Accident
Investigation Board
Norway

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REPORT Road 2019/04

REPORT ON HEAD-ON COLLISION BETWEEN TWO BUSES ON COUNTY ROAD FV 450, AT NAFSTAD IN ULLENSAKER ON 17 NOVEMBER 2017

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Photos: AIBN

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REPORT ON ROAD TRAFFIC ACCIDENT

Date and time:	17 November 2017, 13:00	
Site of the accident:	Nafstad in Ullensaker municipality in Akershus county	
Road no, main section, km:	County road Fv 450, main section 2, m 1394, Kongsvingervegen	
Type of accident:	Head-on collision between two buses	
	Eastbound bus	**Westbound bus**
Vehicle type and combination:	Volvo 8700, 2009 model	Volvo 8700, 2009 model
Type of transport operation:	Passenger transport (local service)	Passenger transport (local service)
Transport firm responsible:	Nettbuss AS	Nettbuss AS

NOTIFICATION OF THE ACCIDENT

The Traffic Control Centre (VTS) Region East notified the Accident Investigation Board Norway (AIBN) at 13:28 on Friday, 17 November 2017 of a head-on collision between two buses on scheduled service on county road Fv 450, Kongsvingervegen, at Nafstad, south-east of Borgen in Ullensaker municipality. The AIBN contacted the police in order to instruct them to secure the vehicles and obtain necessary information about the accident and site of the accident.

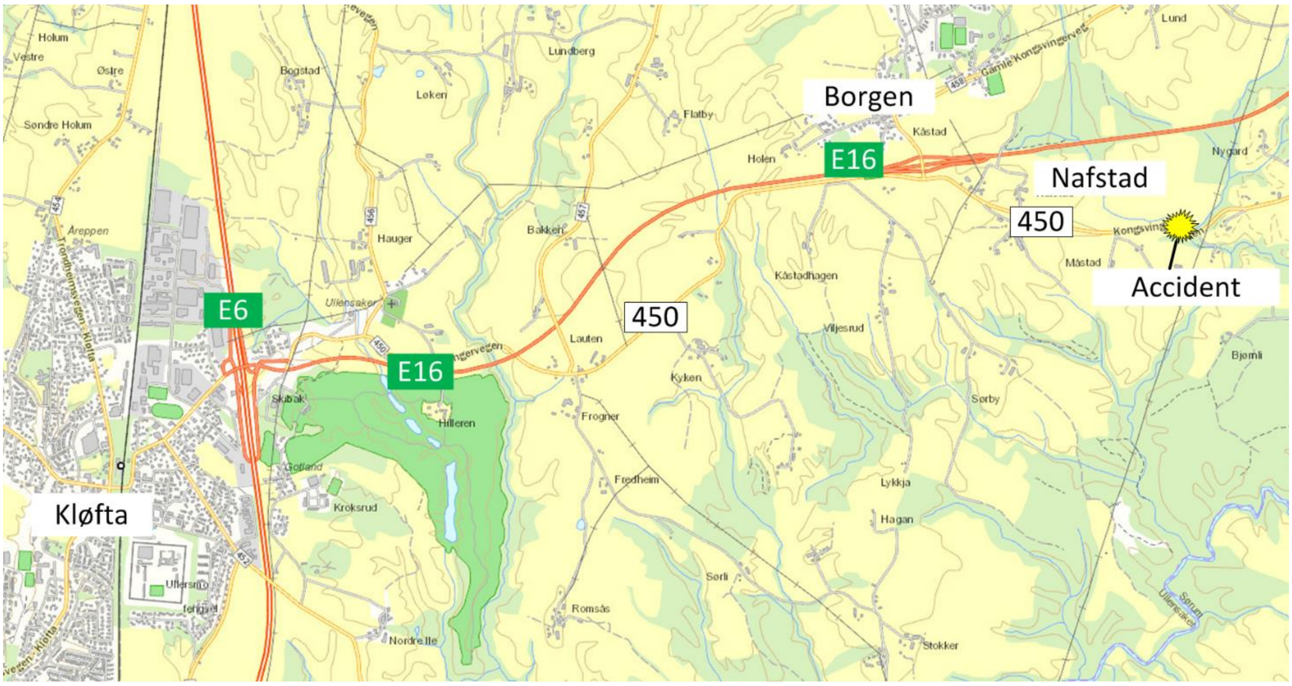

Figure 1: The site of the accident on Fv 450 at Nafstad is shown in yellow. Map: Kystinfo, the Norwegian Coastal Administration

SUMMARY

At 13:00 on Friday 17 November 2017, two buses on scheduled service for the same bus company, driving in opposite directions, collided head-on at the exit from the bend at the bottom of Nafstad hill on the Fv 450 near Borgen in Ullensaker municipality.

The investigation showed that a layer of rime frost and film of ice had developed locally on Nafstad hill, due to shade from vegetation on an otherwise bare road. The eastbound bus, which was fitted with studless winter tyres, struggled to maintain control down the slope, and veered into the opposite lane when exiting a sharp right-hand bend with little camber at the bottom of the slope. There it collided head-on with the westbound scheduled bus, which was of the same type. None of the passengers sustained serious injuries.

The road had last been sanded at 5:30 that morning, and the investigation has shown that the combination of local conditions, multiple winter maintenance strategies and various measures on the roads in Akershus is a challenge for bus drivers. The formation of rime frost during the winter season is particularly challenging, since, for environmental reasons, the contracting authority has banned the use of studded tyres for public transport.

Speed data downloaded from the bus showed that the driver of the eastbound bus had applied the brakes, thereby activating the ABS system, approximately 150 metres from the site of the collision. Over a period of 10 seconds, the bus driver managed to reduce the speed to 34 km/h before the collision. The oncoming westbound bus was travelling at a speed of 33 km/h at the time of impact. The front of each bus penetrated about one metre into the other bus. The driver of the eastbound bus was killed instantly, and the driver of the westbound bus was critically injured in the accident.

The AIBN considers the deformations and the injuries caused by the collision to be extensive, given the relatively slow speeds both buses were travelling at.

The buses that collided were of identical make and year: Volvo 8700 (2009). The investigation has shown that, although these buses met both national and international regulatory requirements, such buses are subject to less stringent crashworthiness requirements than other groups of vehicles.

The AIBN submits six safety recommendations as a result of this investigation.

1. FACTUAL INFORMATION

1.1 Sequence of events

At 13:00 on Friday 17 November 2017, two buses on scheduled service were travelling in opposite directions on county road Fv 450 at Nafstad. The weather was clear with occasional sun and light cloud, and the air temperature was around 3.5°C.

The eastbound bus was on schedule and was descending a hill leading to a double bend shaded from the sun by a copse of trees. The road was bare on the section before the hill, but on the hill and in the double bend, a layer of rime frost and film of ice had formed on the road. Speed data downloaded from the tachograph on the bus showed that the driver of the eastbound bus braked as it approached the bend (see section 1.11). Halfway down the hill, the bus lost its grip on the road and veered into the opposite lane as it was leaving the bend. At that moment, the westbound bus was entering the same bend.

The buses collided head-on with an overlap of approximately half the width of the front of the buses, and each bus penetrated the other in the driver's cab area. According to the downloaded speed data, both buses were travelling at a speed of approximately 33-34 km/h at the moment of impact.

The driver's cab in the eastbound bus was pushed directly backwards into the bus, while the driver's cab in the westbound bus was pushed backwards and in towards the aisle. Both drivers' cabs were severely deformed. The driver of the eastbound bus was killed instantly, and the driver of the westbound bus was critically injured. There were only two passengers on board the eastbound bus, and they were only slightly injured. The westbound bus had no passengers.

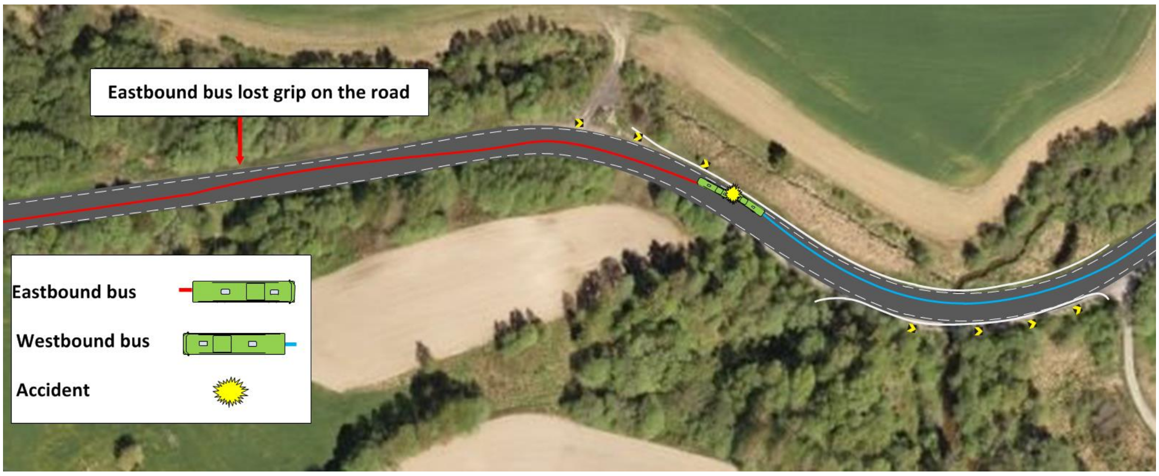

Figure 2: Sequence of events for the head-on collision between eastbound and westbound buses on Fv 450. Map: © Norwegian Mapping Authority. Illustration: AIBN

1.2 Personal injuries

There were two passengers on the eastbound bus, both of whom were slightly injured. One passenger was wearing a seatbelt. The other passenger was not wearing a seatbelt, and was thrown against the seat in front with such force that the back of the seat broke.

The post-mortem examination of the driver of the eastbound bus showed that he had sustained extensive crush injuries resulting in immediate death.

The driver of the westbound bus sustained life-threatening injuries and had to be cut free before being transferred to an air ambulance and flown to Ullevål University Hospital. He suffered a fractured skull, spleen and intestinal injuries, as well as extensive fractures and crush injuries in the lower part of his body. His left leg had to be amputated above the knee.

Both bus drivers were wearing seatbelts.

Table 1: Personal injuries

Injuries	Driver	Passengers	Others
Dead	1		
Serious	1		
Minor/none		2	

1.3 Survival aspects

1.3.1 Survival space in the buses

The A-pillar of the westbound bus penetrated the eastbound bus at the driver's cab, and this pushed the entire driver's cab back as far as the first row of passenger seats. As a consequence of this penetration, there was then no survival space.[1]

There was also little survival space in the westbound bus, but the side wall on the driver's side collapsed in towards the centre in the collision, which meant that the driver was pushed almost as far back as the driver of the eastbound bus and slightly towards the centre; see Figure 11.

1.3.2 Rescue operations

The police were notified of the accident at 13:00, and they then notified the Emergency Medical Communication Centre (EMCC), fire service and VTS East. The first police patrol was on the scene at 13:09 and the air ambulance arrived at the scene of the accident at 13:14. The fire service began cutting free the driver trapped in the westbound bus at 13:21. An extensive extrication operation took place at the scene, and the driver of the westbound bus was flown to Ullevål University Hospital at 14:13.

1.4 Damage to vehicles

1.4.1 Eastbound bus

The front of the eastbound bus was pushed approximately 1–1.3 metres back into the driver's cab. The dashboard was pushed in, and the steering wheel and steering column were broken and pushed into the driver's seat. The driver's seat was torn loose from its fixings and pushed backward through the back wall to the first row of passenger seats behind the B-pillar on the left-hand side. The front of the bus was severed at the top and bottom of the left-hand side, immediately inside the side wall, and pushed back. The

[1] The survival space available to the driver in the compartment after deformation or compression of the vehicle body in a collision.

westbound bus had penetrated above floor level, in towards the raised floor in the passenger compartment, shown in Figure 4.

Figure 3: Damage to the front of the eastbound bus. Photo: AIBN

Figure 4: Deformations of the driver's cab in the eastbound bus, seen from above. Photo: AIBN

1.4.2 Westbound bus

The front of the westbound bus was pushed approximately 1–1.3 metres back towards the centre of the bus in the driver's cab area. The steering wheel and steering column were broken and pushed back, and the floor plate was crushed. The driver's seat and dashboard were squeezed in towards the left-hand side wall. The front was collapsed in the centre, and the left-hand side wall on the driver's side was twisted in and back towards the aisle. The cross-beam at the far left of the chassis was severed in the collision.

Figure 5: Damage to the front of the westbound bus. Photo: AIBN

Figure 6: Cross-beam severed on the left-hand side, seen from the side. Photo: AIBN

1.5 The scene of the accident

The collision occurred in the middle of a double bend on Fv 450, Kongsvingervegen, east of Nafstad farm. For the eastbound bus, the collision took place at the exit from a right-hand bend after descending a downhill slope . For the westbound bus, the accident occurred on a short straight and flat section, just before the start of a left-hand bend and slight uphill slope.

The Norwegian Public Roads Administration's accident team was at the scene of the accident approximately 50 minutes after it occurred, and it performed retardation measurements at the scene of the accident. They calculated that the road friction level was 0.19. According to the police at the scene, there was a thin film of ice that made the road extremely slippery, and the rescue crews had to spread sand at the scene in order to be able to do their job. The police patrol at the scene stated that there was bare asphalt at Nafstad east of the hill. Figure 7 shows photos of the final positions of the buses, taken facing east. This figure clearly shows rime frost on both sides of the road and on adjacent terrain. Figure 8 shows the skid marks from the right front wheel of the eastbound bus. It is possible to see here that the wheel is angled to the right, and that there are lines made by grit on the asphalt in the tyre tracks. The film of ice, which was described by those who were at the scene, can also be glimpsed here.

Figure 7: Final positions seen from the east. Photo: NPRA

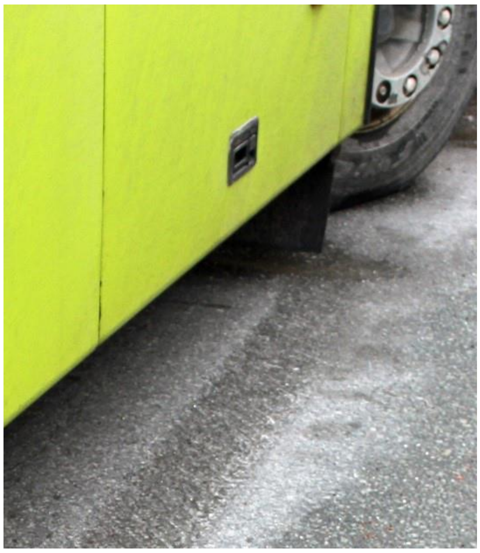

Figure 8: Tyre tracks from front wheel of eastbound bus. Photo: NPRA

Figure 9: Overlap and penetration between the buses at the scene of the accident. Photo: NPRA

Figure 10: Final positions seen from the west. Photo: NPRA

Figure 9 shows the overlap and penetration between the buses at the front, and Figure 10 shows the final position of the buses, seen facing westwards.

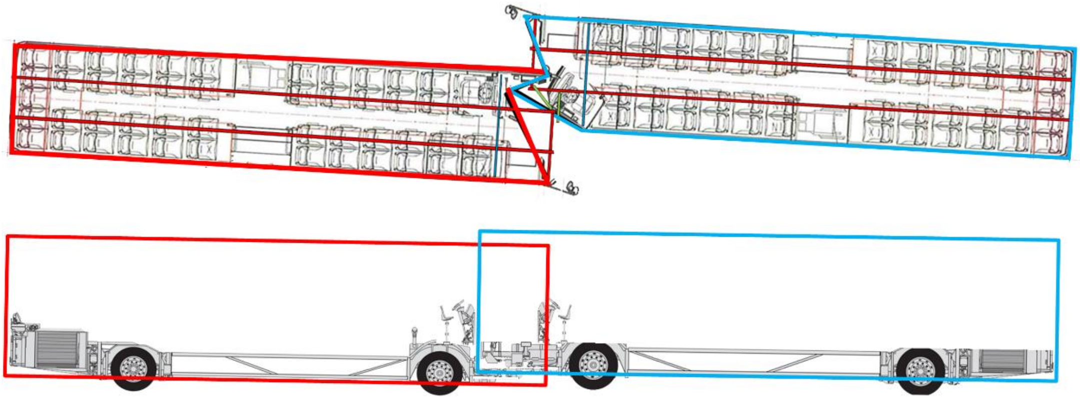

Figure 11: Illustration of the penetration between the eastbound bus and westbound bus. Illustration: AIBN

1.6 Road users

1.6.1 Driver of the eastbound bus

The driver (55) was Polish, and had a driving licence for categories BE, C1E, D1E, D, S, T, as well as a valid Driver Certificate of Professional Competence (CPC) for goods and passenger transport. He had a heavy vehicle licence from 2009. He extended his driving licence to category D in Norway four months before the accident, and had worked for Nettbuss from 15 September 2017. The driver had undergone Nettbuss's training programme for new employees.

Blood samples were taken from the deceased bus driver, and they showed no substances which could have played a part in impairing his ability to drive.

The bus driver started his shift at around 6:00 in the morning of Friday 17 November, and he had driven past the accident site several times earlier that day.

1.6.2 Driver of the westbound bus

The bus driver (59) was Norwegian, and had a driving licence for categories BE, C1E, D1E, DE, S, T, as well as a valid Driver Certificate of Professional Competence (CPC) for goods and passenger transport. He had many years of experience of driving heavy vehicles, and had been a standby driver for Nettbuss during the period 2005–2008. He became a full-time employee of Nettbuss on 1 September 2017, and had undergone Nettbuss's training programme for new employees.

The bus driver started his shift just before 6:00 in the morning of Friday 17 November.

1.6.3 Map of the bus routes

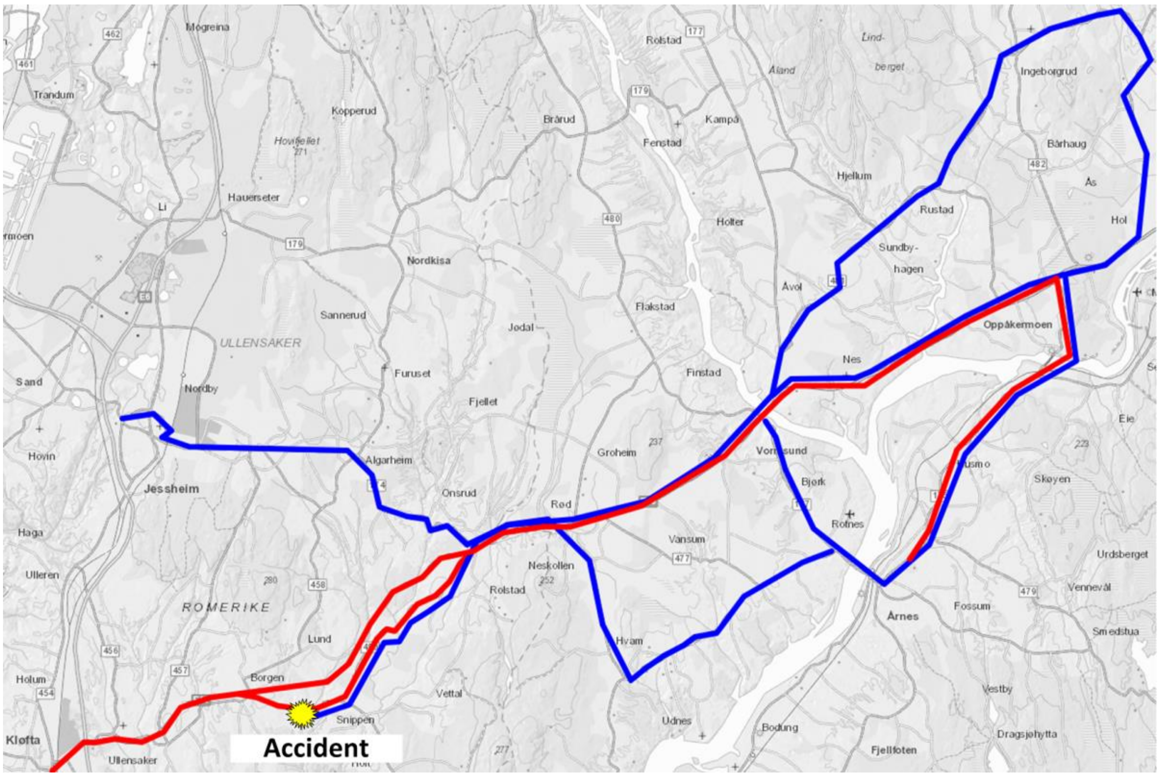

Figure 12: Logged route of the eastbound bus (red) and westbound bus (blue), 17 November 2017. Map: The Norwegian Coastal Administration's online map service Kystinfo. Illustration: AIBN

The driver of the eastbound bus had driven the section several times earlier that day, and passed the accident site just before 7:00, 8:30, 9:00, 10:00 (travelling west), 11:00 (travelling east), 12:00 (travelling west). The eastbound bus was on schedule on his route at 13:00.

The driver of the westbound bus was driving the section for the first time that day.

1.7 Vehicles and load

1.7.1 General

The eastbound and westbound buses were both of the Volvo 8700 type, and had individual vehicle approval in Norway. The buses were first registered in 2009 and were owned by Nettbuss AS. The buses were built on a B12B chassis manufactured in Sweden, with the body manufactured in Poland. The buses belonged to vehicle group M3, Euro 5 environmental category, classified in Norway as a category 2 bus, with 50 seats and standing capacity for 12 people. The buses were fitted with ABS brakes through an electronically controlled braking system (EBS).

Upon initial registration, both buses had a net weight without driver of 13,060 kg, with 4,580 kg on the first axle and 8,480 kg on the second axle.

Figure 13: Eastbound bus as it appeared on initial registration in 2009. Photo: NPRA

Figure 14: Driver's cab of eastbound bus on initial registration in 2009. Photo: NPRA

The odometer reading for the eastbound bus was 395,265 km, and 390,179 km for the westbound bus. Periodic roadworthiness tests were performed on 13 November 2017 for the eastbound bus and on 28 June 2017 for the westbound bus.

1.7.2 Tyres on eastbound bus

The bus was fitted with tyres of the Pirelli type, FW-01 295/80 R22.5 on the forward axle. They were winter/all-season tyres with longitudinal main grooves and a tread pattern depth of approximately 10–11 mm. The tyres on the back axle had been retreaded with a Nokian block pattern, and a tread pattern depth of approximately 17 mm.

Figure 15: The tyres on the back axle of the eastbound bus. Photo: AIBN

Figure 16: One of the tyres on the forward axle of the eastbound bus. Photo: AIBN

Both the rear tyres and front tyres were marked with 'M+S' and the 3-peak mountain snowflake (3PMSF).

1.7.3 Chassis and body

The driver's cab on the buses was built on the outside of the load-bearing chassis, and was located on the left hand side of the bus at the very front. Volvo has informed the AIBN that there is no regulatory requirement to provide either structural collision protection for the driver's cab or underrun protection on these buses. The chassis was made of conventional steel, and the front structure had a generally low level of energy absorption, shown in Figure 17.

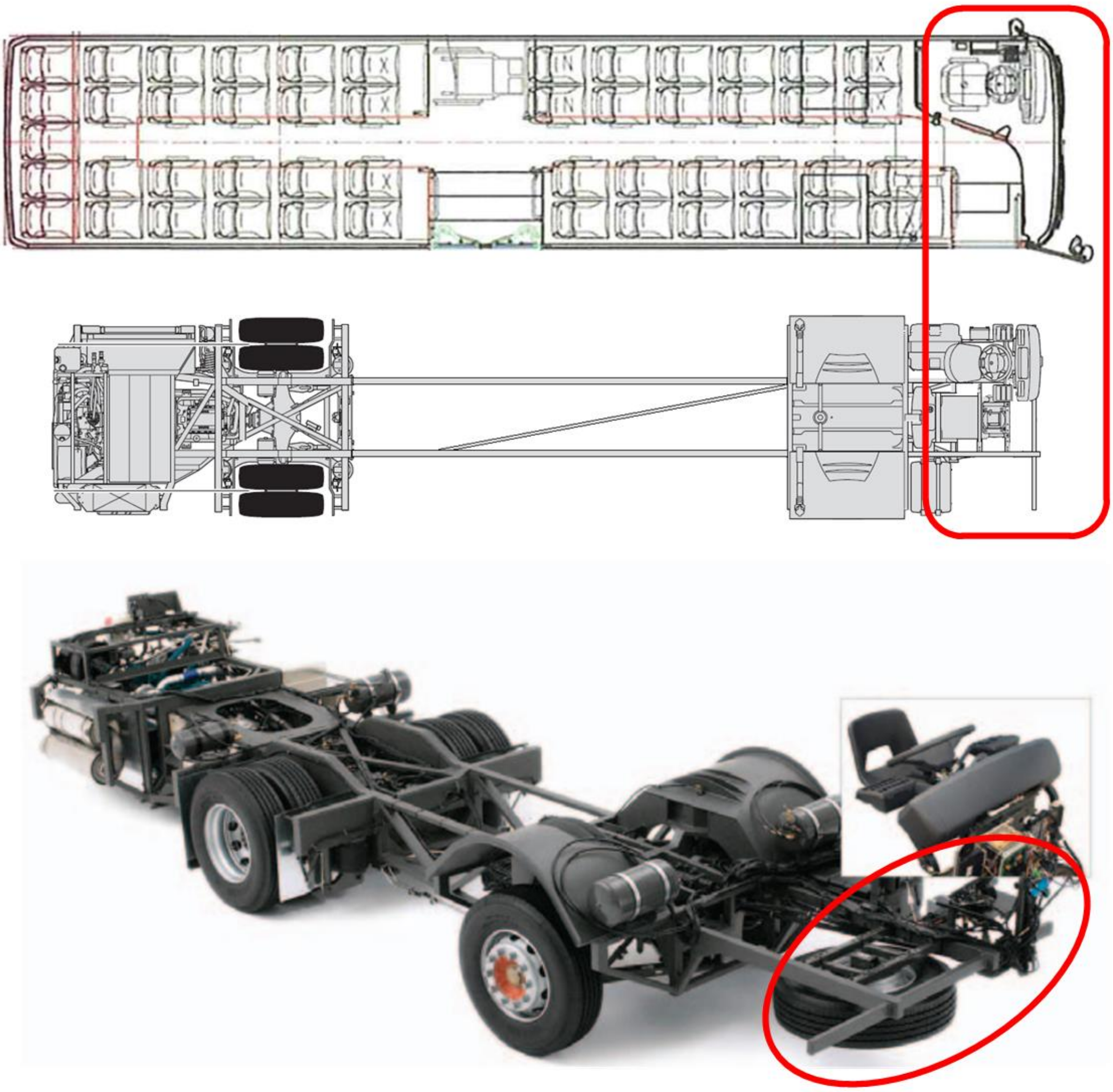

Figure 17: Volvo B12B chassis and body structure. The cross-beams in the front are circled in red. Illustration/photo: Volvo Bus

1.8 Road conditions

The Fv 450 is located south of the E16 and runs east from Kløfta before re-entering the E16 west of Neskollen. The speed limit at the accident site is 80 km/h. In 2017, the section's annual average daily traffic (AADT) was 838. The road is owned by Akershus county authority, and the Norwegian Public Roads Administration operates and maintains the county roads on behalf of the county authority through a joint road administration system.

Mesta AS holds the maintenance contract for roads in the area (0205 central Romerike 2016–2021). The Fv 450 was maintained in accordance with winter maintenance class DkC (see section 1.13.5), and the requirement was bare road. In relation to friction, the area around the accident site was not subject to additional maintenance.

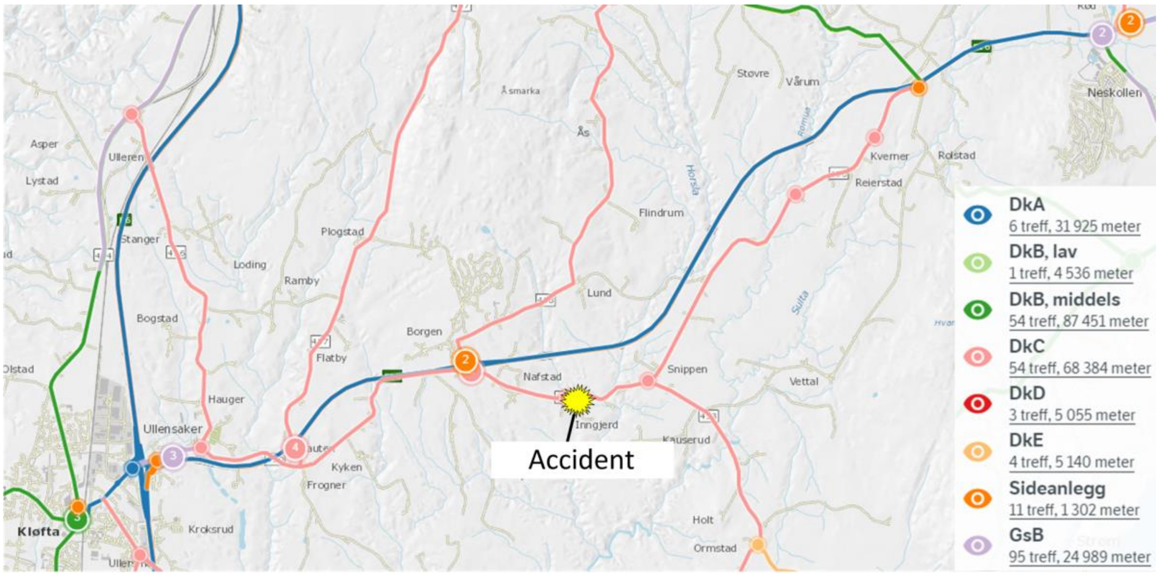

Figure 18: Map showing the winter maintenance classes on the roads in the area where the buses operated. Map: Road map, NPRA

At the accident site, the road had a total asphalted width of 8 metres. The road was marked with broken white edge lines on both sides of the road, with no yellow centre line. West of the accident site there was a straight downhill section of approximately 271 metres, of which the last half had a gradient of approximately 4.8%, and was known as 'Nafstad hill'. The right-hand bend where the eastbound bus lost its grip on the road has a radius of 100 metres, a crossfall of 2–3% and a gradient of approximately 1.7%. The bend and two other bends in an eastward direction were signposted with warning sign 904 'dangerous bends'.

About 500 metres east of the accident site, the road was marked with hazard warning sign 102.2 'dangerous bends' on the westbound approach to the accident site. No such sign had been erected on the eastbound approach to the accident site.

Adjacent to the entire hill and accident site is a copse of trees in the side terrain on the north and south sides.

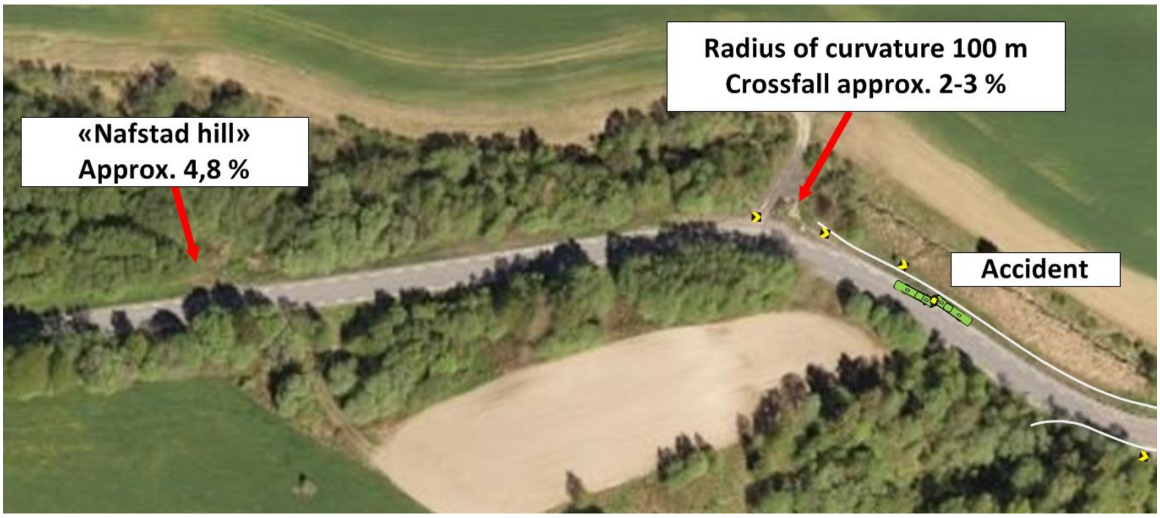

Figure 19: Overview photo of 'Nafstad hill'. Map: © Norwegian Mapping Authority. Illustration: AIBN

In terms of sunshine on Nafstad hill in late autumn, the roadway lies in the shadow of vegetation from around Molstad bus stop, west of the accident site, all the way down the hill and through the double bend as far as the site where the accident occurred, as shown in Figure 20.

Figure 20: Area of shade seen facing east from Molstad bus stop down Nafstad hill towards the right-hand bend. The photo was taken at 12:30 on 26 November 2018 in subzero temperatures. Photo: AIBN

From 1969, there was no vegetation on the south side of the road, but between 1986 and 2003, a small copse of trees was established which remains there today; see the aerial photos in Figure 21.

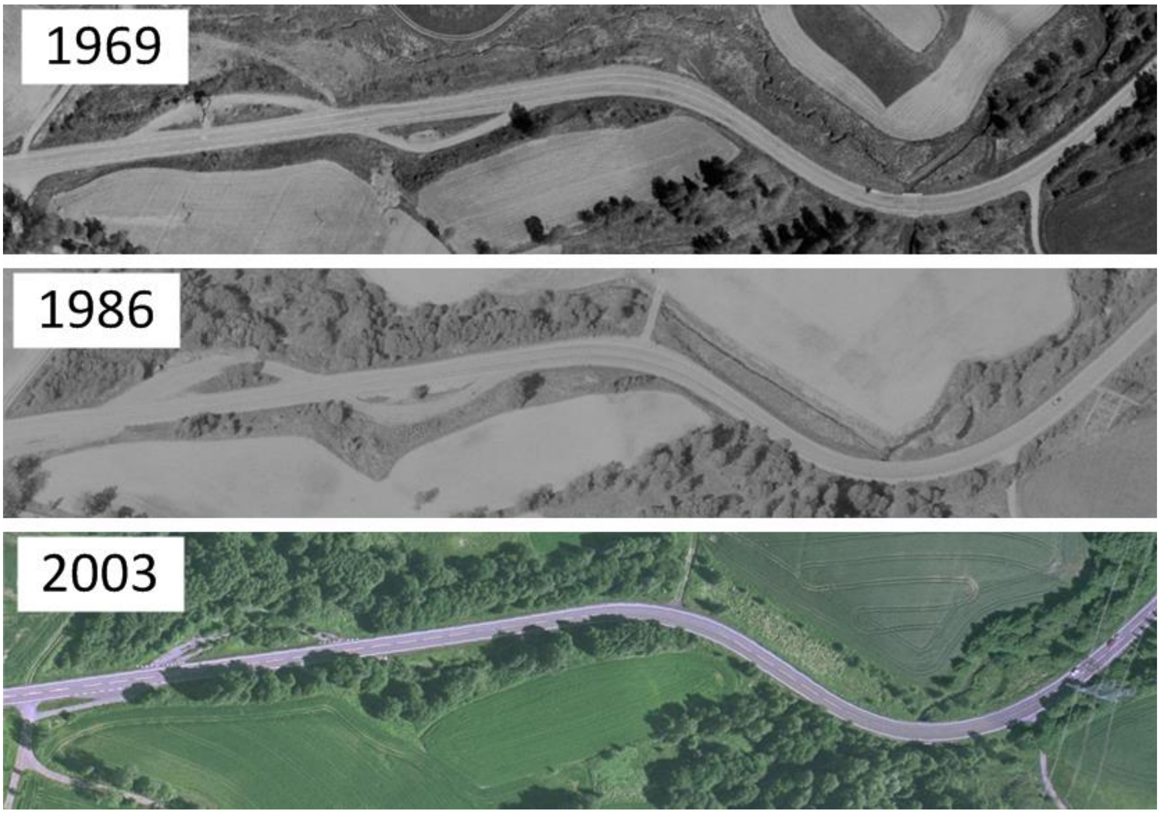

Figure 21: Growth of vegetation on Nafstad hill, 1969 to 2003. Photo: Norge i bilder

The Norwegian Public Roads Administration has recorded 11 accidents or mishaps on this bend between 1977 and the date of this accident. Seven of the accidents were head-on collisions involving two vehicles, while four were run-off-the-road accidents involving single vehicles. In several of the earlier recorded accidents, 'Nafstad hill' is used to describe the accident site.

1.9 Weather and driving conditions

1.9.1 Weather conditions

At 13:00 on 17 November 2017, the cloud cover was high and light, and the weather was clear.

The AIBN has been unable to obtain the weather forecasts for that day, but has obtained meteorological data for the weather as it was recorded. The Gardermoen and Ulvesund bru weather stations are approximately 10 km and 16 km, respectively, from Nafstad, as the crow flies. Both weather stations describe road surface temperature, relative humidity and dewpoint in combination; see Figure 22 and Figure 23. The meteorograms for that day show that the dewpoint and road surface temperature at both weather stations were similar between 8:00 and 13:00, with the air temperature rising as the day progressed.

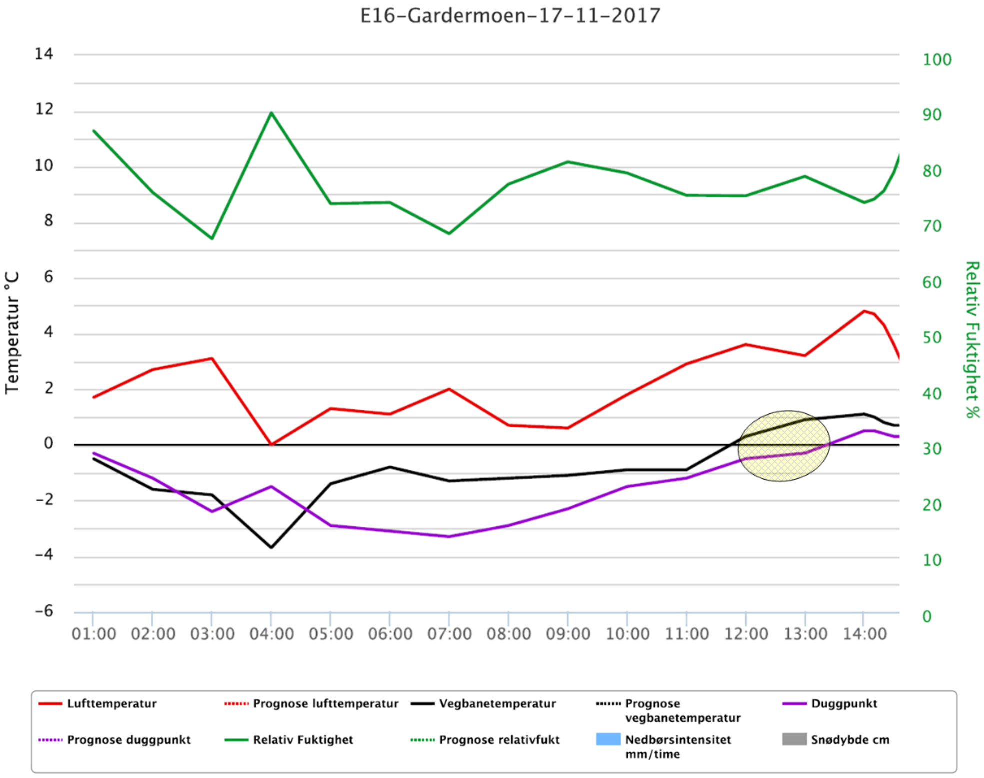

Figure 22: Meteorogram for E16 Gardermoen weather station, 17 November 2017. Source: Vegvær.no/AIBN

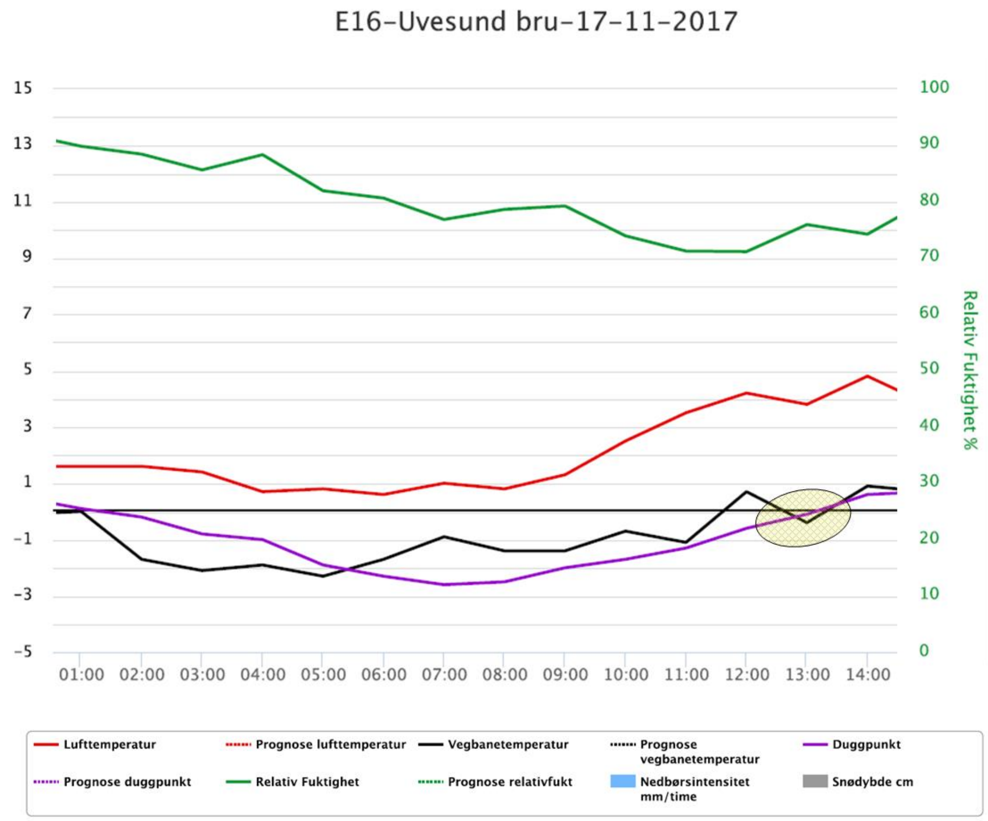

Figure 23: Meteorogram for E16 Ulvesund bru, 17 November 2017. Source: Vegvær.no/AIBN

At Gardermoen, the road surface temperature rose throughout the morning and exceeded zero degrees at around 12:00. At Ulvesund, on the other hand, the road surface temperature did the reverse, falling from above zero at 12:00 to below zero at around 12:30, while the dewpoint rose and exceeded the road surface temperature. This is shown in the shaded area in Figure 22 and Figure 23. The conditions at Ulvesund bru would allow rime frost to form, as described in section 1.15.1.

1.10 Operation and maintenance

On 17 November, the Fv 450 was sanded by Mesta at 5:30. From 9:43 and throughout the morning, several sections of road, for example on the E6, Fv 256, Fv 257 and Fv 452, were reported to be slippery. Measures were taken on these roads, including prewetted salt or sanding, depending on the maintenance class that applied to the particular road.

A representative from Mesta drove along the Fv 450 at around 10:00 and, according to him, did not find the road to be slippery at that time.

1.11 Technical registration systems

Both tachographs were sent to Germany and the data downloaded at a resolution of ¼ second. Retardations were found that could be related to the collision, braking and activation of the ABS system. While driving, the tachographs can have a margin of error of approximately ± 6 km/h, and the data presented have not been adjusted.

1.11.1 Eastbound bus

The eastbound bus was travelling at just under 80 km/h on the flat section west of Nafstad hill. As shown in Figure 24, the bus had reduced its speed to approximately 74 km/h on the slope, approximately 150 metres before the site of the accident. Halfway down Nafstad hill, there is a noticeable change in the curve of the speed graph 8.5 seconds before the accident. This is probably because the ABS system was activated and blocked the rear wheels. This indicates emergency braking for approximately 2.5 seconds (marked with a dotted red line). Approximately 60 metres before the collision, the bus entered the right-hand bend at a speed of approximately 58 km/h. Through the bend, the braking was stable, until approximately 1 second before the collision, until there are again signs of emergency braking. Based on the recordings, it is estimated that the eastbound bus collided at approximately 34 km/h.

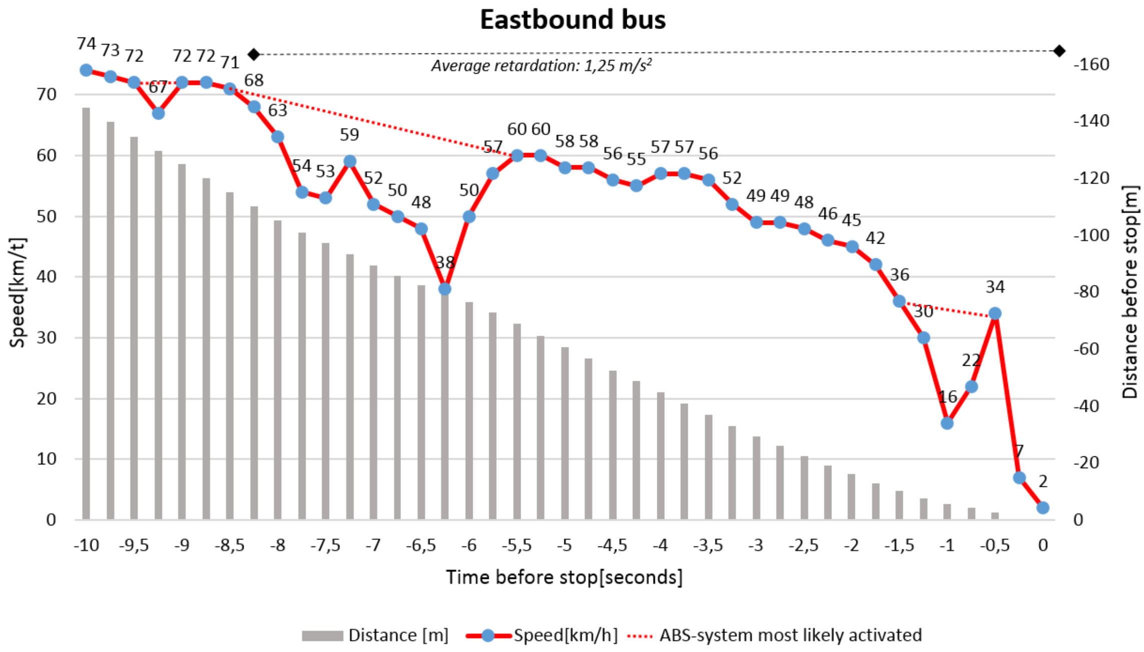

Figure 24: Recorded speed and distance data for the eastbound bus for the 10 seconds leading up to the collision. Illustration: AIBN

1.11.2 Westbound bus

The westbound bus was driving at a steady speed of around 40 km/h until approximately 1 second before the collision. Based on the recordings, it is estimated that the westbound bus collided at approximately 33 km/h.

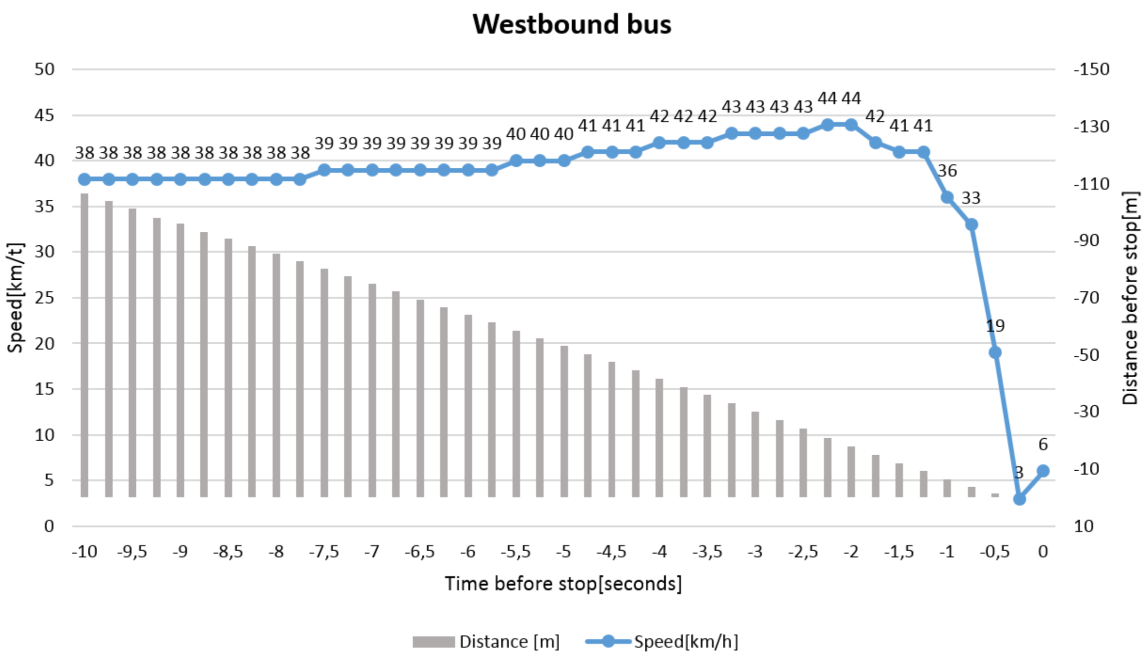

Figure 25: Recorded speed and distance data for the westbound bus for the 10 seconds leading up to the collision. Illustration: AIBN

1.12 Special investigations

1.12.1 Calculation of critical skid speed of eastbound bus

After the accident, the friction value on the road was calculated by the Norwegian Public Roads Administration to be μ=0.19. Average retardation of the eastbound bus during the 7.5 seconds leading up to the collision was 1.25 m/s^2 (see Figure 24), which gives a friction value of just under μ=0.1.

The AIBN has performed a simplified calculation of the critical skid speed of a bend similar to the bend involved in the accident, with a radius of 100 metres. The calculations included two friction values, which calculate the critical skid speed on a bend with a crossfall similar to the bend in the accident. The skid speed was calculated in the same way for a similar bend cambered with an 8% crossfall, which is within the handbook requirement for the camber on bends (Vegdirektoratet, Premisser for geometrisk utforming av veger Håndbok V120, 2014).

Table 2: Critical skid speed on bend with 100 metre radius, varying friction and crossfall. Source: AIBN

Radius (m)	Crossfall %	Critical speed [km/h] (μ=0.1, from speed data)	Critical speed [km/h] (μ=0.19, retardation measurement)
100	3%	41	54
100	8%	48	59

Based on these calculations, the critical skid speed on the bend at the accident site was somewhere between 41 and 54 km/h. If the bend had been cambered (i.e. 8% crossfall), and had the same friction value (μ=0.1), the critical speed would have been approximately 7 km/h higher, and, at the retardation measured (μ=0.19), approximately 5 km/h higher.

1.13 Laws, regulations and standards

1.13.1 The Car Regulations

The purpose of Regulations no 817 of 5 July 2012 on the approval of vehicles and road vehicle trailers (*'Forskrift om godkjenning av bil og tilhenger til bil'* - in Norwegian only) (the Car Regulations) is to ensure that approved vehicles and road vehicle trailers meet road safety requirements.

The appendix to these regulations contains a list of requirements for the approval of the various vehicle groups, where the buses involved in the accident were classified as M_3, highlighted in yellow in Table 3.

Table 3: Extract from safety requirements for the various vehicle groups. Source: AIBN/Lovdata

Requirement area	*Basis/legal act*	*Latest directive, regulation, rules*	*Entry into force in Norway*	*Applies to vehicle groups*									
				M_1	M_2	M_3	N_1	N_2	N_3	O_1	O_2	O_3	O_4
46: Tyres	92/23/EEC	2005/11/EC	31/12/2005	X	X	X	X	X	X	X	X	X	X
52A: General structure	EC 661/2009	EU 2016/1004	16/11/2016		X	X							

	UNECE 107	UNECE 107.05	16/11/2016		X	X							
52B: Strength of body	EC 661/2009	EU 523/2012	11/12/2012		X	X							
	UNECE 66	UNECE 66.02	19/08/2010		X	X							
53A: Protection of passengers in head-on collision	EC 661/2009	EU 523/2012	11/12/2012	X									
	UNECE 94	UNECE 94.02	23/06/2011	X									
54: Collision from side	96/27/EC		25/11/1997	X			X						
54A: Protection of passengers in side-on collision	EC 661/2009	EU 2016/1004	16/11/2016	X			X						
	UNECE 95	UNECE 95.03	16/11/2016	X			X						
57A: Front underrun protective devices	EC 661/2009	EU 523/2012	11/12/2012					X	X				
	UNECE 93	UNECE 93.00	27/02/1994					X	X				
71: Strength of driver's cab	EC 661/2009 UNECE 29	EU 2015/166	15/06/2015				X	X	X				

1.13.2 Collision protection requirements

1.13.2.1 *General*

Regulations no 817 of 5 July 2012 on the approval of vehicles and road vehicle trailers (the Car Regulations) are the currently applicable regulations, with the requirements mainly being based on European regulations.

The buses have individual and type approval pursuant to directive 2007/46/EC, which includes a description of underrun protection requirements.

Figure 26 illustrates the most relevant UNECE[2] regulations for collision protection on urban buses (bus categories 1 and 2), express coaches (bus category 3), tractors and passenger cars.

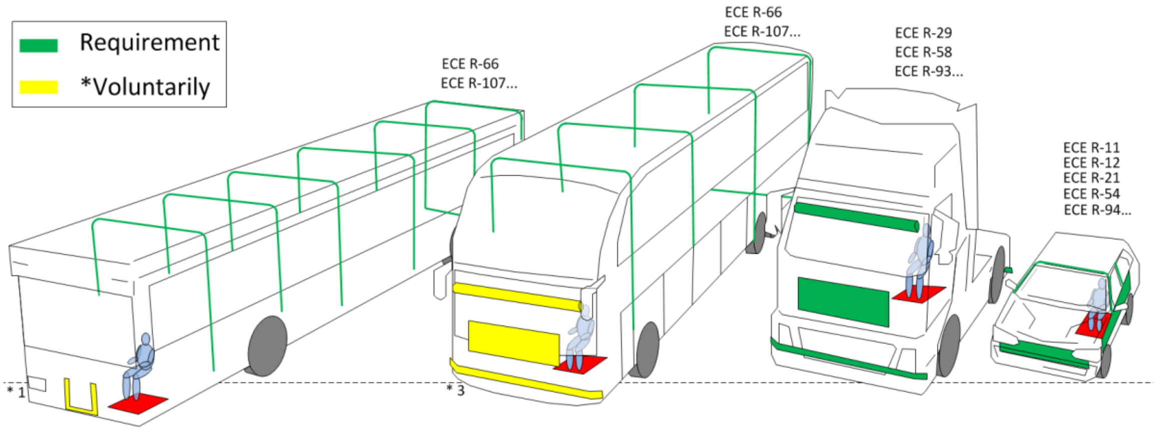

Figure 26: Collision protection requirements for various vehicle groups. Illustration: AIBN

Overall, passenger cars are subject to the most collision protection requirements. There are no underrun protection requirements for cars, but there are front and side collision protection requirements; see Table 3. In many cases, collision tests have also been performed on passenger cars by Euro-NCAP, which rates cars according to how well they

[2] United Nations Economic Commission for Europe (see section 1.14.5)

address safety for adults, children and pedestrians, and which active driver support systems a car is fitted with.

Buses must pass a rollover test in which the bus is turned over on its side. This test is intended to ensure that the roof of the bus does not collapse onto the passengers. However, there are no front underrun protection requirements, nor are there any other front collision protection requirements. The yellow markings in the illustration above are features which a few bus manufacturers have installed voluntarily. These are described in more detail in section 1.15.2.

1.13.2.2 *Collision protection requirements for heavy goods vehicles*

Heavy goods vehicles must have front and rear underrun protective devices in accordance with the Car Regulations. Requirements applying to underrun protective devices are described in UNECE-R-93. The purpose of underrun protective devices on heavy goods vehicles is to ensure compatibility[3] between a heavy goods vehicle and a passenger car in the event of a head-on collision. The protection of occupants of heavy goods vehicles, in relation to penetration into the cab, is described in UNECE-R-29. This describes three tests: two different pendulum tests and one test in which a load is applied to the roof.

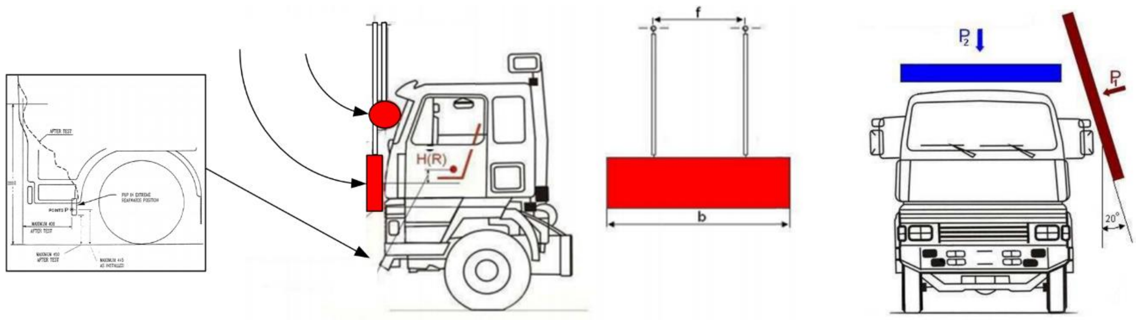

Figure 27: Underrun protection requirements UNECE-R-93 (left), and driver's cab protection with roof and pendulum tests described in UNECE-R-29 (right). Illustration: UNECE/AIBN

The requirements stipulated for underrun protection in heavy goods vehicles can be related to the requirements in UNECE-R-94, which concerns frontal collision protection in passenger cars.

Regulations that include bumpers, or 'cow catchers', are available for all vehicle groups, but these are not a requirement (EEG, 1979).

1.13.3 Requirements for vehicles engaged in transport for which a permit is required

In accordance with Regulations no 1438 of 3 December 2009 relating to the universal design of motor vehicles, category II and III buses which will be used for scheduled passenger transport (*'Forskrift om universell utforming i løyvepliktig transport mv.'* - in Norwegian only) are required to be approved by the Norwegian Public Roads Administration in accordance with the requirements in the regulations section 4 and section 5 (national requirements), as well as with the requirements in the Motor Vehicle Regulations ('*Kjøretøyforskriften*' - in Norwegian only) (international requirements).

[3]Compatibility is understood to be the degree to which the vehicle protects both the occupants of the vehicle and of the colliding vehicle.

This is because, in 2009, changes were made to the approval directive for vehicles in the EU which could not be adapted to the provisions in individual countries. At that time, Norway already had national requirements for seat belts on category II buses (Samferdselsdepartementet, 2009), which could no longer be upheld through only one directive.

In order to maintain the requirement for seat belts in category II buses in Norway, the requirement was incorporated in the regulations relating to universal design. The awarding of permits for scheduled transport services through competitive tender also created an opportunity to stipulate vehicular requirements in addition to those stipulated in the regulations.

1.13.4 Tyre requirements

Regulations no 92 of 25 January 1990 concerning the use of vehicles (‘*Forskrift om bruk av kjøretøy*’ - in Norwegian only) describes the requirements for the use of winter tyres. In 2015, new requirements were introduced for winter tyres on heavy vehicles during the winter season in Norway. The definition of the winter season is from 15 November until 31 March. Winter tyres can either be studded tyres or studless ‘friction tyres’. They must be specially designed for winter driving, and specially labelled with: M+S, MS, M&S, M-S, ‘Mud and Snow’ or 3PMSF (‘3 peak mountain snowflake’).

The ‘M+S’ mark is based on the way the tread pattern is designed in order to disperse water and gain traction in muddy and snowy conditions.

The ‘3PMSF’ (‘3 peak mountain snowflake’) mark is based on an acceleration test in snow conditions.

No winter tyres are currently subject to requirements for retardation or manoeuvre testing on snow or ice, neither on straight sections nor bends.

1.13.5 Requirements for winter maintenance of roads

Winter maintenance of the road network is classified in winter maintenance classes, cf. section 9.3 of Manual R610 – Standard for operation and maintenance of national roads (‘*Standard for drift og vedlikehold av riksveger*’ - in Norwegian only) (Vegdirektoratet, Standard for drift og vedlikehold av veier håndbok R610, 2014). Winter maintenance classes describe the requirements for approved driving conditions, methods of improving friction and measures to be taken in the event of weather events.

Table 4: Requirements for winter maintenance class DkC, 2014-05-01. Source: NPRA (in Norwegian only)

DkC Metode for friksjonsforbedring	Sand skal nyttes på snø- og isdekke, også som preventivt tiltak. Salt skal nyttes preventivt for å forhindre glatt veg forårsaket av tynt snø/isdekke eller rim. I perioder uten snønedbør skal det benyttes salt for å opprettholde bar veg. Så lenge det er snø/isdekke på deler av vegbanen, skal salt kun benyttes når dekketemperaturen er over –3°C, ellers skal det brukes sand som strømiddel.

Godkjent føreforhold *Godkjent føreforhold i høyere vinterdriftsklasse er også godkjent føreforhold*			**DkC**
Tilstand på vegen			I periode med lite nedbør/rimdannelse eller temperatur rundt 0°C: Bar (våt/tørr) Hardt og jevnt snø- og isdekke med maks 2 cm løs snø i kald periode
Friksjon (gjelder strøareal)		Ved værforhold hvor salt tillates benyttet og gir ønsket effekt:	Snø- og isfri (bar) veg
		Ved værforhold hvor salt ikke tillates benyttet eller ikke gir ønsket effekt:	Større enn 0,25
Friksjon på strekninger med forsterket krav til friksjon (gjelder strøareal)		Ved værforhold hvor salt tillates benyttet og gir ønsket effekt:	Snø- og isfri (bar) veg
		Ved værforhold hvor salt ikke tillates benyttet eller ikke gir ønsket effekt:	Større enn 0,3
Hard snø/is	Tykkelse	Ved værforhold hvor salt tillates benyttet og gir ønsket effekt:	Snø- og isfri (bar) veg
		Ved værforhold hvor salt ikke tillates benyttet eller ikke gir ønsket effekt:	Mindre enn 2 cm
		Spordybde i snø/is-dekke (kravet gjelder foran krav til tykkelse)	Ved værforhold hvor salt ikke tillates benyttet eller ikke gir ønsket effekt: Dersom spordybde i snø/is-dekket overstiger 2,5 cm, tillates ikke snø/is-dekke på toppen av ryggen mellom hjulspor og langs kant-/midtlinje.
	Ujevnhet		Ujevnheter i snø- og isdekket som kjettingspor, vaskebrett, o.a. skal være mindre enn 1,5 cm

1.14 Authorities, organisations and management

1.14.1 Akershus county authority

Akershus county authority owns the county road network and is responsible for the overall planning of transportation in Akershus county. Akershus county authority is responsible for 1,816 km of county roads. The 2016–2025 transport plan for Akershus contained goals and strategies for the county authority's priorities through its programme of action. The Norwegian Public Roads Administration manages, operates and maintains the county road network through the 'joint road administration' system. See section 1.14.3.

The county authority also has overall responsibility for public transport, but has delegated authority for this to Ruter. See section 1.14.2.

Salt SMART was a research and development (R&D) project that ran from 2007 until 2011, and it has been continued in Akershus (Sivertsen, 2012).

Akershus county authority's annual report entitled 'The Green County, 2017' describes the following in the section entitled 'Environmental measures on the county roads will continue':

It is one of the county authority's objectives to reduce road salting and increase the use of sanded winter roads. Road salting is intended to improve traffic safety, but it is a source of ground and watercourse pollution. The use of salt varies in Akershus, depending on precipitation, humidity and temperature fluctuations. Between 2010 and 2017, the amount of salt used was reduced by around 35 per cent. Weather conditions have resulted in slightly higher salt consumption in recent winters; see table. The maintenance contracts contain a requirement to reduce salting by using the Norwegian Public Roads Administration's SaltSMART programme. Winter personnel receive training in SaltSMART.

1.14.2 Ruter AS

1.14.2.1 *General*

Ruter AS is a limited company that is responsible for planning, coordinating and marketing scheduled public transport services in Oslo and Akershus. Operating grants are provided by Oslo municipality and Akershus county authority. As well as ordinary scheduled transport, Ruter is responsible for school transport services in Akershus.

1.14.2.2 *Bus services in Romerike*

In 2008, Ruter put the operation of public bus transport services in Romerike out to tender among pre-qualified bidders. The operator Nettbuss AS won the tender.

In its invitation to tender, Ruter set out several requirements of Nettbuss, which included financial, operational and vehicular requirements. In the description of the assignment, it was Ruter's responsibility to ensure that public transport services comply with the requirements of public authorities. It was Nettbuss's responsibility to comply with requirements from the public authorities as regards factors that affected *day-to-day operations*, such as road maintenance, asphalting, snow clearance, excavation work and temporary diversions.

The vehicular requirements that applied to Nettbuss were described in Appendix 2 to this invitation to tender. Section 4, environmental requirements, which contained emission and noise requirements, stated:

4.1.4 Tyres - Studded tyres must not be used on the buses.

In the recently concluded 'Romerike Tender 2019' tender procedure, concerning public transport services in Akershus, section 3 allowed the operator to propose additional safety measures to those described by Ruter:

'The operator is welcome to propose measures to improve safety in addition to those measures described in this document'.

The requirement that buses must not be fitted with studded tyres still applied in section 4, Environment.

1.14.3 Norwegian Public Roads Administration (NPRA)

The NPRA is an administrative agency under the authority of the Ministry of Transport and Communications. The agency has two administrative levels: the Directorate of Public

Roads and five regional offices. They are responsible for the planning, construction, operation and maintenance of national roads, and for approval and supervision of vehicles and road users. The NPRA also issues rules and guidelines for road design, operation and maintenance, road traffic, road user training and vehicles. The NPRA is also the national licensing authority.

The NPRA has been assigned the task of providing uniform road administration for county roads at the regional level. The NPRA is responsible for monitoring the operation and maintenance of the Fv 450 on behalf of Akershus county authority through the joint road administration system, described in section 10 of the Road Act (‘*Veglova*’ - in Norwegian only), and for following up the instructions issued by the Ministry of Transport and Communications to the NPRA.

1.14.4 Mesta

Mesta was the maintenance contractor for this section of road and had a contract with the NPRA for winter maintenance in Romerike. In 2016 and 2017, a total of 82 people from Mesta attended courses in winter maintenance, with the focus on traffic safety, held by the NPRA’s Eastern Region.

1.14.5 The United Nations Economic Commission for Europe (UNECE)

The UNECE is the UN’s agency for economic cooperation in Europe. The working group, The Working Party on General Safety (GRSG) is a subsidiary body of the World Forum for Harmonization of Vehicle Regulations (WP.29), and it prepares regulatory proposals for the World Forum for the improvement of general safety. The GRSG works on technical regulation of the vehicle sector, and addresses safety and environmental measures concerning vehicles and vehicle systems.

The NPRA represents Norway in this forum. The question of requirements for frontal protection on buses was raised by Norway at meetings of UNECE-GRSG in October 2018 and April 2019. Since there are few accidents of this type internationally, the proposal for frontal collision protection on buses was not supported by the other member countries. The document was therefore withdrawn at the meeting in April 2019.

1.14.6 Nettbuss AS

1.14.6.1 *General*

Nettbuss AS is a wholly-owned subsidiary of NSB and is organised in nine regions in Norway. Through a tender contract with Ruter AS, Nettbuss AS won a contract to operate public transport services in selected areas, including Akershus, from 1 July 2009. The group comprising Nettbuss and NSB changed its name to Vy on 24 April 2019.

Nettbuss has a training programme for new employees which consists of several modules. Before this course, heads of department must ensure that staff have undergone a number of checks, including test drives. The recommended duration of the course is three days, and new bus drivers receive training in many subjects ranging from quality systems, use of mobile phones, first aid and a review of the technical side of buses, to the use of chains. Both drivers involved in the accident had undergone this training programme.

1.14.6.2 *Nettbuss's tyre contract with Gummiservice Produksjon AS*

Nettbuss had a tyre contract with Gummiservice Produksjon AS at the time of the accident. Under the tyre contract Gummiservice was responsible for measuring tread depth, changing and retreading tyres and for monitoring that the tyres complied with Norwegian regulations. Part of the contract was designed to ensure that, as far as possible, tyres would be replaced with new tyres in the autumn. This agreement allowed for services such as siping, studding and removing studs from tyres.

1.15 Other information

1.15.1 Risk of dew formation, rime frost and ice on roads

In general terms, the structure of the road has a bearing on the road's ability to store and conduct heat. Good heat storage reduces the effect of temperature increases and reductions on the surface of the road, while structures such as bridges can amplify the cooling effect due to their limited ability to store heat (Statens vegvesen, 2015).

Dew formation is a phenomenon that occurs when air saturated with water can no longer retain its moisture and causes water droplets to form on surfaces. The air's ability to retain water changes with the air temperature and, at higher temperatures, air can absorb higher quantities of water than at lower temperatures. The phenomenon occurs when a surface receives less infrared radiation (such as solar radiation, low cloud cover) than it emits. Dew forms most easily on surfaces that have poor thermal conductivity, and also when there is little wind.

If the dewpoint temperature is below 0°C, this is called the frost point, since dew will not form as water droplets, but as frost or rime frost.

The risk that road surfaces will become slippery arises when the roadway temperature is lower than the dewpoint temperature, at the same time as the roadway temperature is lower than 0°C (Aas, Mahle, & Rogstad, 2001), explained this as follows:

> *When the roadway temperature is lower than the dewpoint temperature, moisture is deposited onto the roadway. If at the same time, the roadway temperature is lower than zero degrees, the moisture will freeze on the road.*

If cloud cover clears, this increases the emission of radiation and lowers temperatures. The report 'Supercooled rain and other weather conditions that cause road conditions to rapidly change to slippery' ('*Underkjølt regn og andre værforhold som gir hurtig glatt veg')* (Holen, Mahle, & Johansen, 2019) describes how the roadway temperature can then fall below the dewpoint temperature, causing rime frost to form on the road (if the roadway temperature is below freezing point). The ice formed is not a thick layer, but a thin layer of rime frost. The quantity/thickness depends on how big the difference is between the roadway temperature and the dewpoint temperature, and thereby how much moisture will be deposited.

1.15.2 Collision protection voluntarily installed by various bus manufacturers

The AIBN is aware that, on their own initiative, some bus manufacturers have installed collision protection at the front of some bus models, over and above that required by

European regulations. Below is a brief summary of the models and installed measures about which the AIBN has information.

Volvo introduced underrun protection on its express coaches in 2007. Since then, this underrun protection has also been modified and reinforced in newer models.

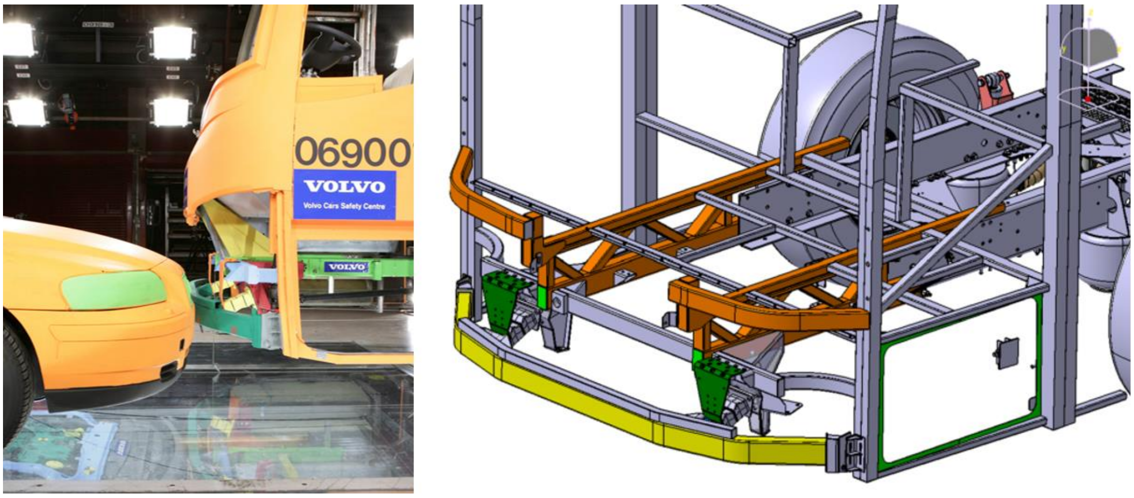

Figure 28: Front underrun protection (FUP) on Volvo's express coaches after 2007 (left) and later reinforcements (right). Photo: Volvo Bus

As well as installing underrun protection, Volvo has also performed collision tests based on the UNECE-R-29 pendulum test. To improve safety even further, Volvo has also performed its own tests using a heavier weight and longer pendulum arm.

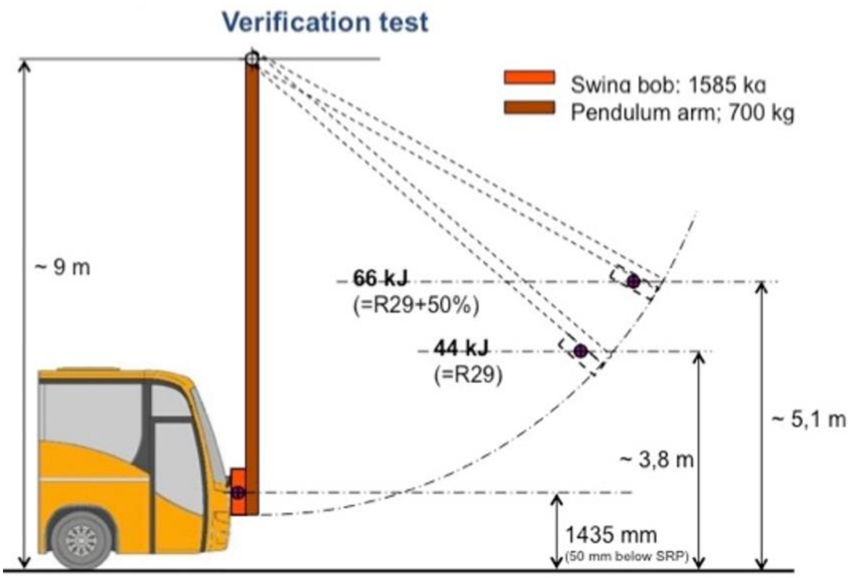

Figure 29: Volvo's pendulum test on its express coach, based on the UNECE-R-29 requirement for heavy goods vehicles. Illustration: Volvo Bus

The bus manufacturer Setra also has collision protection at the front of its express coaches. In 2012, DEKRA performed two collision tests at its test centre on the Setra

Comfort Class 500 model, in which the underrun protection was tested in full-scale at 25 km/h. The UNECE-R-29 requirement was satisfied in this test (Alexander Berg, 2012).

Figure 30: Underrun protection on the Setra Comfort Class 500 in 2012 (left), and front collision test at 25 km/h (right) Photo: DEKRA

Mercedes Benz is another bus manufacturer that has integrated underrun protection on its express coaches. It has also reinforced the area in the centre front of one of its urban bus models. However, this reinforcement does not cover the entire frontage. Tests performed by DEKRA on the Travego express coach model and the Citario urban bus model showed that both bus types satisfied the requirements of UNECE-R-29.

Figure 31: Reinforcement at the front of the Mercedes-Benz Citario, to comply with the requirements of UNECE-R-29. Photo: Mercedes-Benz, 2011

1.15.3 Evaluations of the GRSG concerning crash protection for bus drivers

In 2007, the Working Party on General Safety (GRSG) received a report from an international expert team on the importance of crash protection for bus drivers (GRSG, 2007). Based on the accident statistics from several countries for the period 1978–1999 and on approximately 3,000 accidents involving buses, the working group concluded that frontal collisions were the most prominent accident type. The working group stated that GRSG/GRSP should gradually implement front collision protection in more regulations.

	Object of regulatory work	Related ECE Regulation	Related EU Directive	Responsible GR	Proposed priority	Estimation of needed work
1.	Strength of bus seats and their anchorages	R.80/01 R.17/04	91/676-03/20EC	GRSP	A	M
2.	General safety of buses (all kind)	R.107/Rev.1.	2001/85/EC	GRSG	B	M
3.	External projection	R.61/00		GRSG	B	S
4.	Safety belt anchorage	R.14/05 R.16/04	76/115-96/38EC 77/541-00/3EC	GRSP	B	S
5.	Structural integrity	R.107/Rev.1*	2001/85/EC	GRSG	A	M
6.	Underrun protection	R.93/00	92/114/EC	GRSG	B	M
7.	Limit of deceleration	-	-	GRSG	B	L
8.	Compatibility and agressivity	-	-	GRSP	B	M

Figure 32: Further work and prioritisations presented by the expert group on driver safety in buses in 2007. Source: GRSG-92-7 (92nd GRSG, 16-20 April 2007 agenda item 2.2.7.)

1.15.4 Head-on collision between express coach and passenger car, Finland, 4 July 2015

The Safety Investigation Authority of Finland investigated a head-on collision between an express coach and a car in Karkkila in 2015 (SIAF, 2016). Based on the investigation, the Safety Investigation Authority of Finland submitted six safety recommendations, including a recommendation to improve the crashworthiness of buses in head-on collisions:

The Finnish Transport Safety Agency should propose an amendment to the E regulations to the United Nations Economic Commission for Europe's (UNECE) World Forum for Harmonization of Vehicle Regulations (WP.29) regarding the reinforcement of the front structure of heavy vehicles and the protection of their steering equipment in the event of a collision.

1.16 Implemented measures

During the last winter season, Mesta systematically developed its own registration system with the aim of documenting weather forecasts to ensure that they are available to the persons making decisions on the planning and implementation of winter maintenance measures.

In 2017, the staff of the Årnes branch of Nettbuss proposed applying for dispensation from Ruter’s prohibition on the use of studded tyres. This was granted, with the result that, in the 2018/2019 winter season, the front wheels of 12 school buses were fitted with studded tyres.

Ruter has indicated to the AIBN that the group is currently in the process of clarifying roles and responsibilities in the area of traffic safety.

2. ANALYSIS

2.1 Introduction

The AIBN chose to investigate this accident on the basis of the sequence of events and severity of injuries, also taking into account the fact that two buses on scheduled public transport were involved. The investigation uncovered at an early stage that there could be a learning potential for traffic safety on several points. The changing condition of the road and operating conditions made high demands of the drivers, and the buses were not fitted with tyres that were suitable for the condition of the road. The injuries to the drivers were extremely severe, despite the low speeds.

In the rest of the analysis, the sequence of events and contributory factors will be discussed, including survival factors and the crashworthiness of buses and how they could be improved.

2.2 Assessment of the sequence of events

The eastbound bus was on schedule, and the tachograph data showed that the driver was maintaining a speed below the applicable speed limit. The AIBN considers that the driver's choice of speed was suitable for the driving conditions, with bare asphalt and good friction on the road. The driver had driven the section earlier that day with no problems, and the AIBN believes that his choice of speed can be seen in this light.

The AIBN considers that the bus driver made every attempt to reduce his speed over a section of approximately 150 metres before the bend where the accident occurred at the bottom of the hill. When the bus entered the right-hand bend, the available friction between the tyres and road surface was low ($\mu=0.1$), and in addition the bend only had a slight camber. These factors caused the bus to lose its grip on the road and skid over into the opposite lane, where it collided head-on with the oncoming westbound bus.

The westbound bus was approaching the icy shaded area at the bottom of the hill at a slow speed, and was about to accelerate out of the double bend and up Nafstad hill when the eastbound bus skidded over into the opposite lane. Despite the fact that both buses were maintaining a low speed, neither of the bus drivers was able to see the other because of the short sightlines, until only a few seconds before the collision occurred. In the AIBN's assessment, the driver of the westbound bus had no possibility of avoiding the collision.

2.3 Driving conditions and design of the bends at the accident site

Using information from meteorograms, tyre tracks at the scene of the accident and logs provided by contractor, the AIBN has formed a picture of the condition of the road at the scene of the accident.

The meteorogram from Ulvesund bru shows that the roadway temperature dropped below the dewpoint and that both temperatures were below zero degrees just before 13:00 at this location. This situation can result in rime frost on the roadway. In the AIBN's assessment, this was also the case in the shaded area down Nafstad hill in the interval between 12:30 and 13:00, and a layer of rime frost formed. Photos from the site of the accident taken after the accident support this. People who were at the scene also described that there was a film of ice on the roadway.

The Fv 450 was maintained in accordance with winter maintenance class DkC, and sanding was used as the method at 5:30 that morning. Tyre deposits on the road from the front wheels of the eastbound bus show scrape marks, which indicates that there was still a little grit on the roadway from the sanding that had been performed earlier that morning. However, in the AIBN's assessment, this had little effect on the bus's ability to reduce its speed or stay in its lane through the bend.

The bend at the bottom of Nafstad hill is sharp, and the crossfall in the road is sufficient for run-off, but if the bend had been cambered, this would have increased the safety margin in terms of maintaining road grip. The AIBN believes that the design of the bend was also a contributory factor to the eastbound bus driver being unable to keep the bus on his side of the road as it exited the bend with the friction that was available.

The copse of trees on the south side of the hill has not always been there. Aerial photos show that trees have grown alongside Nafstad hill since 1986. The trees have gradually led to an increase in shade on the roadway, which has resulted in an increased risk of rime and frost formation in certain weather conditions. In the AIBN's view, this also affects safety on this section.

East of the accident site, the road in the westbound direction is marked with the sign 102.2 ‘Dangerous bends, first to the left’, with a sign below indicating ‘100–800 metres’. The road is not signposted with the same signs for drivers approaching from the east towards Nafstad hill. The AIBN believes that the same signage should be posted on the approach to this area from both sides, and that the authorities should consider posting ‘risk of ice’ signs as a consequence of this accident.

In the two or three hours before the accident, Mesta received reports that several roads had become icy, but had not received any report for the Fv 450. The AIBN believes that the sand spread by the contractor that morning was not sufficient to counter the rime frost and film of ice that developed on Nafstad hill and the bend between 12:30 and 13:00.

The AIBN has been unable to obtain weather forecasts, and it is not clear whether the contractor would have been aware of the risk of rime frost when planning operations the day before. The AIBN believes that neither the method (sanding) nor the frequency were sufficient to prevent low friction in the shaded area due to the film of ice that formed.

The AIBN submits a safety recommendation concerning road safety at the accident site.

2.4 Responsibility for tyres

The eastbound bus was fitted with approved winter tyres with sufficient tread depth pursuant to the regulations, with longitudinal treads on the front tyres but no studs. The tyres on the eastbound bus were marked with ‘M+S’ and the 3PMSF symbol.

Although the tyres are legal pursuant to the regulations, the AIBN's assessment is that the tyres on the bus's front wheels did not have optimum control properties in the prevailing road conditions at the bottom of Nafstad hill, and that studs would have increased the safety margins in this case.

Anyone driving a private vehicle on this road has the option of considering whether to use studded tyres. They increase the safety margins on icy roads, provided that the speed is not increased. For environmental reasons, Ruter has made it a contractual condition that no buses in the area may be fitted with studded tyres. Nettbuss therefore did not have the option of fitting its buses with studded tyres, even if it or its drivers wanted them.

Public transport in Akershus operates on many roads, which fall under different winter maintenance classes. This means that the bus drivers must adapt their driving behaviour to many types of driving conditions, due to the vehicles and the tyres available to them. During the winter season, driving conditions are affected both by the weather and by the relevant maintenance category. Both buses involved in this accident had driven through three different winter maintenance categories on their respective routes that day – all subject to different winter maintenance requirements and measures.

The Norwegian Road Traffic Act states that responsibility for having legal and appropriate tyres rests with the operator and driver. The investigation has shown that dispensation from this requirement is now granted in some cases. However, the AIBN is critical of the fact that Ruter continues to apply this requirement in its contracts with operators, without any compensatory measures, such as adjusted timetables, since responsibility rests with the driver in an accident situation.

The AIBN submits a safety recommendation on this issue.

2.5 Crashworthiness of buses

The buses collided head-on with each other at around the same speed, approximately 33-34 km/h. The overlap was approximately one metre between the buses in the collision, but a small angle between them meant that the outcome was different for the drivers. The A-pillar on the westbound bus penetrated right into the driver’s cab of the eastbound bus, which meant that the driver of the eastbound bus was killed instantly. The side wall of the westbound bus was still intact and was bent in towards the centre of the bus, which protected the driver somewhat. The driver of the westbound bus survived the accident with very serious injuries.

Although the collision occurred at a low speed, the weight of the buses is considerable, and the collision cannot be regarded as a low-energy accident. The AIBN nevertheless believes that the severity of the injuries was very extensive, considering the relatively low collision speeds of the buses.

The AIBN believes that the severity of the injuries was greatly affected by the buses’ weak collision protection in the drivers’ cabs. This is connected to the fact that current regulations do not address the crashworthiness of buses in the same way as for passenger cars or heavy goods vehicles (see Figure 26 and Table 3). In the AIBN's assessment, there are several ways to introduce improved crash protection for bus drivers, and this is described in more detail below.

2.5.1 International regulations

The regulations, statements from expert groups and investigations by other investigation boards which the AIBN has compared have shown that front collision protection requirements for buses are generally low. Bus drivers are thereby exposed to a high risk of injuries in the event of frontal collisions, even at low speeds. The lack of regulatory requirements for the protection of bus drivers is an international challenge.

There is documentation showing that, in 2007, endeavours were made at the EU level to improve the regulations concerning the crashworthiness of buses, but as far as the AIBN can see, this work has not resulted in any structural changes to UNECE regulations that have improved crash protection in buses' driver’s cabs.

The regulations relating to front underrun protection on heavy vehicles are intended to address compatibility between a heavy goods vehicle and a passenger car. The AIBN believes that the same need for compatibility also applies to buses.

The Norwegian Public Roads Administration has endeavoured on several occasions to put this on the UNECE-GRSG’s agenda, most recently in April 2019, when it was rejected. On the basis of this and other investigations, the AIBN believes that the Norwegian Public Roads Administration should raise this issue again, if necessary in collaboration with the Finnish traffic authorities, who have also received a recommendation on this matter.

By mutually supporting each other, it should be possible to submit a joint proposal to the UNECE-GRSG (WP.29) in the EU to improve crash protection in buses. The objective should be to harmonise buses with other vehicle groups that are already subject to such requirements.

The AIBN submits a safety recommendation on this point.

2.5.2 Usage requirements relating to public permits in Norway

Norway must abide by European regulations as regards which technical requirements for buses it can include in the Car Regulations. In 2009, the Norwegian Public Roads Administration established an additional requirement for seat belts in buses operating services subject to a permit. The legal authority for this was the Regulations relating to universal design, which made the requirements for category II buses more stringent than the international requirements. This illustrates that there is some latitude within national regulations to raise the level of safety for buses in Norway. Section 5 of the regulations also allows for the introduction of more stringent requirements for vehicles than those already described in the regulations. The AIBN can see nothing to prevent the authorities from proposing a requirement for underrun protection for buses through the Regulations relating to universal design, in the same way as the requirement for seat belts on category II buses was introduced.

The AIBN submits a safety recommendation on this issue.

2.5.3 Bus manufacturers

In Europe, there are currently around 20 major manufacturers of buses. Some bus manufacturers, including Volvo, have chosen to install collision protection on express coaches (M3, category III) by using the same regulations as for heavy goods vehicles. Mercedes has reinforced the front of its Citario urban bus, the only manufacturer to do this so far. The AIBN notes that, although there are no international crashworthiness requirements, several manufacturers have taken steps to go further than the regulatory requirements.

In this accident, two identical Volvo buses manufactured in 2009 collided, both travelling at a speed of 33–34 km/h. These buses were built in a way that satisfied all regulatory requirements, but the accident shows that, even at low speeds, their design and crashworthiness affected the severity of injuries suffered in the accident.

The AIBN submits a safety recommendation to Volvo to improve the crashworthiness of its buses used on scheduled services.

2.5.4 Safety requirements described in invitation to tender for public transport services

As the bodies responsible for public transport, Akershus county authority and Ruter set requirements for operators and for the county’s bus fleet. The invitation to tender is an opportunity for the authorities to impose explicit safety requirements on the operators competing for a permit to operate public transport services in Akershus.

By specifying higher level of level of crash protection for the driver’s cab as a safety measure in the invitation to tender, Akershus county authority and Ruter could motivate bus manufacturers and operators to raise the crashworthiness level of buses.

The AIBN submits a safety recommendation on this issue.

3. CONCLUSION

3.1 Operational and technical factors

a) Rime frost and a film of ice had developed in the shaded area on Nafstad hill prior to the accident, which resulted in friction between the bus and surface of approximately $\mu=0.1$.

b) In the 80 km/h zone, when the eastbound bus was travelling at a speed of around 74 km/h down Nafstad hill, the bus driver made every attempt to reduce his speed as much as possible over the approximately 150-metre-long section leading to and exiting from the right-hand bend further down the slope where the collision occurred.

c) The eastbound bus was travelling at a speed of approximately 58 km/h as it entered the bend. An evaluation of the friction and some simple calculations show that this exceeded the critical speed for this type of bend.

d) The chassis and body of the Volvo bus were not designed to protect the driver or driver’s cab in a frontal collision with a similar bus travelling at the same speed of 33-34 km/h.

e) Both buses were equipped with studless winter tyres marked with ‘M+S’ and the '3-peak mountain snowflake' (3PMSF), and had tread depths that complied with the requirements.

3.2 Underlying factors

a) The buses were in compliance with the regulations, but the EU collision protection requirements for the front of buses are weak compared with those for other vehicle groups.

b) Preventive sanding was performed at 5:30 that day. The effect of this was minimal at 13:00, when rime frost formed along the Fv 450 on Nafstad hill.

c) No buses providing public transport in Akershus county were permitted to use studded tyres during the winter season, based on Ruter's descriptions from in 2008.

4. SAFETY RECOMMENDATIONS

The investigation of this accident has identified several areas in which the AIBN deems it necessary to submit safety recommendations for the purpose of improving road safety.[4]

Safety recommendation ROAD no 2019/07T

The investigation of the head-on collision between two buses in regular service on 17 November 2017 has shown that rime frost and a film of ice formed between 11:00 and 13:00 in the area along Nafstad hill that was in the shade. The sanding of the road at approximately 05:30 did not have the desired effect on this frost formation. The investigation has shown challenges with the design of the road, vegetation, and signage as well.

The Accident Investigation Board Norway recommends that Akershus county authority carry out a safety-review on sections of road in the area near the accident.

Safety recommendation ROAD no 2019/08T

The investigation of the head-on collision between two buses in regular service on 17 November 2017 has shown that Ruter, for environmental reasons, has made it a requirement that its bus service operators cannot use studded tyres in public transport in Akershus county. There is no description of any compensatory safety measures. The AIBN is of the opinion that this requirement affects road safety and that the choice of tyres should be up to the bus service operators and drivers.

The Norwegian Accident Investigation Board recommends that Ruter review the road safety consequences of the requirements set out in contracts with bus service operators.

Safety recommendation ROAD no 2019/09T

The investigation of the head-on collision between two buses in regular service on 17 November 2017 has shown that both the buses were travelling at a speed of 33–34 km/h at the time of impact. The AIBN believes that the severity of the accident could have been reduced if the international regulations relating to crashworthiness for buses, which is reflected in the Norwegian Car Regulations, had been strengthened. Following a similar accident, the Finnish Accident Investigation Board issued a safety recommendation on this issue to the Finnish traffic authorities in 2015, and Norway has made several attempts to raise the issue at the international level, most recently in April 2019.

The Accident Investigation Board Norway recommends that the Norwegian Public Roads Administration, in cooperation with the Finnish traffic authorities and the other Nordic countries, submit a proposal to the World Forum for Harmonization of Vehicle Regulations (UNECE-GRSG, WP.29) on enhanced crash protection requirements for bus drivers.

[4] The investigation report will be 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. the Regulations of 30 June 2005 on Public Investigation and Notification of Traffic Accidents etc. Section 14.

Safety recommendation ROAD no 2019/10T

The investigation of the head-on collision between two buses in regular service on 17 November 2017 has shown that the buses were equipped and approved in accordance with Norwegian and international regulations. The Norwegian Public Roads Administration has previously made use of the opportunity to demand seatbelts in class II buses engaged in transport for which a permit is required in Norway, through the regulations relating to universal design of motor vehicles (*Forskrift om universell utforming av motorvogn i løyvepliktig transport mv.*). The regulations also permit the introduction of additional requirements for material in competitive tenders for transport requiring a permit. The AIBN is of the opinion that Section 5 of these regulations can be used to achieve enhanced crash protection for bus drivers.

The Norwegian Accident Investigation Board recommends that the Norwegian Public Roads Administration consider using national regulations as the basis for improving the crashworthiness of buses used in transport for which a permit is required in Norway.

Safety recommendation ROAD no 2019/11T

The investigation of the head-on collision between two buses in regular service on 17 November 2017 has shown that the buses were both travelling at a speed of 33–34 km/h at the time of impact. The buses were of the same make (Volvo 8700), and both were 2009 models. Since 2007, Volvo has installed underrun protection systems on its express coaches (M3, class III). This exceeds the requirements under international regulations, and the AIBN believes that this accident illustrates the need for enhanced crash protection for drivers of ordinary buses in regular service.

The Norwegian Accident Investigation Board recommends that Volvo as a manufacturer, improve the crash protection for drivers on all its bus types.

Safety recommendation ROAD no 2019/12T

The investigation of the head-on collision between two buses in regular service on 17 November 2017 has shown that the buses were equipped and approved in accordance with Norwegian and international regulations. The buses met the requirements set by Ruter in connection with the invitation to tender in 2008. At the same time, the AIBN sees that the safety requirements Ruter applies in tenders for bus service operators may be used to achieve better crashworthiness than the level achieved through Norwegian and international regulations.

The Norwegian Accident Investigation Board recommends that Akershus county authority and Ruter introduce crash protection requirements for drivers as a criterion in connection with tenders for new public transport services.

Accident Investigation Board Norway

Lillestrøm, 24 June 2019

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