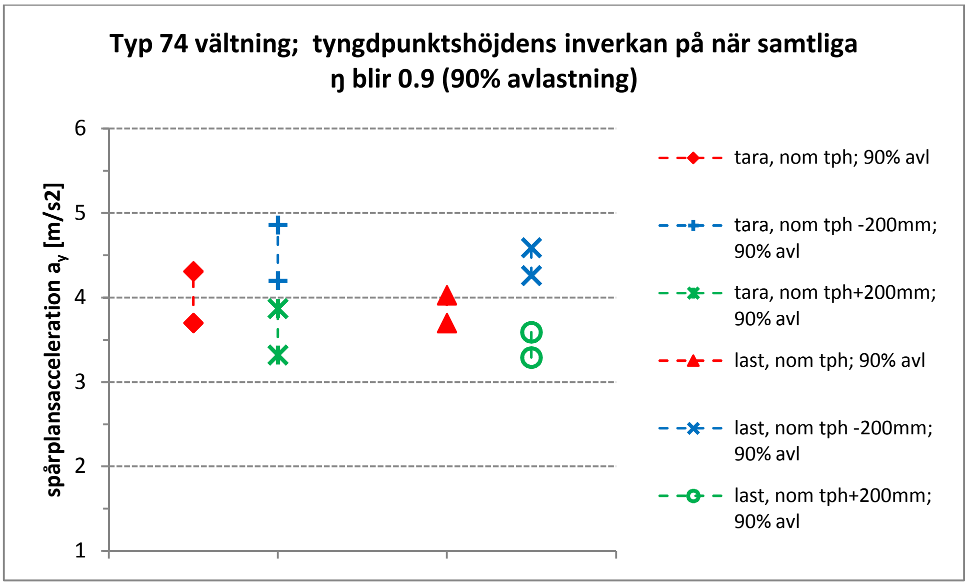
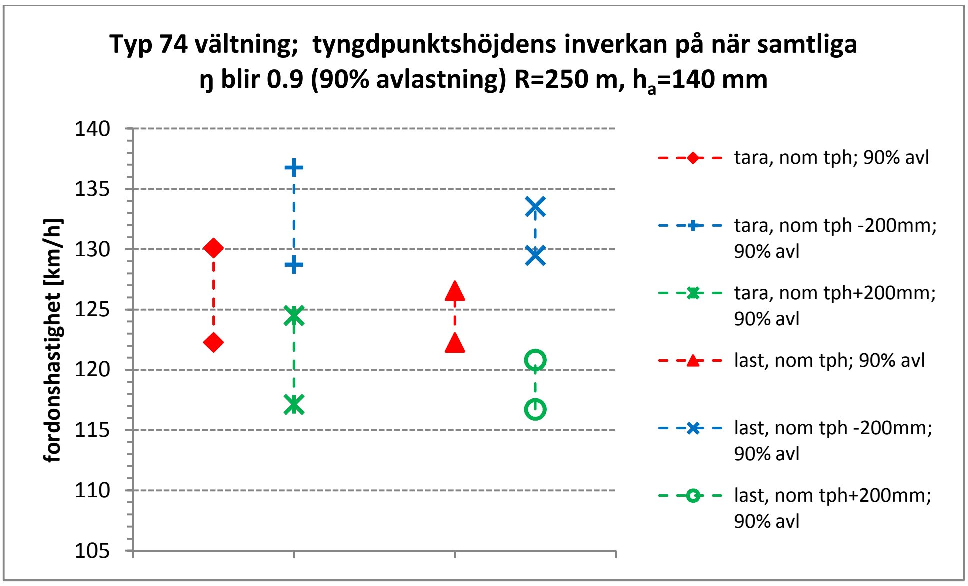


Figur 8. Inverkan av tyngdpunktens höjd på spårplansaccelerationen för η = 0.9 för typ 74.

Motsvarande diagram uttryckt i fordonshastighet i en kurva med radie 250 m och rälsförhöjning 140 mm visas i Figur 9.



Figur 9. Motsvarande diagram som Figur 8, men uttryckt i fordonshastighet för en kurva med kurvradie 250 m och rälsförhöjning 140 mm.

4.3 Dynamisk vältningsberäkning för typ 74

Förutom de kvasistatiska vältningsberäkningarna har även simuleringar gjorts för typ 74 på spår med spårlägesfel för att ge en uppfattning om de dynamiska tillskotten till η.

Simuleringar har gjorts på banavsnitten enligt avsnitt 3.5. På banavsnitt 2, Sörlandsbanan, har simuleringar gjorts med spårplansaccelerationerna c:a 2 och 3 m/s^2. På banavsnitt 1, Dovrebanan, har simuleringar med c:a 2.0, 3.0, 3.7 och 4.0 m/s^2 gjorts. Vid c:a 4.2 m/s^2 inträffade vältning.

Spårplansaccelerationerna motsvarar hastigheterna enligt Tabell 3 nedan.

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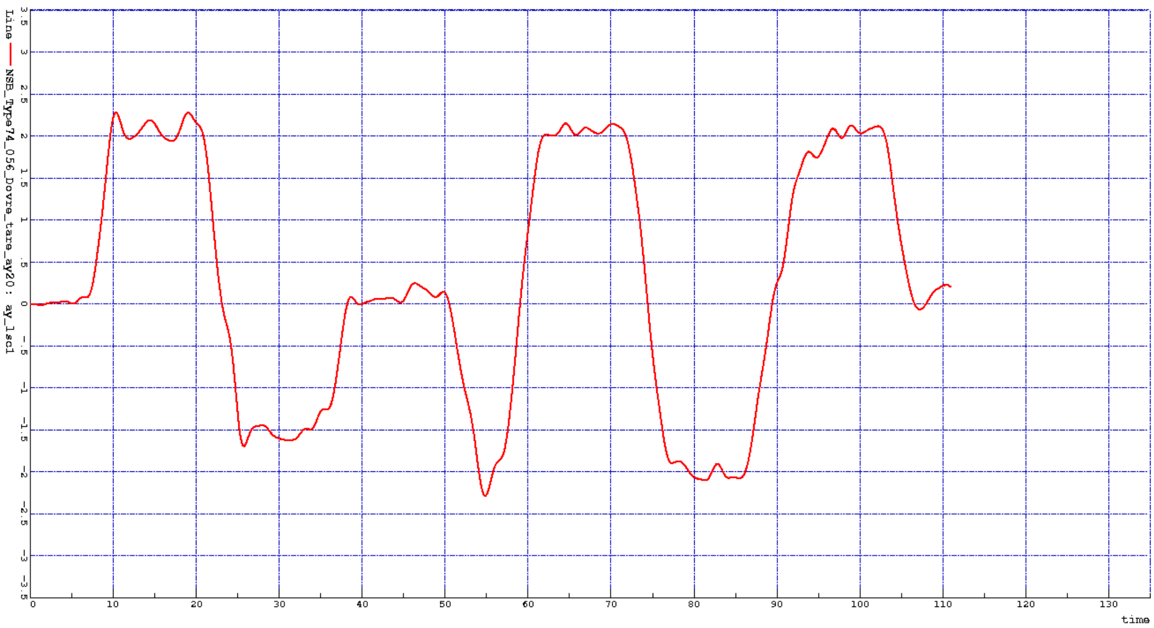
Tabell 3. Hastigheter och motsvarande approximativa spårplansaccelerationer som har simulerats.

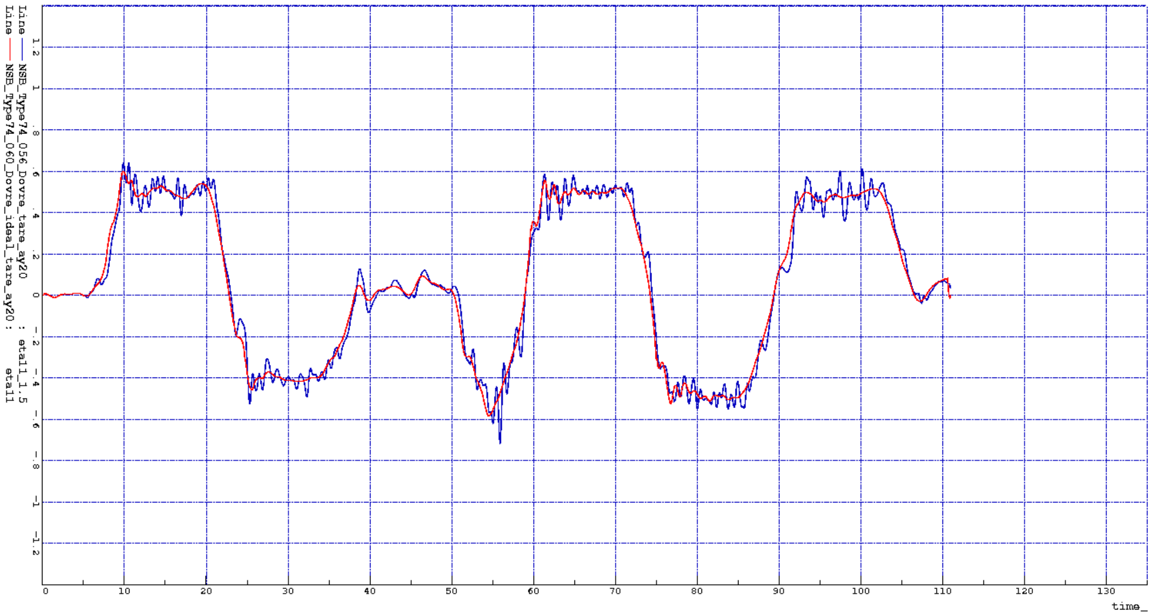
	Banavsnitt 1 Sörlandsbanan	Banavsnitt 2 Dovrebanan
Spårplansacceleration [m/s^2]	Hastighet [km/h]	Hastighet [km/h]
2.0	107	98
3.0	123	113
3.7	–	122
4.0	–	126

Hastigheterna är anpassade så att spårplansaccelerationerna i de undersökta kurvorna motsvarar värdena ovan. Eftersom den aktuella geometrin varierar mellan kurvorna kommer också den verkliga accelerationen att variera, se Figur 10. Men accelerationen 2.0 m/s^2 i det aktuella fallet stämmer ändå rätt bra i fem av kurvorna. Det är bara i dessa fem kurvor från avsnitt 2 och motsvarande fyra kurvor från avsnitt 1 som bedöms med avseende på dynamiken.

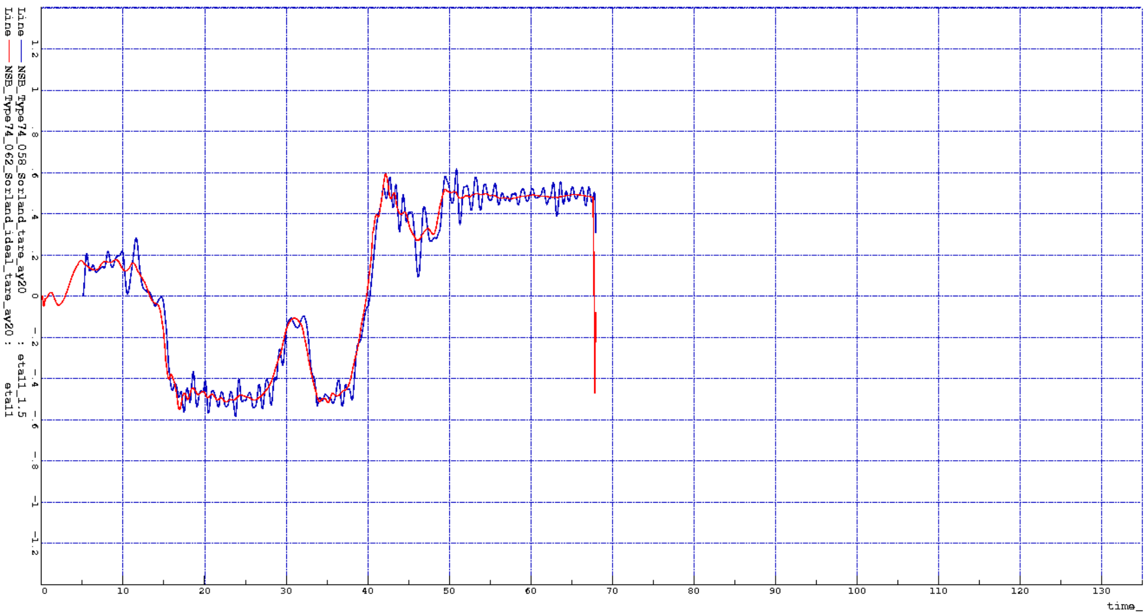


Figur 10. Aktuell spårplansacceleration, med riktvärdet 2 m/s^2, i hastigheten 98 km/h på banavsnitt 2.

I Figur 11 visas η för typ 74, boggi 11, med spårplansaccelerationen 2 m/s^2 på banavsnitt 2 (Dovrebanan). I Figur 12 visas motsvarande resultat för banavsnitt 1 (Sörlandsbanan).



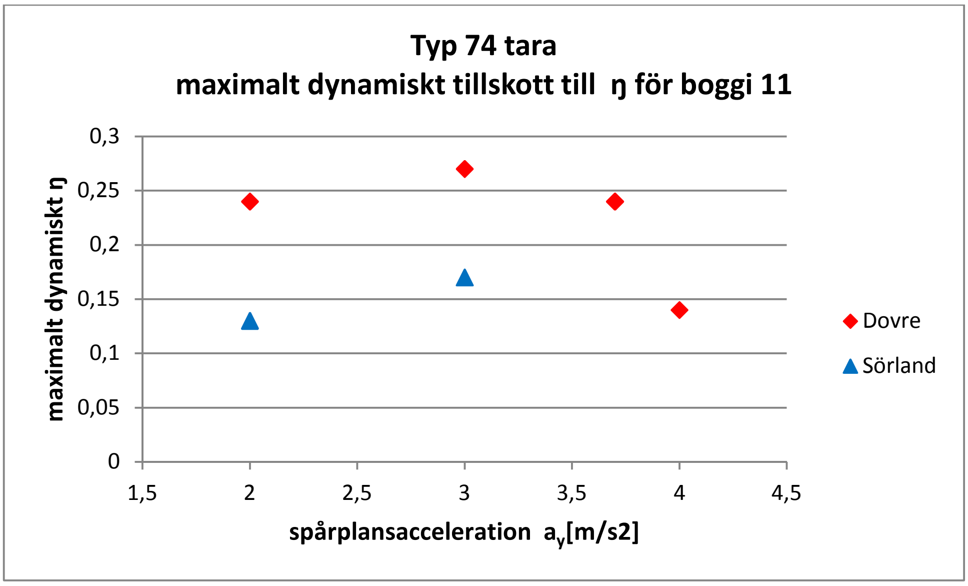
Figur 11. Dynamiskt η för typ 74, boggi 11, med spårplansaccelerationen 2 m/s² på banavsnitt 2 (Dovrebanan). Röd kurva avser simulering i idealt spår och blå kurva simulering med verkligt spårläge.



Figur 12. Dynamiskt η för typ 74, boggi 11, med spårplansaccelerationen 2 m/s² på banavsnitt 2 (Sörlandsbanan). Röd kurva avser simulering i idealt spår och blå kurva simulering med verkligt spårläge.

I Bilaga 6 visas resultat för dynamiska simuleringar av η för boggi 11 med olika spårplans-acceleration på banavsnitt 2 (Dovrebanan).

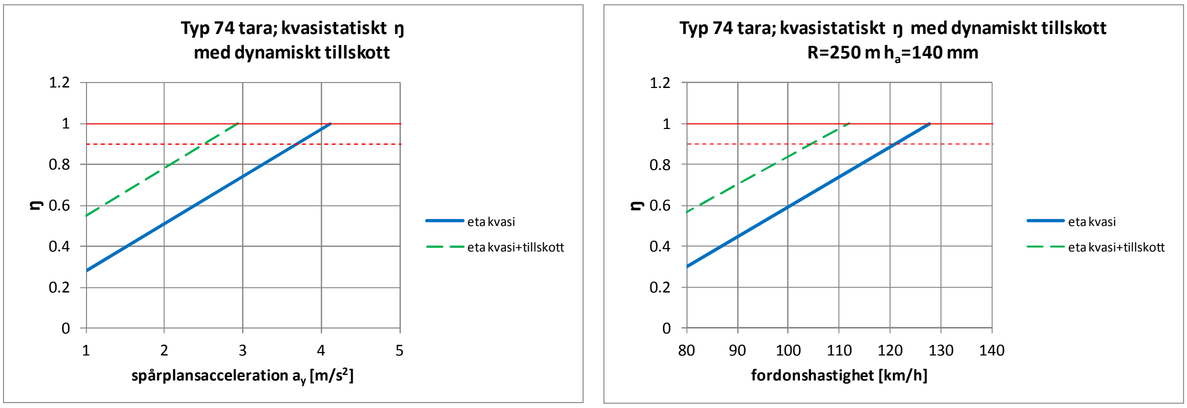
De dynamiska tillskotten till η har utvärderats genom att det kvasistatiska värdet har subtraherats från det dynamiska η. En sammanställning av de maximala dynamiska tillskotten för boggi 11 i de studerade kurvorna visas i Figur 13. Värdena visas som funktion av den nominella spårplansaccelerationen.



Figur 13. Maximalt dynamiskt η för boggi 11 i de studerade kurvorna.

Som synes minskar det dynamiska η för de extrema spårplansaccelerationerna. Detta beror dels på att de mekaniska stoppen kommer i ingrepp i ökad grad och dels på, för 4 m/s^2 fallet, att innerhjulen på den aktuella boggin redan är fullt avlastade momentant, d.v.s. η = 1 är en fysikalisk gräns. Det krävs dock uppenbarligen ytterligare hastighetsökning innan vältning inträffar.

En illustration av effekten av att addera ett dynamiskt tillskott till det kvasistatiska η visas i Figur 14. I dessa diagram har det maximala dynamiska tillskottet för boggi 11, se Figur 13, adderats till det kvasistatiska η för den sämsta boggin enligt Figur 6. Observera att det de simuleringar som är gjorda pekar på att det kan finnas en betydande konservatism i att göra på detta sätt. Värdet η=0.9 uppnås vid spårplansaccelerationen 2.6 m/s^2, medan vältning i simuleringarna på detta spåravsnitt skedde mellan 4.0 och 4.2 m/s^2.



Figur 14. Illustration av effekten av att addera ett dynamiskt tillskott till det kvasistatiska η. Typ 74 tara, med det största dynamiska η från Figur 13.

Som påpekats ovan bedöms den detaljerade beskrivningen och modelleringen av konstruktionselement, som t.ex. de mekaniska stoppen, påverka de dynamiska resultaten signifikant. Den förenklade och till delar uppskattade beskrivningen av dessa parametrar ger därför en osäkerhet för dessa värden. För att kunna dra några bestämda slutsatser i detta avseende krävs en noggrannare beskrivning av fordonen, än vad som varit tillgängligt inom ramen för detta uppdrag.

Det måste också påpekas att, även om svåra spåravsnitt valts ut, det ändå bara är några få km som studerats. Det är därför svårt att göra några generella uttalanden om förväntade dynamiska η.

4.4 Kvasistatiska spårkrafter för typ 74

För typ 74 redovisas även värden på kvasistatiska spårkrafter. Simuleringsmodellen är den mest detaljerade av de fyra fordonstyperna, men det bör påpekas återigen att den innehåller betydande förenklingar. Så är till exempel primärfjädrarna representerade av enbart sina linjäriserade styvheter, och saknar olinjära effekter såsom tilltagande styvhet med ökad deformation och ökad dynamisk styvhet. De spårkrafter som redovisas skall därför ses som indikativa värden och användas med försiktighet.

I Bilaga 7 redovisas kvasistatisk spårförskjutningskraft ΣY som funktion av spårplansacceleration och hastighet i den aktuella kurvan med radie 250 m och rälsförhöjning 140 mm. De redovisade värdena är normerade gentemot gränsvärdet enligt UIC518, där P_0 är den statiska axellasten i kN:

$$\boldsymbol{\Sigma Y_{norm}} = \frac{\boldsymbol{\Sigma Y}}{\mathbf{1.0} \cdot \left(\mathbf{10} + \frac{\boldsymbol{P_0}}{\mathbf{3}}\right)}$$

I Bilaga 8 redovisas kvasistatisk flänsklättringskvot Y/Q på ytterhjulen som funktion av spårplansacceleration och hastighet. Slutligen redovisas laterala spårkrafter Y på ytterhjulen i Bilaga 9 på motsvarande sätt.

5. Sammanfattning

I denna rapport redovisas beräkningar av fordonsvältning för fyra olika fordon, NSB typ 74, 70, 72 och 5. Beräkningarna är gjorda med fordonsdynamiska simuleringar, och fordonsmodeller har tagits fram med hjälp av fordonsdata erhållna från NSB och Stadler. Fokus har varit på att ge en korrekt beskrivning av de kvasistatiska värdena utifrån givna förutsättningar, och fordonsmodellernas komplexitet har anpassats för detta. Beräkningarna visar att de olika fordonstyperna har i princip likvärdiga marginaler mot vältning.

Utöver de kvasistatiska vältningsberäkningarna har även dynamiska simuleringar genomförts för typ 74 med hjälp av uppmätta spårdata. Dessa beräkningar ställer betydligt högre krav på modelleringen de ingående fordonskomponenterna, varför onoggrannheten är betydligt större i dessa resultat. Längden på de spåravsnitt som har simulerats har dessutom varit mycket begränsad, varför det är svårt att göra några generella uttalande om dynamikens inverkan på vältningsrisken. Simuleringarna indikerar att det är möjligt att kortvarigt helt avlasta en boggi utan att fordonet välter.

Slutligen redovisas kvasistatiska spårkrafter, ΣY, Y/Q och Y för typ 74 som funktion av spårplansacceleration. Även i detta fall bör resultaten användas med försiktighet på grund av begränsningarna i den använda fordonsmodellen.

6. Referenser

[1] TSD Höghastighet, Rullande materiel: L245/405 Teknisk specifikation för driftskompatibilitet (TSD) avseende delsystemet "Rullande materiel". 12.9.2002.

[2] EN 14067-6:2010; Railway applications – Aerodynamics, Part 6: requirement and test procedures for cross wind assessment.

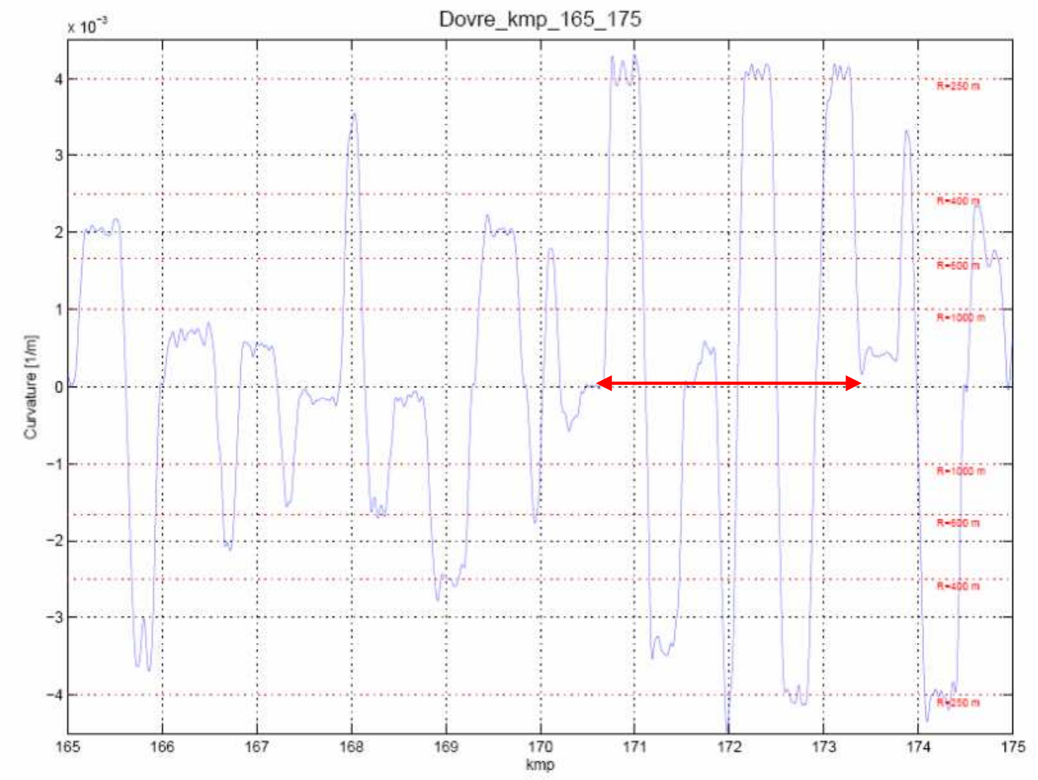
[3] UIC 518-1; Supplement to UIC leaflet 518: application to vehicles equipped with a cant deficiency compensation system and/or to vehicles intedned to operate with a higher cant deficiency than stated for categories I to III. 1st edition, May 2004.

[4] Gensys homepage: www.gensys.se

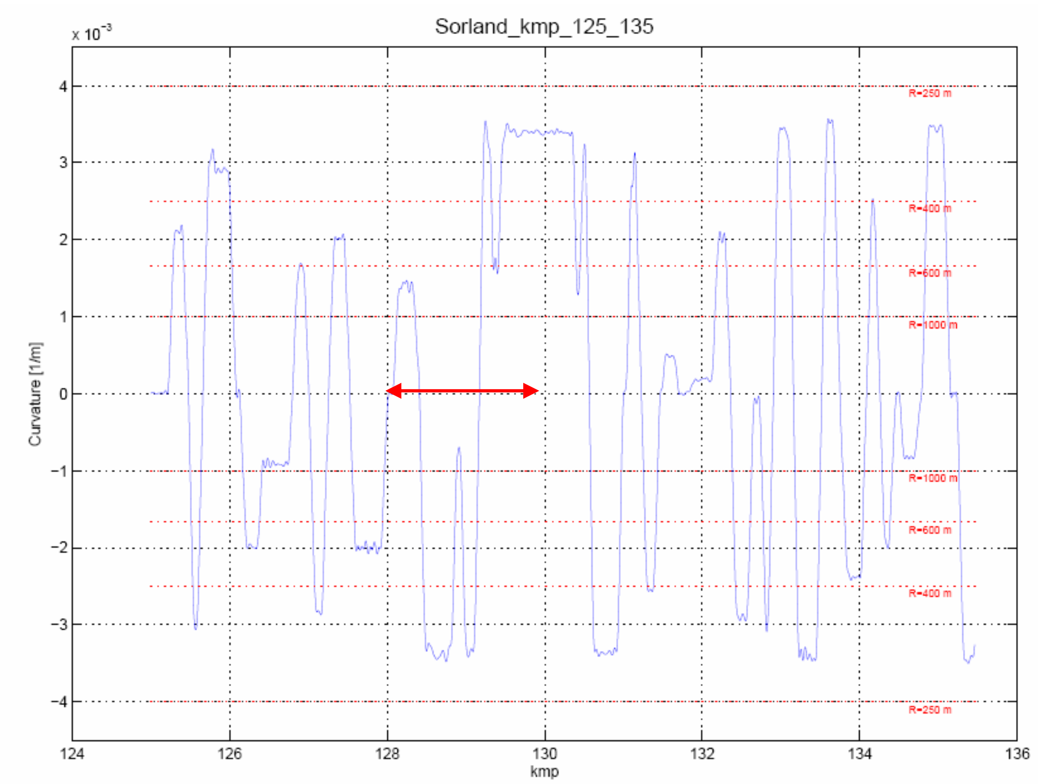
C.bl.06-5

Bilaga 1: Spåravsnitt för dynamiska beräkningar

1. Dovrebanan mellan km 170.5 och 173.5



2. Sörlandsbanan mellan km 128 och 130



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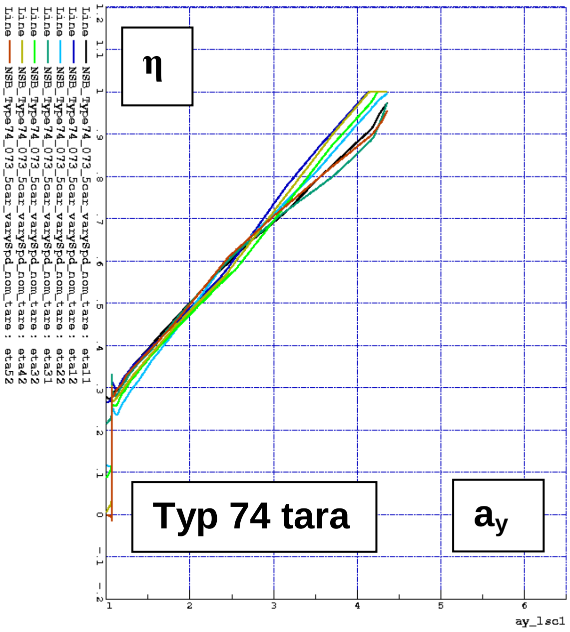
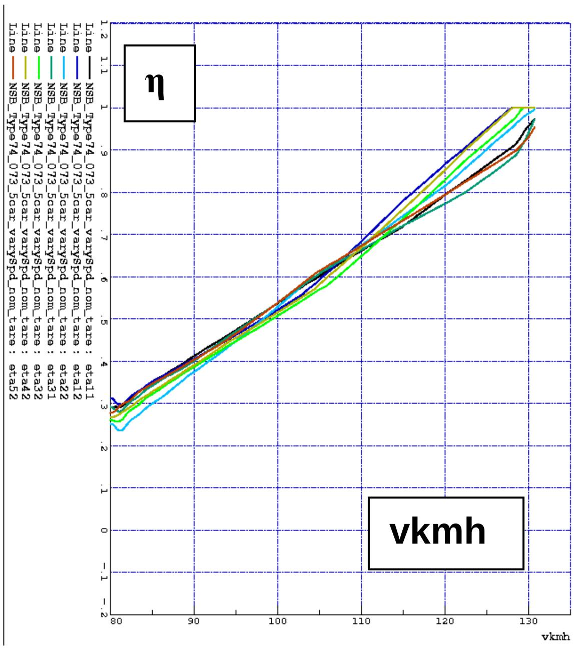
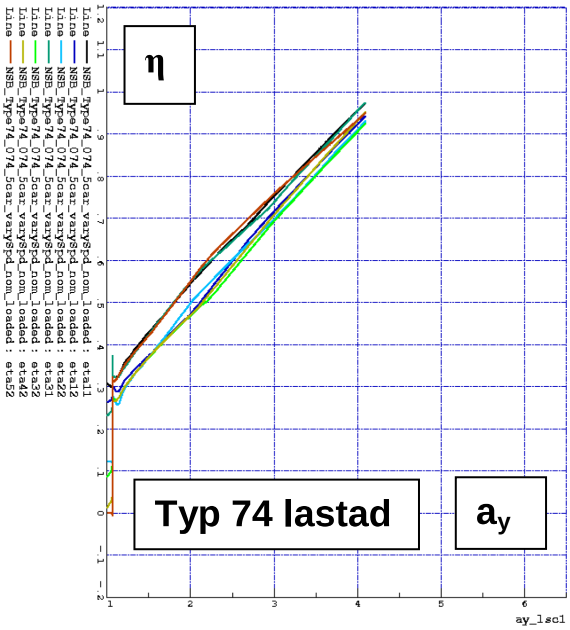
Bilaga 2: Typ 74, kvasistatiska η

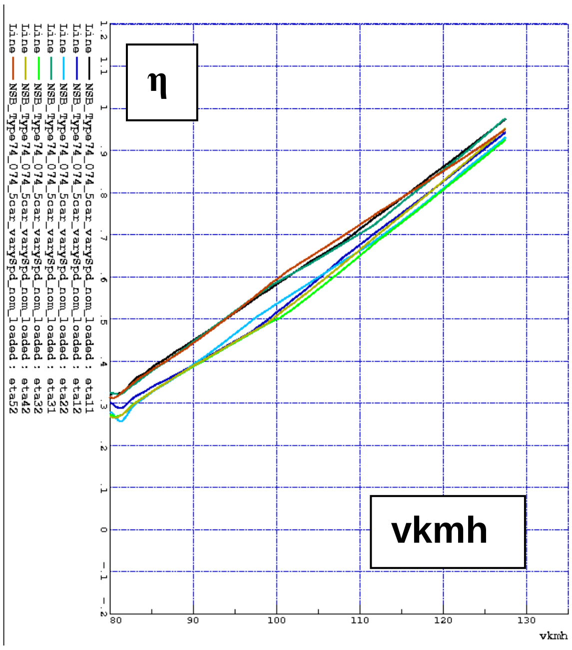
Tara:





Sittande + 4 stående/m2

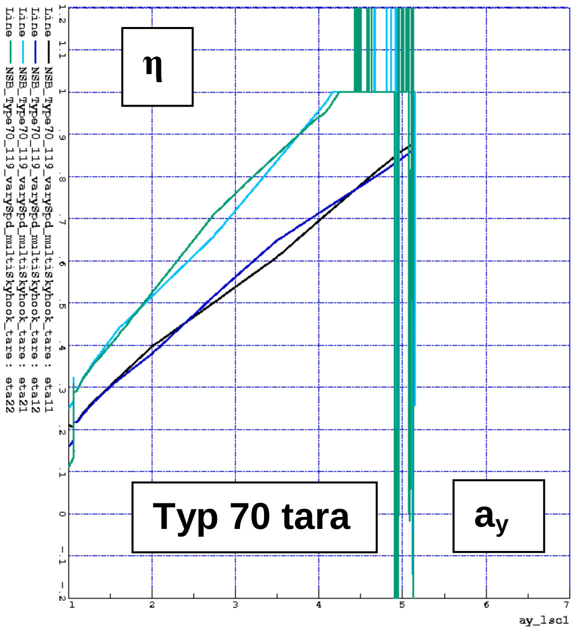


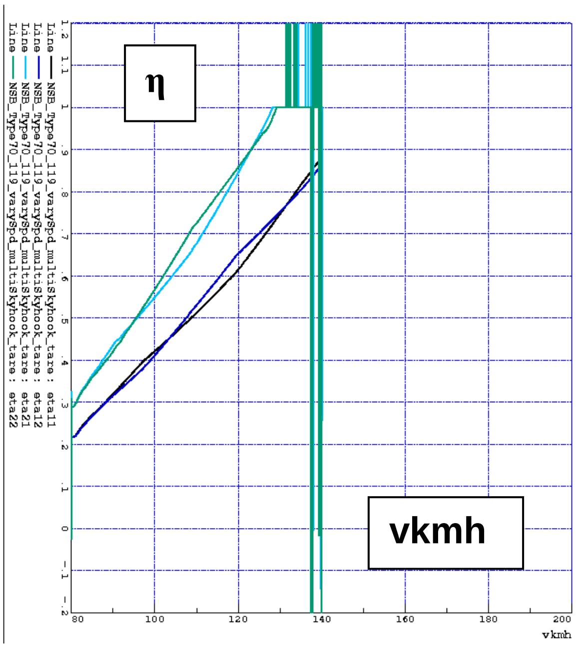


C.bl.06-5

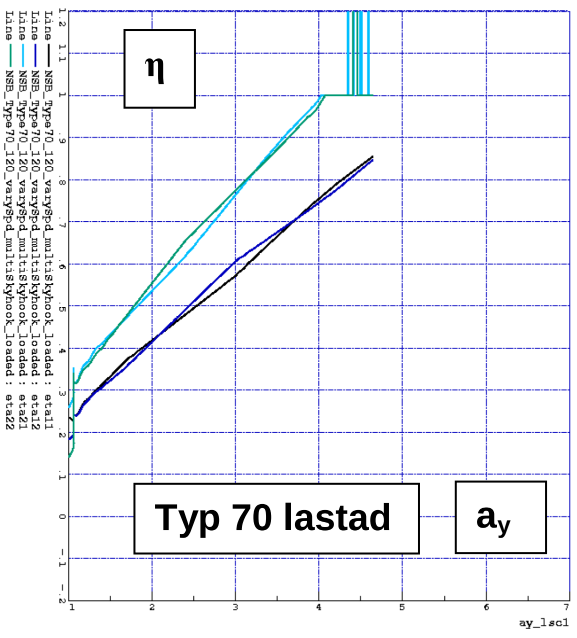
Bilaga 3: Typ 70, kvasistatiska η

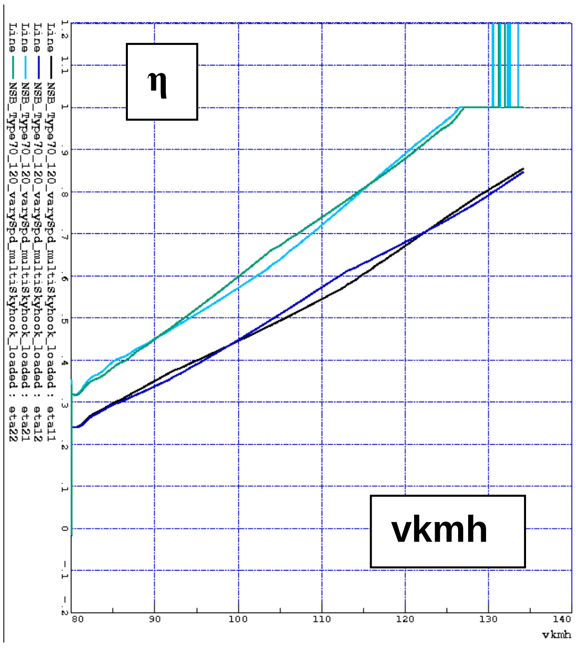
Tara:





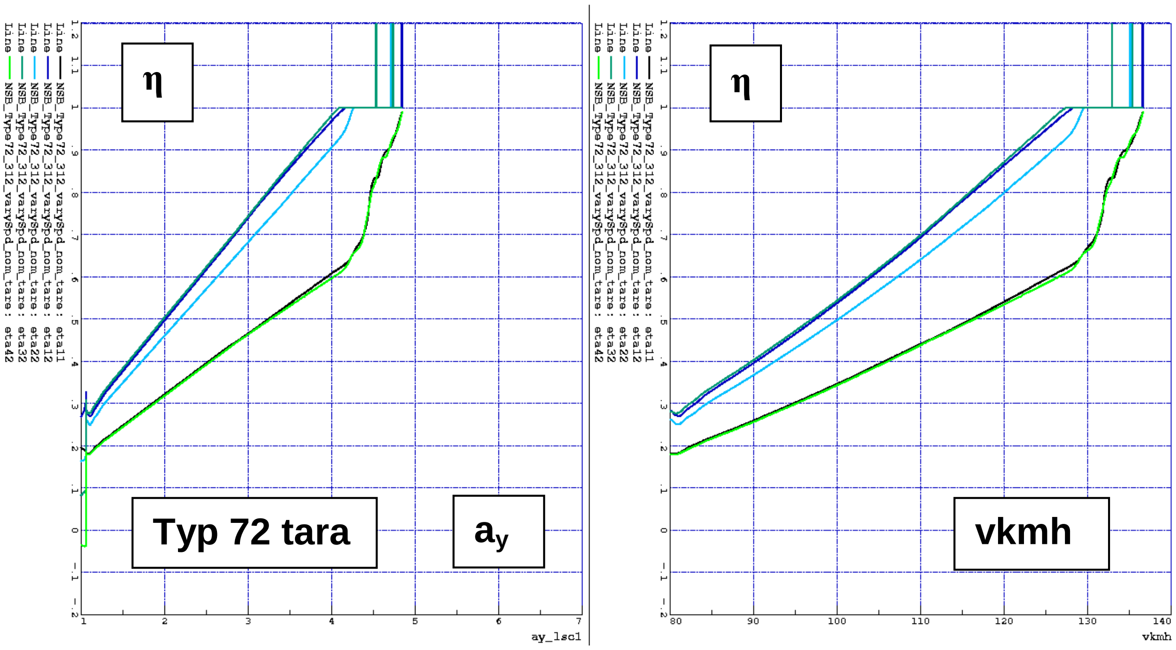
Sittande + 4 stående/m2



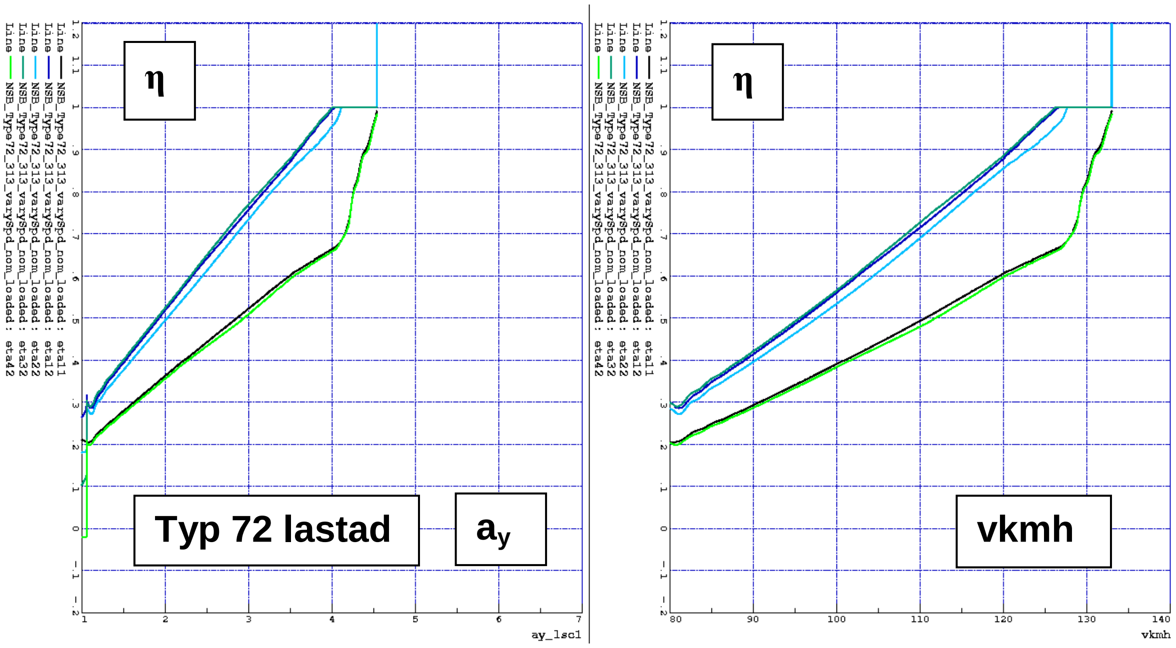


Bilaga 4: Typ 72, kvasistatiska η

Tara:

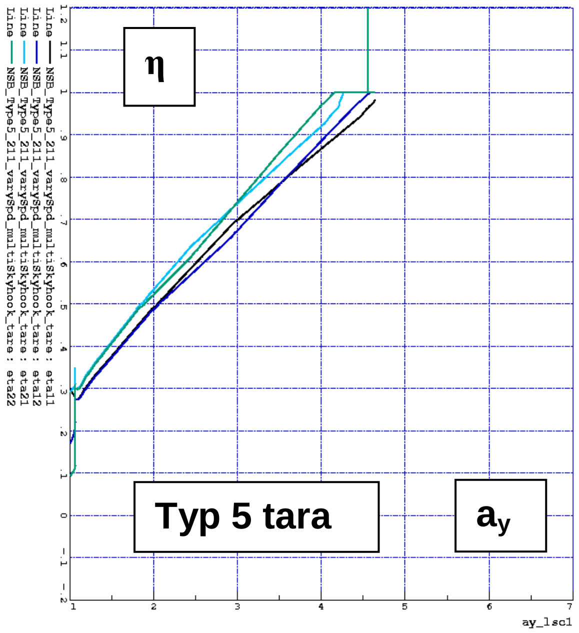


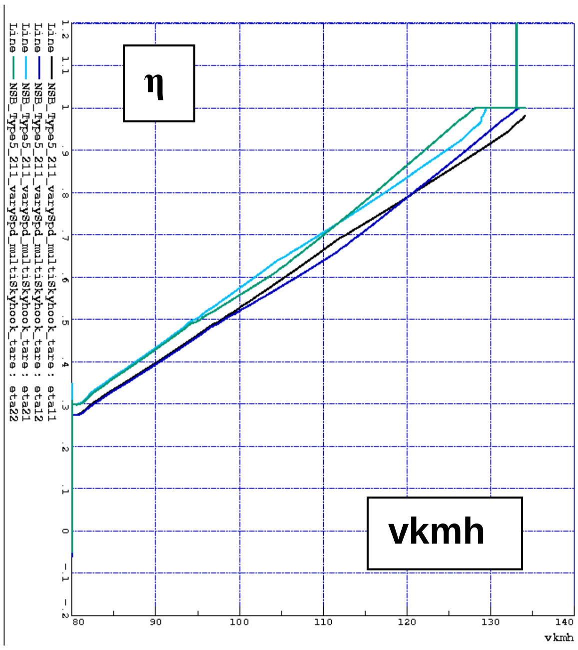
Sittande + 4 stående/m2



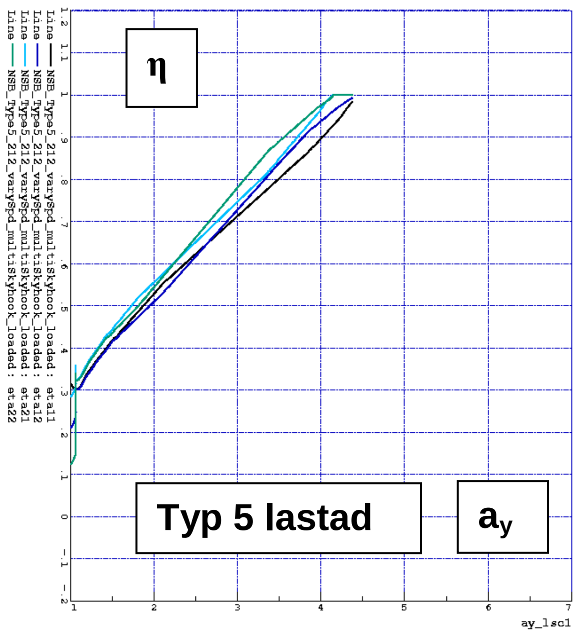
Bilaga 5: Typ 5, kvasistatiska η

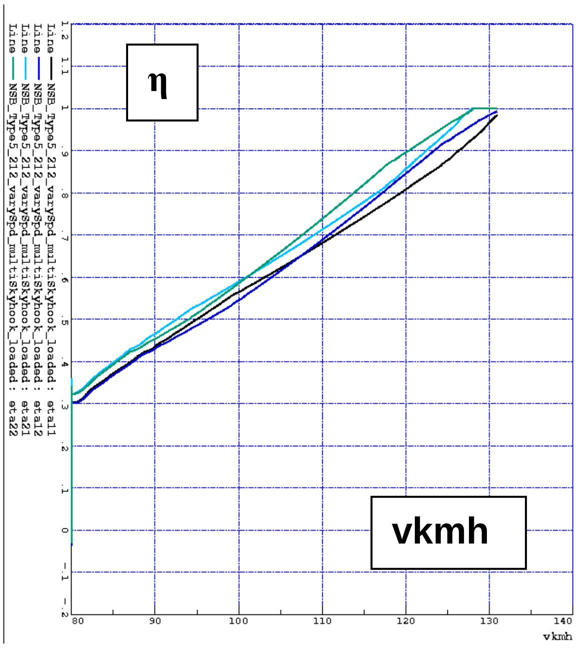
Tara:





Sittande + 4 stående/m2





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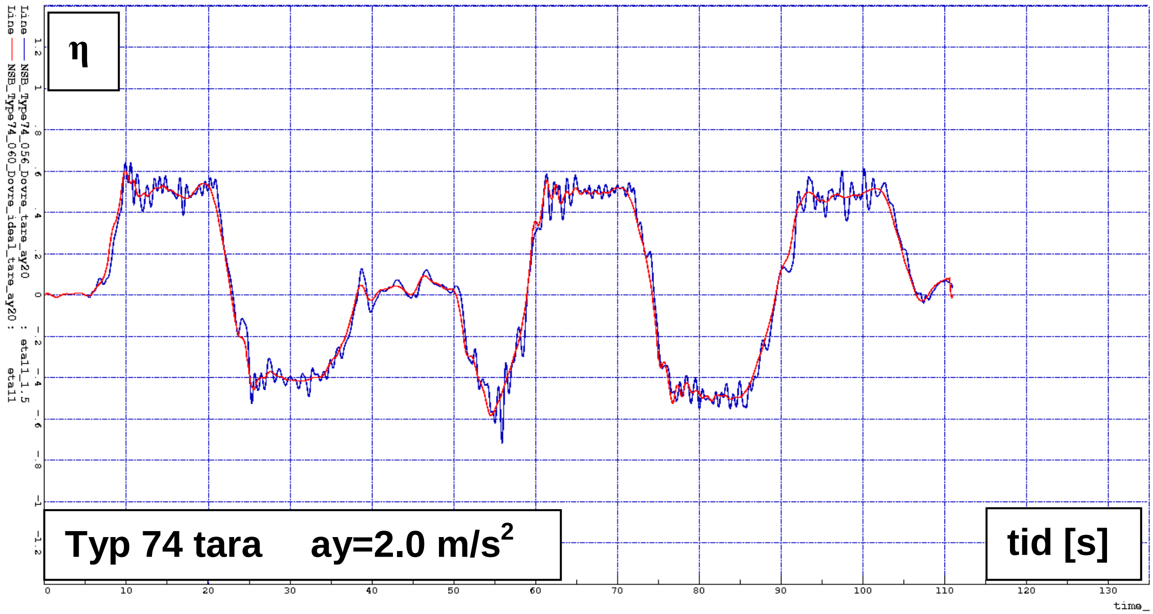
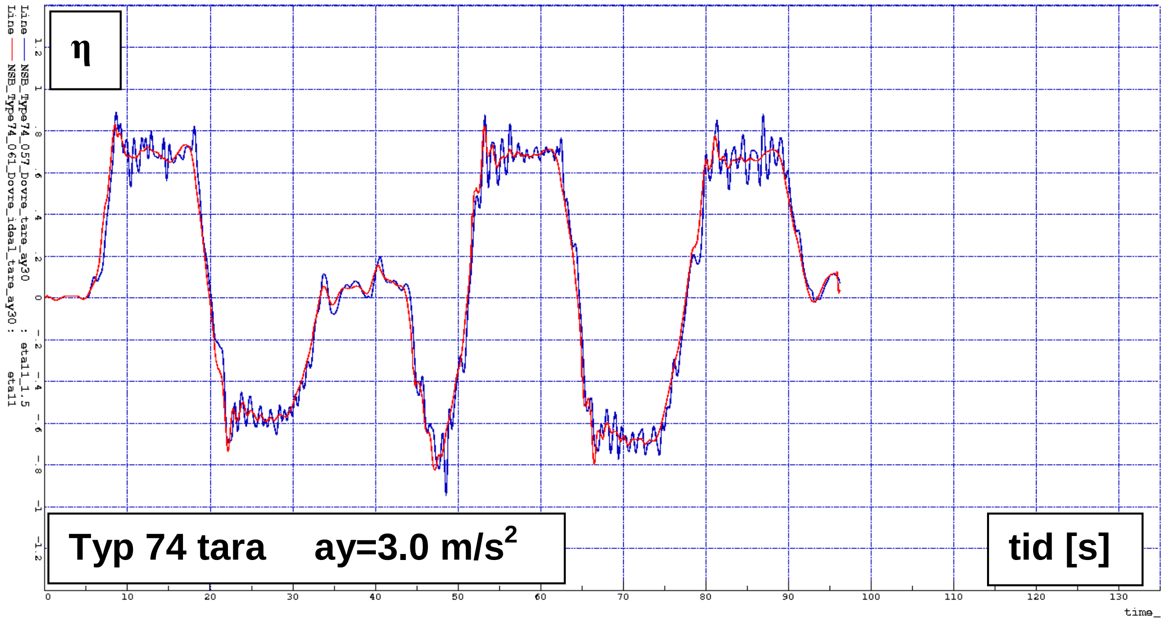
Bilaga 6: Typ 74, dynamiska η

Exempel på η för boggi 1 på banavsnitt 2, Dovrebanan, i olika spårplansaccelerationer. Röd kurva avser simulering i idealt spår och blå kurva simulering med verkligt spårläge.





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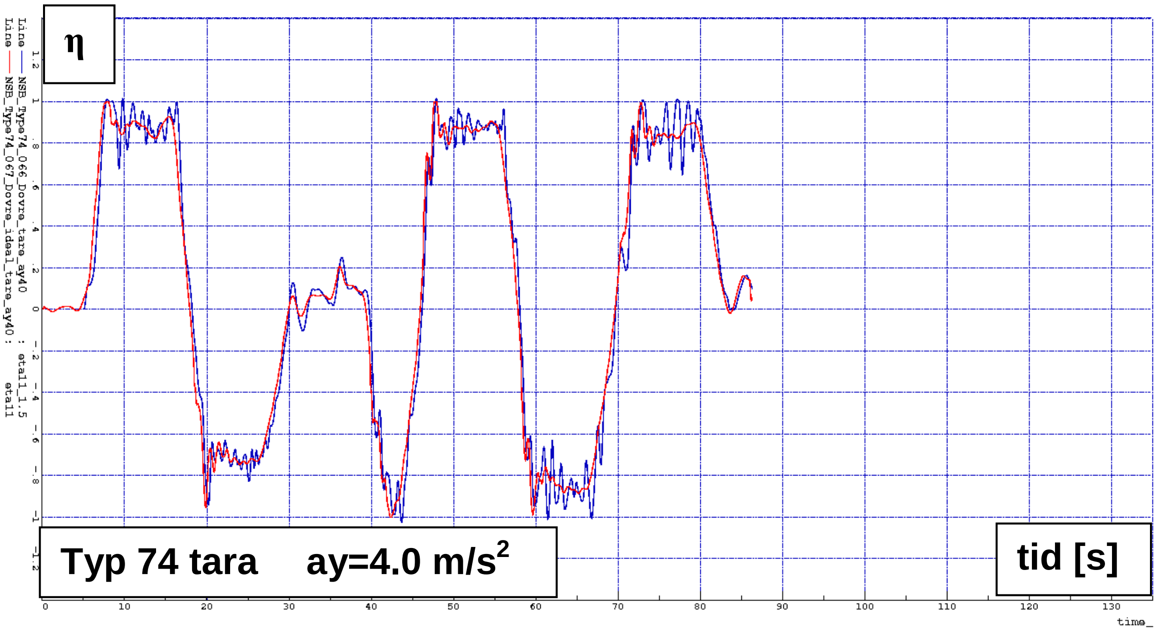

η
Line —— NSB_Type74_066_Dovre_tara_ay40 : eta11_1.5
Line —— NSB_Type74_067_Dovre_ideal_tara_ay40 : eta11
Typ 74 tara ay=4.0 m/s2
tid [s]
time_

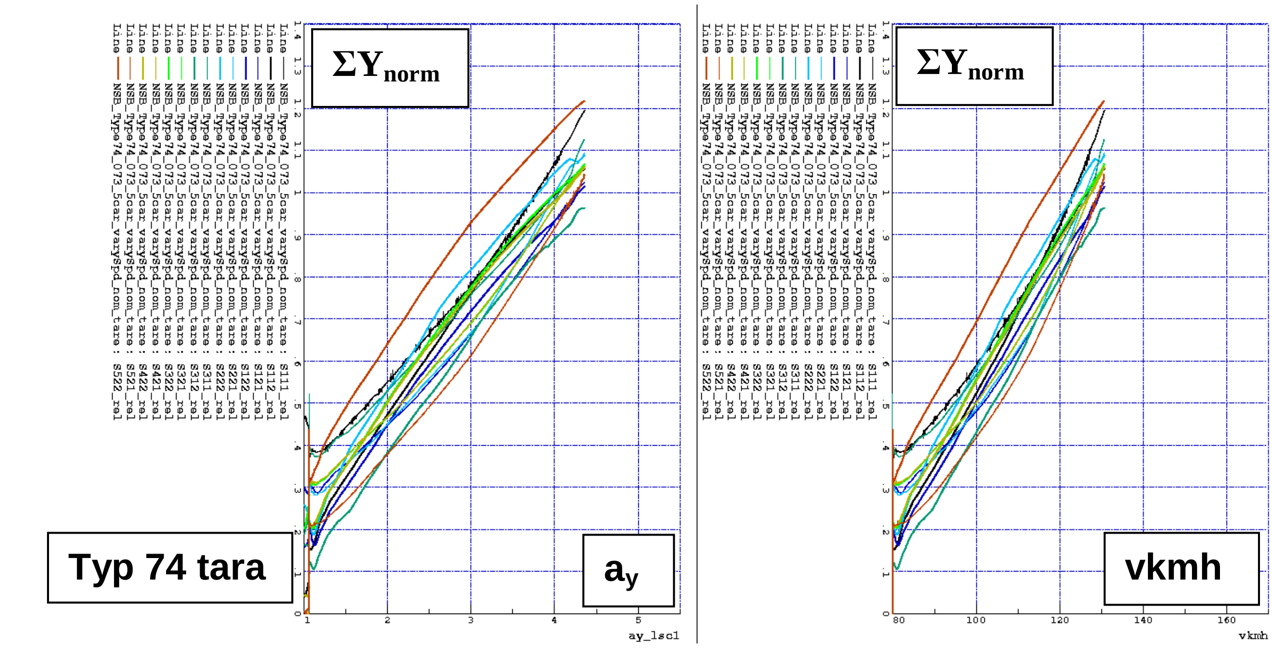
C.bl.06-5

Bilaga 7: Typ 74, kvasistatiska ΣY

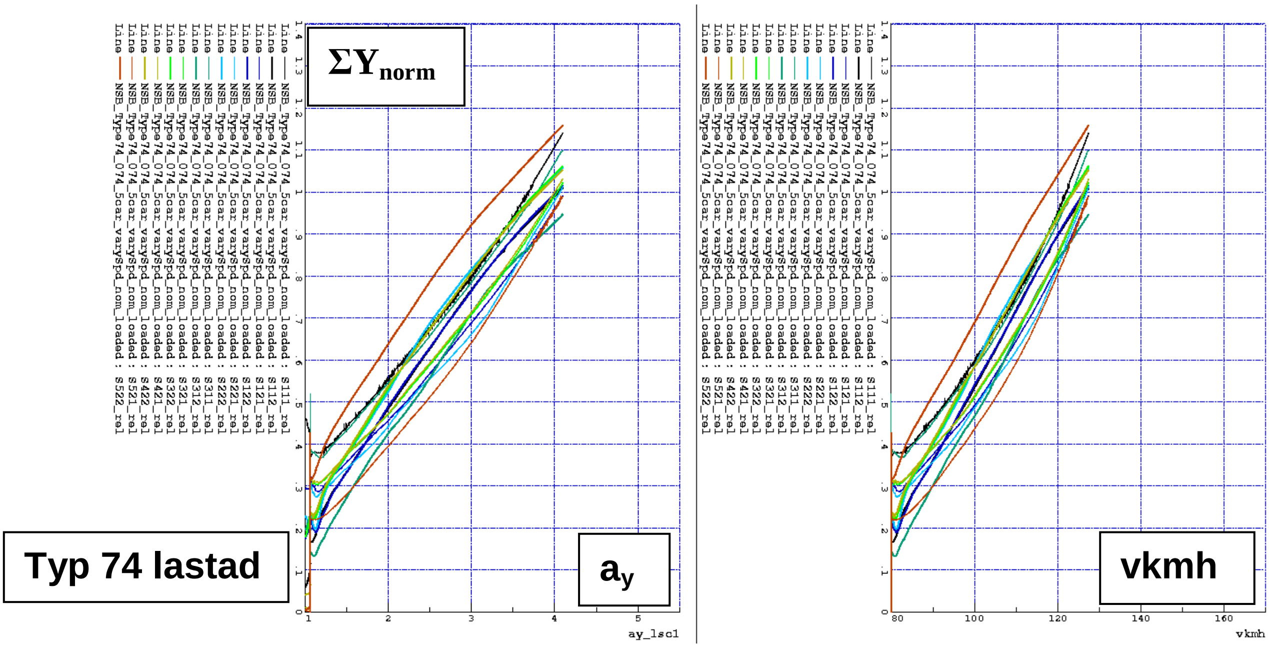
Diagrammen visar kvasistatisk spårförskjutningskraft ΣY som funktion av spårplansacceleration och fordonshastighet vid friktionskoefficient μ=0.3. Kurvorna är normerade gentemot gränsvärdet enligt UIC518 (Prudhomme), där P_0 är statisk axellast uttryckt i kN:

$$\Sigma Y_{norm} = \frac{\Sigma Y}{1.0 \cdot \left(10 + \frac{P_0}{3}\right)}$$

Tara:



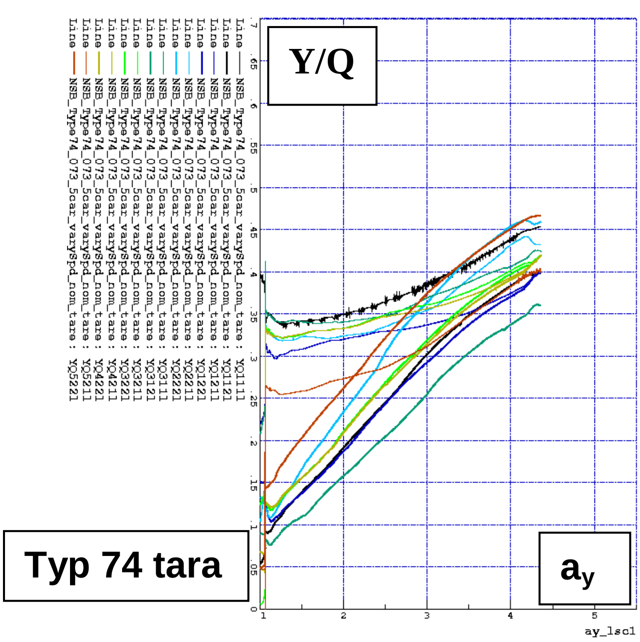
Sittande + 4 stående/m2

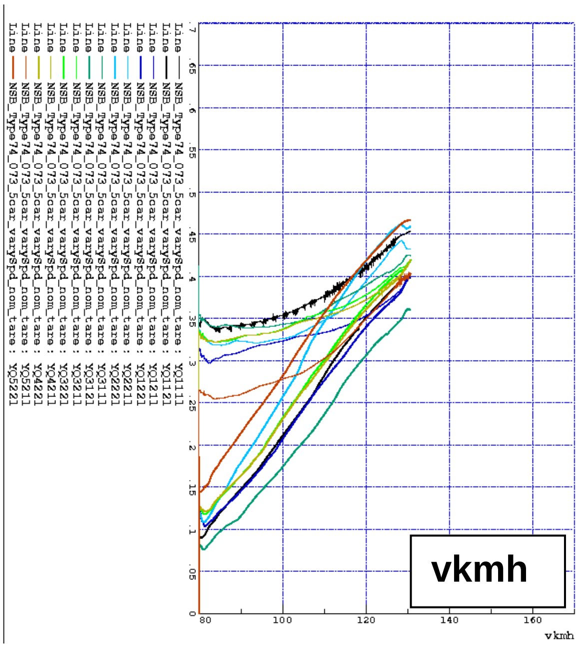


Bilaga 8: Typ 74, kvasistatiska Y/Q

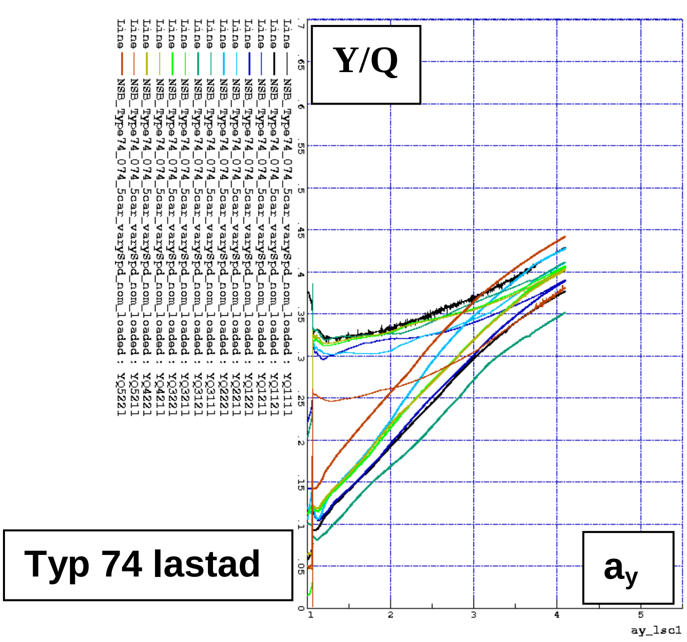
Diagrammen visar kvasistatisk flänsklättringskvot Y/Q som funktion av spårplansacceleration och fordonshastighet vid friktionskoefficient μ=0.3.

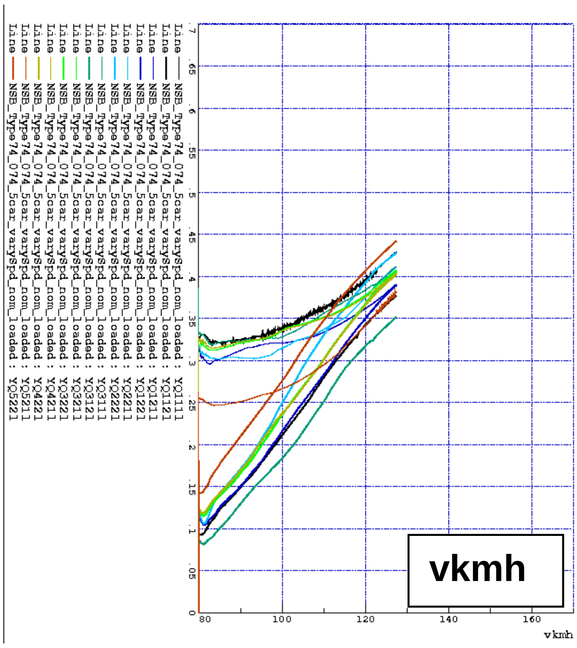
Tara:





Sittande + 4 stående/m2

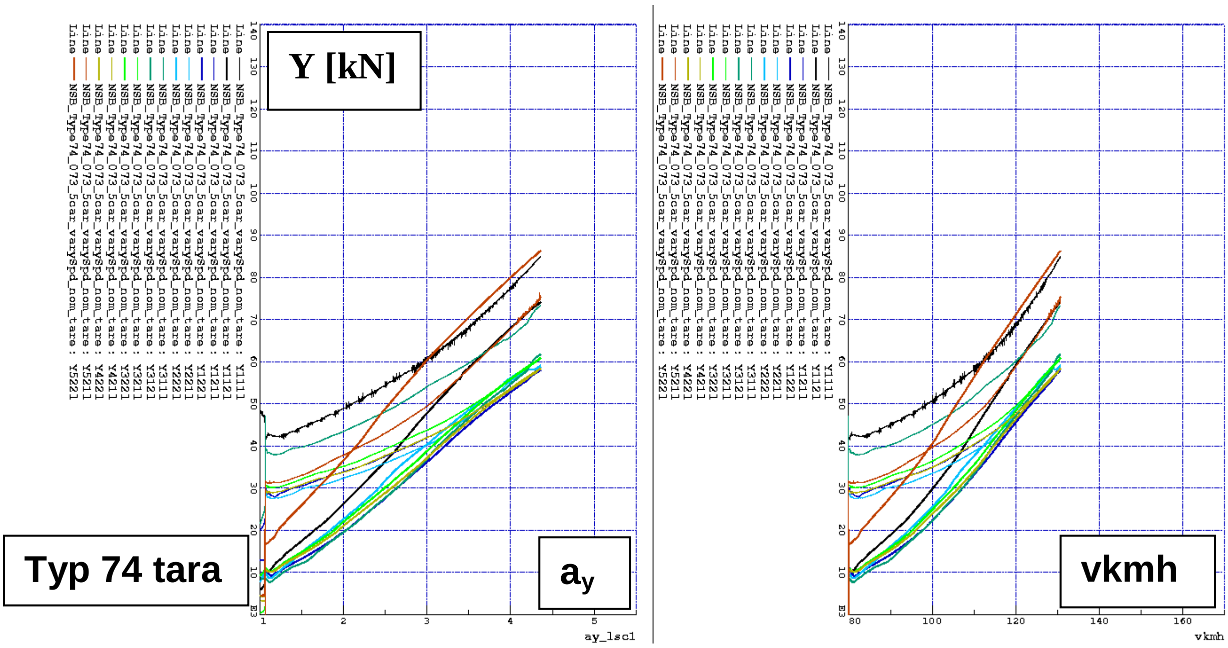




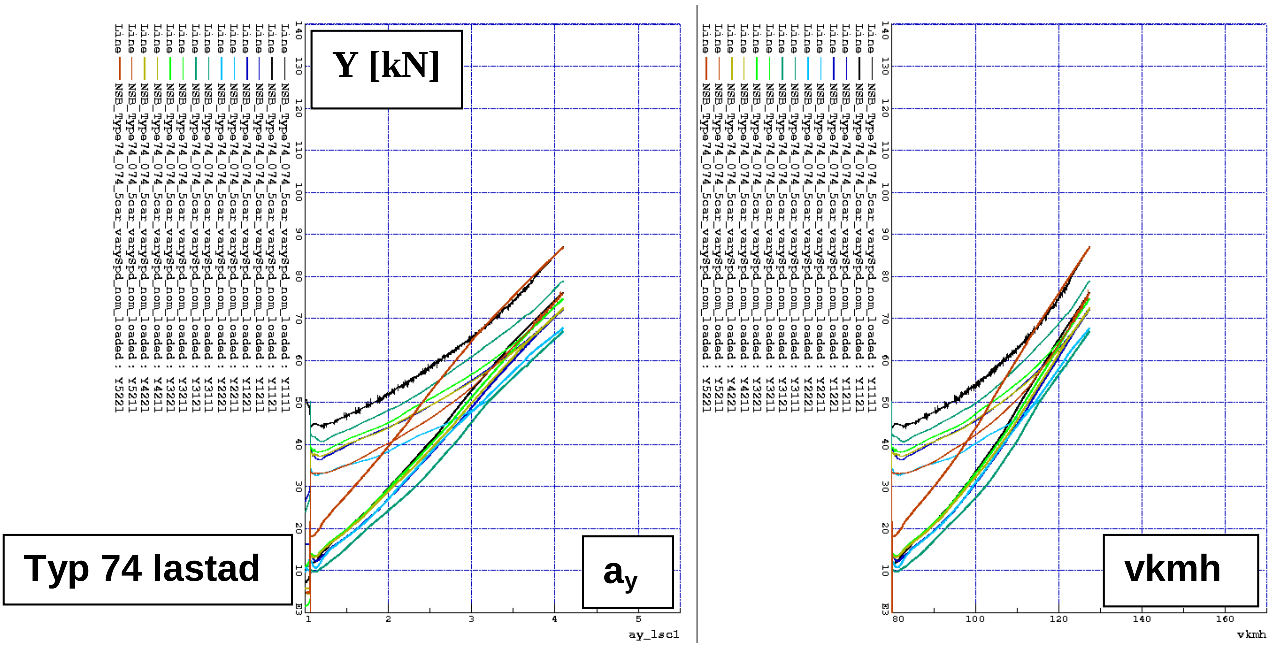
Bilaga 9: Typ 74, kvasistatiska Y

Diagrammen visar kvasistatisk lateralkraft Y på ytterhjulen som funktion av spårplansacceleration och fordonshastighet vid friktionskoefficient μ=0.3.

Tara:



Sittande + 4 stående/m2



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VEDLEGG C – KOMMUNIKASJON

Tabellen under oppsummerer hvilke aktiviteter og kommunikasjon som har foregått i toget i tiden før ulykken.

Tabell 1 - Kommunikasjon og aktiviteter i tog 12926

Klokkeslett	Fra	Til	Aktivitet
09:29:15	Fører	Txp Larvik	Gir beskjed om at de er klare til å kjøre tilbake mot Drammen, via togsettes togradio.
09:30			
09:31			
09:32			
09:33			
09:34			
09:35			
09:36			
09:37			
09:38			
09:39			
09:40			
09:41			
09:42			
09:43:27	Txp Larvik	Fører	Mottar kjøretillatelse for tog 12926, via togsettets togradio.
09:44			
Ca. 09:45	Prosjektet	Lokleder	Spørsmål om de kan gjennomfører en funksjonstest av passasjernødbremsen i togsettet, via håndholdt togradio.
09:46			
09:47			
09:48:14			Funksjonstest nødbrems 1.
09:49			
09:50			
09:51:30			Funksjonstest nødbrems 2.
09:52:58			Funksjonstest nødbrems 3.
09:53			
09:54			Ombordansvarlig henter OE i førerrom. Antatt tidspunkt siden det iflg. vitneutsagn ble gjort umiddelbart etter de tre testene.
09:55			
09:56			
09:57	Lokleder	Prosjektet	Gir tilbakemelding på de gjennomførte funksjonstestene, via håndholdt togradio.
09:58			Toget passerer Sandefjord.
09:59			
10:00			
10:01:11	Togleder	Lokleder	Forespørsel om stoppmønster og om toget rekker til Sem, via togsettets togradio.
10:02:22	Lokleder	Txp Tønsberg	Gir beskjed om at de ikke trenger å stoppe, via togsettets togradio.
10:03			
10:04			Ombordansvarlig setter tilbake OE i førerrom

Klokkeslett	Fra	Til	Aktivitet
10:05			
10:06			
10:07			
10:08			
10:09			
10:10			
10:11			
10:12			
10:13			
10:14			
10:15			
10:16			
10:17			
10:18			
10:19			Toget passerer Tønsberg.
10:20			
10:21			Toget passerer Barkåker.
10:22			
10:23			
10:24			
10:25	Lokleder	Prosjektet	Lokleder ringer prosjektet uten å få svar. (Iflg. lokleder og prosjektet var dette mellom 5 og 10 min. før ulykken), via håndholdt togradio.
10:26			
10:27			Toget passerer Skoppum.
10:28			
10:29			Passerer signal 68 A «nedsatt kjørehastighet» ved Nykirke, ca. kl. 10:29:30.
10:30	Prosjektet	Lokleder	Nykirke stasjon. Ulykkestidspunkt. Prosjektet ringer tilbake. Lokleder rekker kun å svare før samtalen blir brutt. Innringer holder samtalen i 11 sekunder uten å få ytterligere kontakt.
10:31			
10:32			