Norwegian Safety Investigation Authority

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REPORT ROAD 2023/05

Head-on collision between two buses on the Rv 110 road in Fredrikstad on 28 December 2022

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The Norwegian Safety Investigation Authority (NSIA) has produced this report exclusively for the purpose of improving road safety.

The object of the NSIA's investigations is to clarify the sequence of events and causal factors, elucidate matters deemed to be important to the prevention of accidents and serious incidents, and to issue safety recommendations if relevant. It is not the NSIA's task to apportion blame or liability under criminal or civil law.

This report should not be used for purposes other than preventive road safety work.

Photo: NPRA

This report has been translated into English and published by the NSIA to facilitate access by international readers. As accurate as the translation might be, the original Norwegian text takes precedence as the report of reference.

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Summary

On the morning of 28 December 2022, two identical buses from Vy Buss AS had a head-on collision on national highway 110 at the Fredrikstad bridge. The buses were of type M3 class 1 MAN Lion's city low entry 2013 model. One bus was empty with no passengers and the other bus had two passengers. Despite the fact that the buses collided at low speed, the accident resulted in one driver being killed and one driver being critically injured. The two passengers in the one bus obtained minor injuries.

The investigation has shown that Bus 5 came from the right lane in the northbound direction into the middle lane and then into the opposite lane in the southbound direction. Bus 5 collided head-on with its left front against the left corner of Bus 113. The collision speed of Bus 5 was approx. 32 km/h and the collision speed of Bus 113 was approx. 35 km/h.

Overall, it is the NSIA's assessment that at some point during the last seconds before the collision, for an unknown reason, the driver of Bus 5 was unable to actively drive the bus, and that this led to a collision with the oncoming bus. The NSIA has investigated, but failed to establish an explanation as to whether something happened to the condition of the driver of Bus 5 in the last 9–10 seconds before the collision.

Both buses sustained extensive damage to the driver's area in the collision. The design with a lack of impact-resistant construction on the buses' left front represents a general technical challenge for several bus manufacturers. This is critical for the safety of bus drivers in frontal collisions between buses with little overlap. Similar challenges in bus constructions were also visible in the accidents in Nafstad (2017) and Tangen (2021). The NSIA believes that bus drivers as employees should be better protected.

New Norwegian requirements for head-on collision protection in new buses entered into force on 1 October 2023 through the Regulations relating to universal design of motor vehicles used for licensed transport etc. The requirement means that a metal plate weighing 1,500 kg attached to a pendular arm, strikes the front of a bus at around 30 km/h. The investigation, however, has shown that the left-hand corner of buses has weaknesses in head-on collisions that occur with a small overlap, and that the weaknesses are not necessarily uncovered in a frontal impact test based on a flat impact against the front of the bus.

In light of the safety recommendation already issued by the NSIA in connection with two previous investigations and the ongoing work relating to the crashworthiness of buses under the auspices of the bus sector, the Ministry of Transport and the NPRA, the NSIA will not issue further safety recommendations in connection with this specific investigation.

However, head-on collisions where a bus is one of the involved vehicles account for 2–3 per cent of all road traffic fatalities. The NSIA therefore believes that more knowledge is needed about the overall challenges relating to the crashworthiness of buses, and what impact this can have on other groups of road users in head-on collisions. The NSIA will therefore conduct further investigations into the crashworthiness of buses.

1. Factual information

1.1 Data relating to the incident

Date and time:	28 December 2022 at 09:12	
Accident location:	Fredrikstad	
Road system reference:	RV110 S3D1 M5595 F2	
Type of accident:	Head-on collision between two buses	
Road conditions:	Wet roadway. A continuous yellow and double centre line with two lanes in the northbound direction (Bus 5) and one lane in the southbound direction (Bus 113). Speed limit 60 km/h.	
Weather conditions:	Cloudy, fair and good visibility, temperature -1°C – -2°C	
Vehicle type and combination:	MAN Lion's City low entry bus, M3 class 1	
Bus involved (local service):	Bus 5	Bus 113
Make and model:	MAN Lion's City 2013 (CNG)	MAN Lion's City 2013 (CNG)
First registered to owner:	31 December 2015	31 December 2015
Last approved periodic roadworthiness test:	13 April 2022 (472,557 km)	24 August 2022 (513,879 km)
Last serviced:	14 October 2021	20 December 2022
Distance travelled at time of accident:	507,615 km	540,305 km
Type of transport:	Passenger transport requiring a licence	Passenger transport requiring a licence
Personal injuries:	Driver critically injured	Driver deceased, two passengers with minor injuries
Damage to vehicles:	Extensive damage front left	Extensive damage front left
Driver's age and experience:	49 years. Has driven a bus for 4 years and an HGV for 14 years.	53 years. Has driven a bus for 27 years.
Transport company:	Vy Buss	Vy Buss
Sources of information:	The NSIA's own investigations at the accident site and technical examinations of the buses, documents from the Norwegian Public Roads Administration and the police, data from IBAS and the tachographs, data from the Norwegian Mapping Authority, information from MAN, fleet management data and CCTV footage from the buses.	
Notification of the accident:	The Traffic Control Centre (VTS East) notified the NSIA about the accident at 09:21 on the day of the accident. The NSIA immediately headed to the accident site.	

1.2 Sequence of events

1.2.1 INTRODUCTION

On Wednesday 28 December 2022, two buses were driving towards each other on the Rv 110 road in Fredrikstad (see Figure 1). Bus 5, on one of main bus routes in Fredrikstad, was travelling from Fredrikstad town centre to the old town without any passengers. Bus 113, on one of the local bus routes, was heading towards the town centre with two passengers on board.

Figure 1: Overview of the accident site in Fredrikstad Map: © Norwegian Mapping Authority. Illustration: NSIA

1.2.2 BUS 5

On the day of the accident, 28 December 2022, the driver of Bus 5 started driving at 05:04. In the time leading up to the accident, the fleet management system showed that the ignition was switched off during three periods: 06:06–06:12 (6 minutes), 06:46–07:00 (14 minutes) and 07:44–08:20 (36 minutes). This is related to breaks that are adapted to suit the route driven.

Bus 5 arrived a little early at the bus stop at the bus terminus in Fredrikstad. The bus was stationary for approx. 1.5 minutes before the driver resumed driving the scheduled route at 09:07:04 and the bus was on schedule.

CCTV footage from the bus was obtained for the time the bus was stationary at the bus terminus and until approx. 90–100 metres before the collision. Video footage of the collision was not saved.

When the bus entered the Rv 110 road after the roundabout, it swung into the right-hand lane on the three-lane road, in a slight left-hand bend heading northwards towards Fredrikstad Bridge. The video footage showed that, at the beginning of this period, the driver's torso was slightly restless while his head and eyes were focused on the traffic situation along the road. The driver has explained that it was perfectly normal for him to sit 'a bit restlessly' while driving.

The last camera image from Bus 5 showed that the bus remained in the right-hand lane heading northwards until approx. 90–100 metres (approx. 9–10 seconds) before the collision. Tachograph data indicate that the bus was travelling at approx. 40 km/h at this point.

In the CCTV footage of the driver, there was no visible indication that a collision was imminent. The driver does not remember anything from the actual collision or from the last five days before the accident.

1.2.3 BUS 113

On the day of the accident, 28 December 2022, the driver of Bus 113 started driving at 06:20.

Footage was obtained from the camera inside the bus from before the bus passed Fredrikstad Bridge and up to the accident site.

The video recording showed that, during this period, the driver's torso was calm, and that his head and eyes were focused on the traffic situation along the road, including when a passenger car overtook the bus on Fredrikstad Bridge.

The last camera image from Bus 113 showed that the bus remained on the right-hand side of its lane heading southwards until approx. 33 metres (approx. 2.5–3 seconds) before the collision. Tachograph data indicate that the bus was travelling at approx. 50 km/h at this point.

There was nothing in the video recording of this driver either to indicate that a collision was imminent. One of the passengers has described that the driver reacted vociferously just before the collision, but the passenger had not seen the run-up to the collision.

1.2.4 COLLATION OF THE SEQUENCE OF EVENTS

Just before the collision, Bus 5 crossed over into the left-hand lane and continued over towards Bus 113 in the oncoming lane. The buses collided head on with a small overlap in the southbound lane. At the moment of impact, Bus 5's speed was approx. 32 km/h, while Bus 113's speed was approx. 35 km/h; see section 1.7.

Figure 2 shows the sequence of events based on the last images from the video cameras on the two buses.

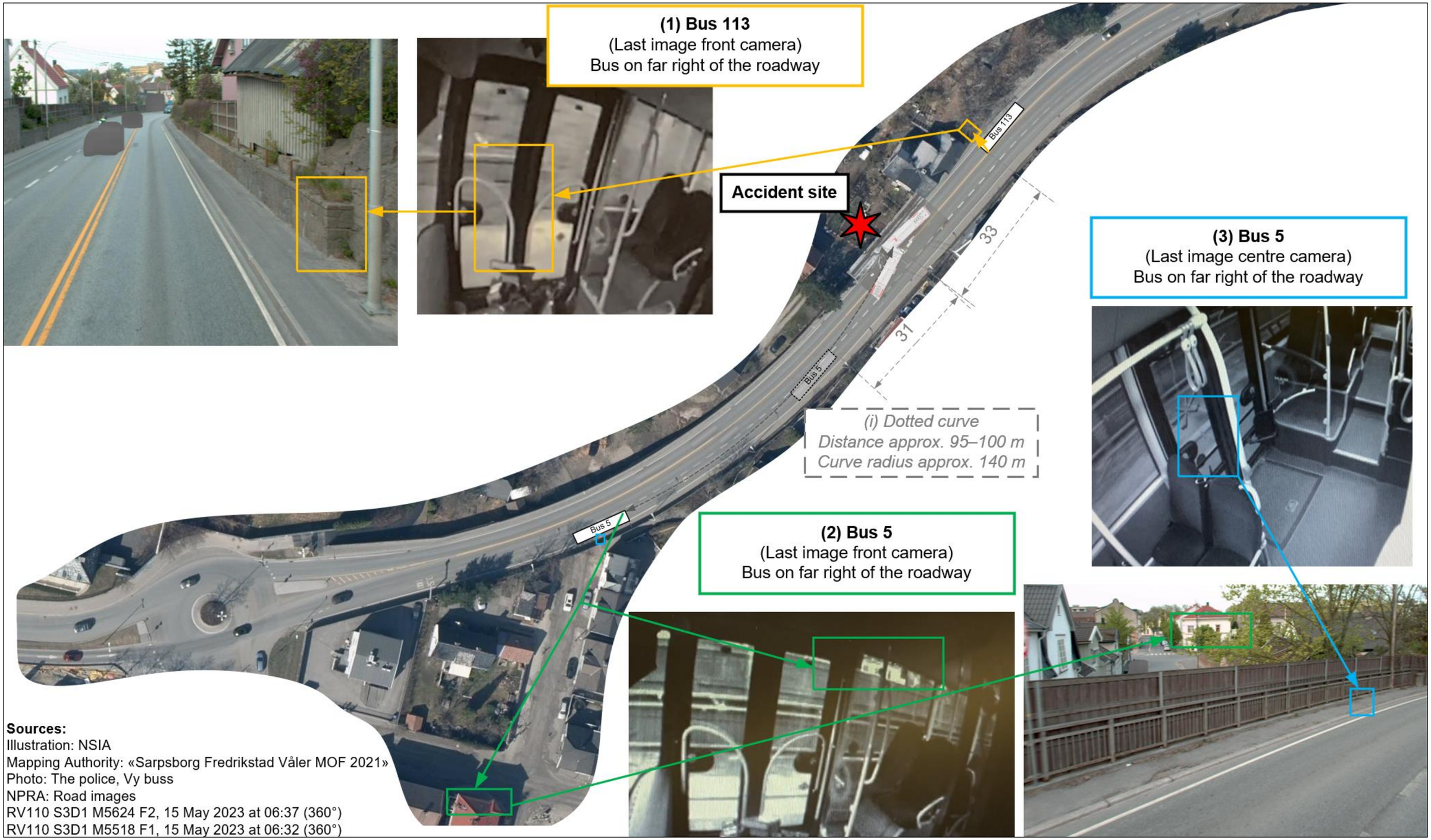

Figure 2: Sequence of events based on the last images from the video cameras on the two buses. Bus 113's last front camera image before the collision is shown together with the roadside terrain (1). Bus 5's last front camera and centre camera images are shown together with the roadside terrain in order to estimate its last documented longitudinal position (2) and its last position in relation to the breadth of the roadway (3) before the collision. The dotted curve (i) shows the possible trajectory of Bus 5. Illustration: NSIA

1.3 Survival aspects and personal injuries

There was no survival space in the driver's cab in Bus 113 because of the penetration of the oncoming bus's side panel into the driver's cab (see Figure 3 and Figure 4). The driver of Bus 113 died as a result of the injuries suffered. The passengers in Bus 113 sustained minor injuries.

Figure 3: Bus 113 seen from the front. Photo: The police

Figure 4: Driver's cab Bus 113. The driver's seat has been pushed backwards. Photo: NSIA

The driver of Bus 5 was conscious after the collision and was trapped in a seated position with critical injuries. The side panel of the oncoming bus penetrated alongside the driver's cab, while other parts of the bus were pressed inwards at seat height (see Figure 5 and Figure 6). There was survival space in the upper part of the driver's cab in Bus 5, but the area below seat height was crushed. The driver was put in a medically induced coma after the accident.

Figure 5: Bus 5 seen from the side. Photo: The police

Figure 6: Driver's cab in Bus 5. Driver's seat intact. Photo: NSIA

1.4 The accident site and vehicles

In the final position, the buses were interlocked at an angle of approx. 23°. The damage was primarily on the front-left side and the front of both buses; see Figure 7. Both buses were examined by the Norwegian Public Roads Administration (NPRA) at the accident site.

The examinations carried out by the NPRA showed that the steering wheel axle on both buses had been knocked loose and that there was no connection between the steering wheel and the wheels. The angle of the steering wheel in Bus 5 indicated a slight turn to the left, while the angle of the steering wheel in Bus 113 indicated a turn to the right in the final position. The NPRA's assessment was that both buses were in the prescribed condition before the accident.

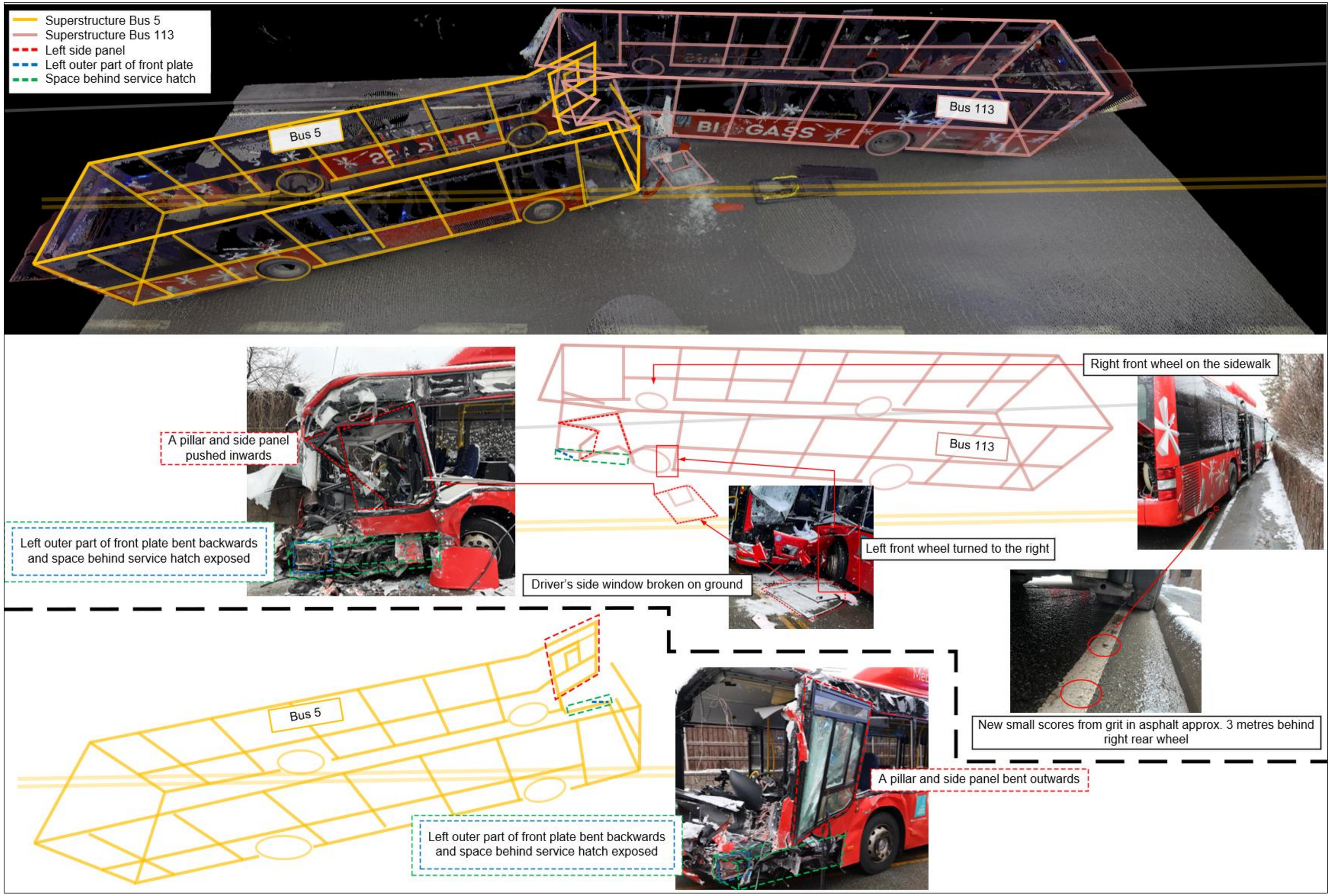

Figure 7: Collation of evidence and findings at the accident site. The deformation of the side panels (dotted red line), the outer parts of the front plates (dotted blue line), the service space (dotted green line) and the final position of the buses has been mapped. Photo/3D scan: NPRA, NSIA. Illustration: NSIA

1.5 Road surface conditions

The road surface at the accident site was wet. Retardation tests were carried out at 10:35 using the NPRA's duty vehicle, which was equipped with studless winter tyres. The retardation was measured in the direction Bus 113 was travelling, where the downward gradient of the roadway was 3.5 degrees. The average retardation was measured and the friction was calculated to be $\mu = 0.55$.

1.6 Bus design

Both the buses were of the make MAN Lion's City, 2013 model. Both buses were approved pursuant to the applicable technical vehicle requirements. The general design of the buses is shown in Figure 8.

Figure 8: Bodywork and superstructure, and chassis on low-entry bus. Source: MAN.

The buses were moved to the NSIA's premises at Lillestrøm and examined by the NSIA. The NSIA's technical examinations have focused on three elements of the design of the front left part of the buses, as shown in Figure 7 and Figure 9:

- Left side panel (dotted red line)
    - This design consists of a vertical A pillar that is connected to the 'superstructure' of the buses.
- Left outer part of the front plate (dotted blue line)
    - The outermost part of a continuous horizontal front plate from corner to corner at the front of the buses. The part is attached to the left part of the vehicle's frame in the driver's cab towards the left-hand corner and the A pillar, and it is approx. 45 cm wide.
- The space inside the service hatch (dotted green line)
    - This space is behind the outer left-hand part of the front plate, and it extends from the left-hand corner back to the left-hand front wheel arch. On these buses, this space is designed as a 'service space', while on other buses it can be designed to house the battery/fuses.

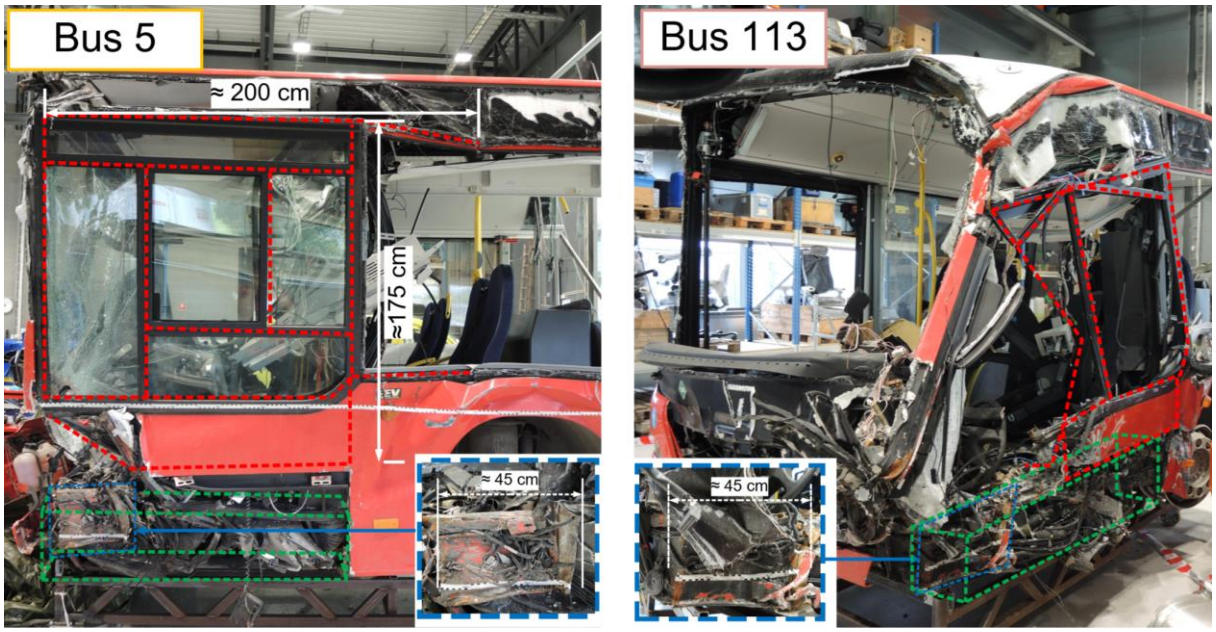

Figure 9: Examination of Bus 5 (to the left) and Bus 113 (to the right)[1] on the NSIA's premises. Photo: NSIA

1.7 Collision speed

The tachographs from both buses were secured, and speeds at one-second resolution were downloaded. During the collision, both the tachographs experienced an error in a file that registers 1/4-second speeds, and the results of attempts to reconstruct it have not become available during the investigation period. The tachographs had unsynchronised clocks, so that the speed curves were synchronised by setting the assumed collision time as the point zero.[2]

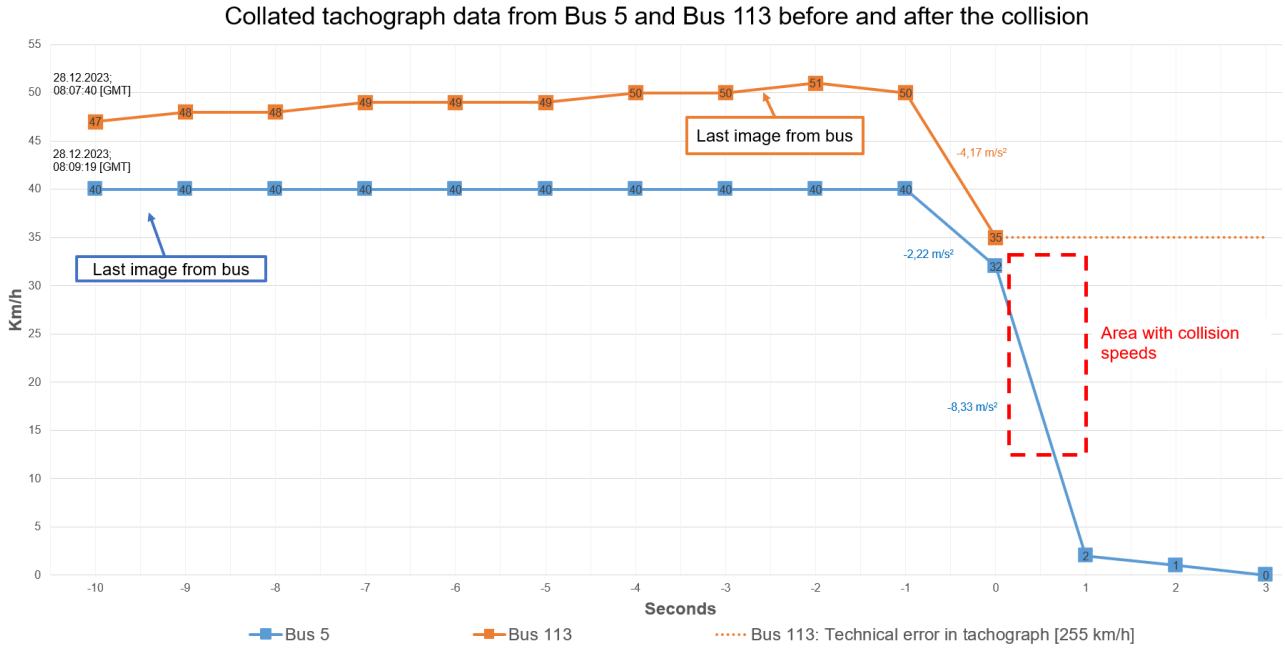

Figure 10: Collation of the buses' tachographs, and the time of the last camera image from the buses. The assumed collision time is set as point zero. Source: NSIA

[1] *Both buses have sustained damage as a result of the salvage work, during which, among other things, the A pillar on Bus 113 was pulled forwards.*
[2] *The assumed collision time is assessed to be the point in time after a registered higher retardation than the available friction on the road surface, or where the technical fault arose.*

On this basis, the collision speed of Bus 5 was approx. 32 km/h, while the collision speed of Bus 113 was approx. 35 km/h.[3]

1.8 The bus drivers

Both drivers were employed by Vy Buss. In Fredrikstad, the working day for bus drivers is organised from 04:00 to 00:30. A system has been established with a stand-by driver, whose working hours are from 04:15 to 07:30. The stand-by driver is in contact with the drivers who start in the morning, is informed if anyone is absent and takes over the driving assignment in question. The stand-by driver did not become aware of anything special relating to the bus drivers involved on the morning of the accident.

The NSIA reviewed traffic data from both drivers' mobile phones, and no signs of active use were found during the period immediately before the accident.

1.9 Previous relevant accidents

The NSIA has previously investigated two similar accidents involving buses travelling at low speed, published as Road traffic report 2019/04 and Road traffic report 2022/02.

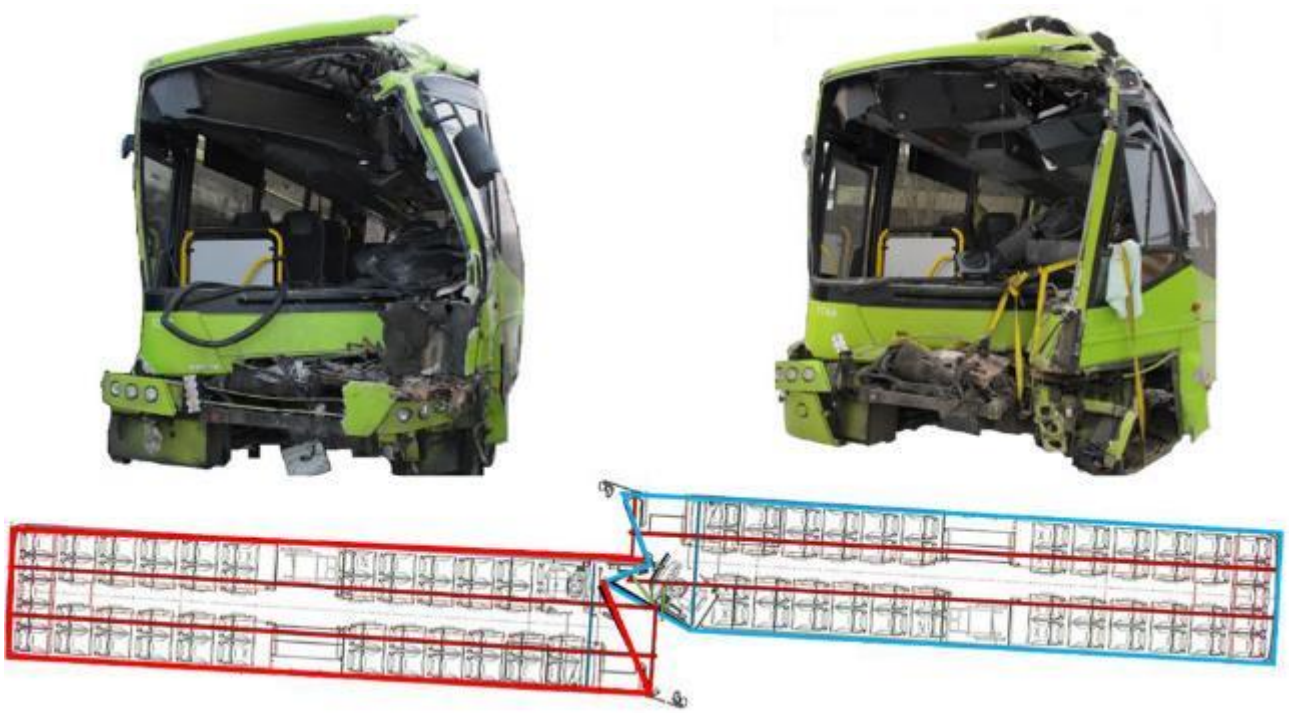

Figure 11: Photo and illustration of the vehicles after a head-on collision on the Fv 4500 road at Nafstad in Ullensaker on 17 November 2017. Source: Road traffic report 2019/04, SHK[4]

[3] *The tachographs can have an error margin of approximately ± 6 km/h.*
[4] *https://www.nsia.no/Road/Published-reports/2019-04-eng*

Figure 12: Photo of the vehicles after the head-on collision on the FV 222 road near Tangen in Stange on 11 March 2021. Source: Road traffic report 2022/02, SHK[5]

In both these head-on collisions, the buses that collided were of two identical models. In both accidents, one of the buses crossed partly over into the oncoming lane, and they collided with each other at a narrow angle and with little overlap on the left-hand side. Two drivers died in the two head-on collisions and one driver was critically injured.

The NSIA's investigations of the accidents have shown that the regulatory requirements for the crashworthiness of buses have been insufficient to ensure the safety of drivers and that the crashworthiness requirement is lower for buses than for other groups of vehicles.

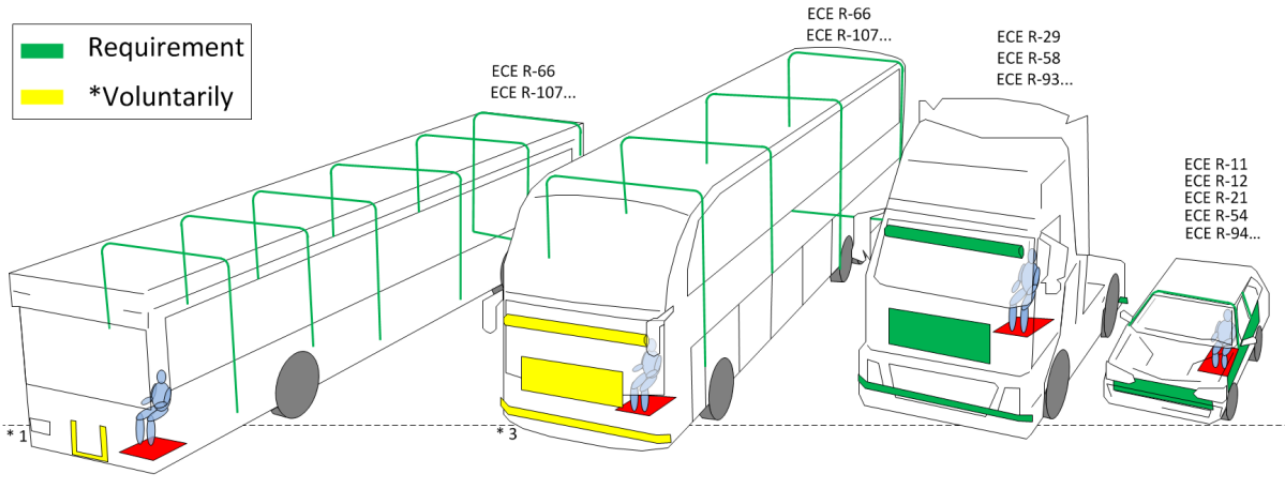

Figure 13: Illustration of the most relevant ECE regulations for the crash protection of urban buses (bus classes 1 and 2), express coaches (bus class 3), tractors and passenger cars. Source: Report 2019/04, Figure 26, NSIA

The NSIA made six safety recommendations in Road traffic report 2019/04. Four of the recommendations concerned improving the crashworthiness of buses by strengthening tender descriptions, product improvement, and making the national and international regulations more stringent. The NSIA made three safety recommendations in Road traffic report 2022/02, one of which concerned strengthening the crashworthiness of buses through tender descriptions.

[5] https://www.nsia.no/Road/Published-reports/2022-02

1.10 Implemented measures and work on the crashworthiness of buses

1.10.1 MAKING NATIONAL REQUIREMENTS MORE STRINGENT

The NSIA (then the AIBN) made the following safety recommendation in Road traffic report 2019/04:

> *Safety recommendation ROAD No 2019/ 10T:*
>
> *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 for licensed transport in Norway.*

The safety recommendation was closed by the NPRA publishing a consultation paper on 27 January 2022, with a deadline for submissions of 27 April 2022, on strengthening the crashworthiness of buses used for licensed transport:[6]

> *On assignment from the Ministry of Transport, the Norwegian Public Roads Administration hereby distributes for public consultation these draft regulations amending Regulations No 1438 of 3 December 2009 relating to universal design of motor vehicles used for licensed transport etc. The Norwegian Public Roads Administration proposes amending Section 4 of the Regulations by introducing a requirement for frontal protection of buses in the M3 categories I, II and III that have a scheduled service or tour bus permit.*
>
> *The reason for this is that there have been a not inconsiderable number of accidents in which buses have been involved and in which bus drivers have been seriously injured or killed in connection with head-on collisions. In its report 2019/04, the Norwegian Safety Investigation Authority (NSIA) has therefore recommended introducing technical requirements for the front of buses in order to reduce the extent of injuries in connection with head-on collisions. The employees' trade unions have also demanded that buses be made more crashworthy.*

In light of the consultation submissions, the Ministry of Transport[7] decided to introduce these requirements by making certain amendments. A fifth paragraph was added to Section 4 of Regulations No 1438 of 3 December 2009 on the universal design of motor vehicles used for licensed transport etc. applicable from 19 June 2023:

> ***Section 4. Requirements that apply to buses***
>
> *[…]*
>
> *Class I, II and III buses that are covered by these Regulations and that are registered for the first time in Norway from and including 1 October 2023, shall meet the requirements for frontal protection described in Section 5 of UN Regulation No 29 when the collision test has been carried out in accordance with Annex 3 Test A where the impact value of the impactor shall be in accordance with Section 5.5.2. The conditions in Section 5.1.6 can be used as an alternative to mechanical testing.*

[6] *Høring om styrket kollisjonsbeskyttelse for buss i løyvepliktig transport. (Consultation on strengthening the crashworthiness of buses used for licensed transport – in Norwegian only). Reference:21-238225-4*
[7] *The Ministry of Transport's consultation process, Reference:23/1021*

1.10.2 UN REGULATION NO 29

'UN Regulation No 29 – Rev. 2 – Cabs of commercial vehicles'[8], Annex 3 describes a frontal impact test where a rectangular plate (800 mm (h) x 2500 mm (b) has an impact energy of 55 kJ. The test is approved pursuant to requirements defined for survival spaces for a test manikin described in paragraph 5.2.

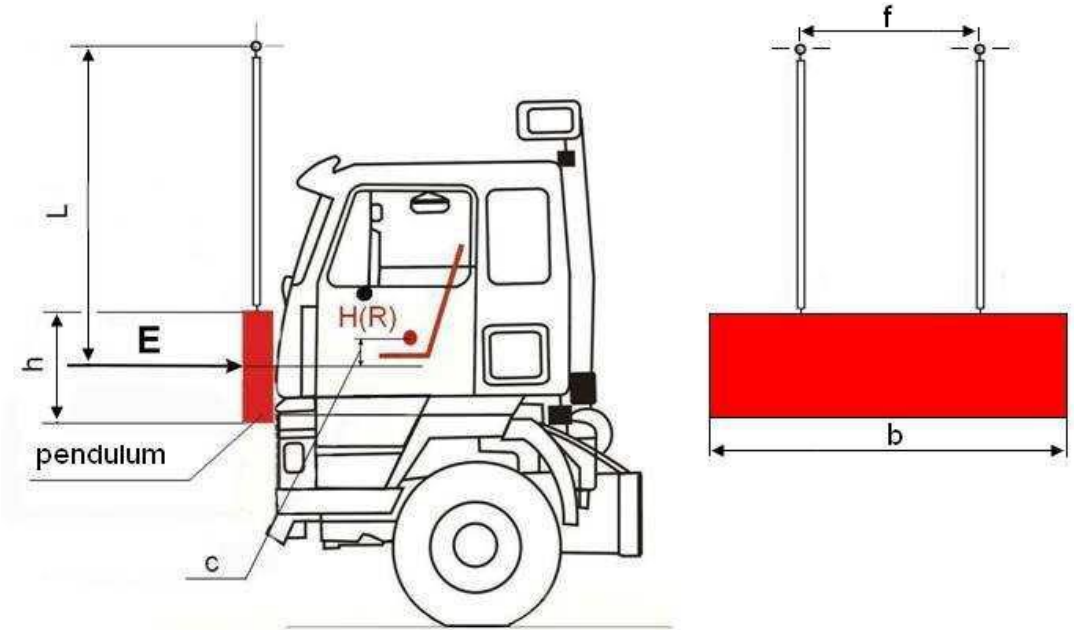

Figure 14: Illustration of the frontal impact test where the front of an HVG vehicle is impacted at the height of the driver's cab, H(R). Source: UN ECE R-29

1.10.3 INTERNATIONAL WORK

The NSIA (then the AIBN) made the following recommendation in Road traffic report 2019/04:

> *Safety recommendation ROAD No 2019/ 09T:*
>
> *The Accident Investigation Board Norway recommends the Norwegian Public Roads Administration, in cooperation with the Finnish traffic authorities and the other Nordic countries, to resubmit a proposal to the World Forum for Harmonization of Vehicle Regulations (UNECE-GRSG, WP.29) for enhanced crash protection requirements for bus drivers.*

The safety recommendation has been closed by the Ministry of Transport. Together with the Swedish authorities, the NPRA has held discussions and submitted input to the work on road safety in similar accidents in connection with a meeting of UNECE GRSP, WP 2917[9] without this resulting in any concrete results.

On 28 March 2023, the Minister of Transport raised the issue with the EU's High Level Group on Road Safety, stating that there is a need for stricter regulation on the construction of buses in order to protect drivers, which should be addressed at EU and international level through the

[8] UN Regulation No. 29 – Rev.2 – Cabs of commercial vehicles.
[9] *The Working Party on Passive Safety (GRSP) is a working group under the World Forum for Harmonization of Vehicle Regulations (WP.29) in the United Nations Economic Commission for Europe (UNECE) that prepares proposals for amendments to regulations relating to passive vehicle safety.*

development of an international safety standard. It was also stated that there is a need for harmonisation with other vehicle classes.[10,11,12]

On 22 May 2023, the Ministry of Transport sent a 'Supplementary allocation letter No 6 to the NPRA – Assignment to study crash protection requirements for buses – step 2'[13], which described the NPRA's follow-up in this area.

1.10.4 WORK BY THE BUS SECTOR

The NSIA is aware that the Norwegian bus sector has for several years been working to improve the safety of drivers in connection with head-on collisions. Among other things, the Public Transport Association has funded a report from the Institute of Transport Economics: *'Safety in bus transport in Europe: Status of safety and discussion of measures benefitting drivers, passengers and other road users',*[14] which was published in September 2023.

[10] *High Level Group on Road Safety – Minutes of meeting 28 march 2023*
[11] *Press release from the Government No: 89/23 (in Norwegian only)*
[12] *Speech/contribution | Date: 10 Oct. 2023 by Minister of Transport Jon-Ivar Nygård*
[13] *Supplerende tildelingsbrev nr. 6 til Statens vegvesen (Referanse 22/2452-17) – in Norwegian only*
[14] *Institute of Transport Economics (TØI), Report No 1984/2023*

2. The NSIA's assessments

2.1 Introduction

The NSIA chose to investigate this accident because of the extent of the damage and injuries in a head-on collision between two buses travelling at relatively low speed. This chapter begins with an assessment of the sequence of events leading up to the collision, provided in section 2.2. Crash protection in buses is discussed in section 2.3.

2.2 Sequence of events

The investigation has shown that the road and driving conditions on the day of the accident were predictable. Nor did the buses have any known technical faults before the accident. Both buses were travelling well below the speed limit of 60 km/h at the location, and there was no active use of the drivers' mobile phones. Both buses were on the right-hand side of their lanes on the three-lane road approx. 9–10 and 2.5–3 seconds, respectively, before the collision.

The investigation has shown that Bus 5 crossed from the right-hand, northbound lane over into the middle lane and then into the southbound lane. The left front of Bus 5 collided head-on with the left front corner of Bus 113. Signs at the accident site indicate that the collision took place at an angle that was relatively similar to the angle of the buses in their final position.

A passenger stated that the driver of Bus 113 reacted in advance of the accident. The speed retardation in the second before the collision and the related signs at the site indicate that the driver braked strenuously at the same time as he made an active avoidance manoeuvre to the right. The video recording from the bus shows no reaction on the part of the driver of Bus 113 approx. 2.5–3 seconds before the collision – when the distance between the buses was approx. 60 metres. This could indicate that Bus 5 did not visibly deviate from normal driving behaviour in the preceding seconds.

Signs at the site indicate that the steering wheel in Bus 5 was turned slightly to the left. There were no skid marks at the accident site, but there was a speed reduction before the collision. The speed reduction can be a sign of braking, but it can also be the result of a slackening of pressure on the accelerator. The NSIA has carried out investigations, but has not reached a conclusion on whether a change occurred in the condition of the driver of Bus 5 during the last 9–10 seconds before the collision.

Findings from the investigation indicate that, just before the collision, the driver of Bus 5 turned the steering wheel but failed to straighten it up again as the roadway straightened out. A possible trajectory, marked (i), for Bus 5 is illustrated in Figure 2. If the bus has followed this trajectory, Bus 5 would not have crossed over into the middle lane before the buses were approx. 60 metres apart, and it would have been difficult for oncoming drivers to detect anything abnormal before that. In the NSIA's assessment, the speed reduction in the last second before the collision is related to the driver probably having passively slackened the pressure on the accelerator, and that it was not the result of active braking. This is because the investigation found no evidence in the roadway to indicate braking or attempts at avoidance manoeuvres before the accident.

The NSIA's overall assessment is that driver at some point during the final seconds before the accident, for reasons unknown, was incapable of actively manoeuvring the bus, and that this led to the collision with the oncoming bus.

Storage units in buses are often fitted internally on the front left-hand side at ceiling height. This means that both tachographs and video storage units are vulnerable to damage and loss of

information in head-on collisions. The NSIA has experience of this from previous accidents and believes that a different placement and better protection of these units could provide a better basis for assessing the sequence of events in safety investigations.

2.3 Crash protection in buses

Despite the fact that the buses collided at low speed, the accident resulted in one driver dying and another being critically injured.

Based on the evidence, the impact point on Bus 113 was the left-hand corner. Bus 5's first impact point was between the left-hand corner and the left-hand frame on the front of the bus, on the outer part of the front plate (up to approx. 45 cm); see Figure 15. At the first impact point, there was an overlap between the buses' A pillars. This meant that the left-hand outer part of the buses' front plates was bent backwards and cut off the lower part of the A pillar, so that the side panels of both buses broke loose.

The side panel of Bus 5 was bent outwards, forming something that can be described as a 3.5 sq m panel hinged on the left front wheel, about 2 metres behind the front. The side panel on Bus 113 collapsed backwards and its strength was reduced as a result of one of the side windows breaking loose. The buses hit each other's left-hand frame, beneath the driver's seat, and then slid along this frame; see Figure 16. The buses stopped when Bus 5's front frame hit the other bus's left forward axle. During this period, Bus 5's side panel penetrated the other bus and swept over the driver's cab; see Figure 17. As a result, there was no survival space for the driver of Bus 113.

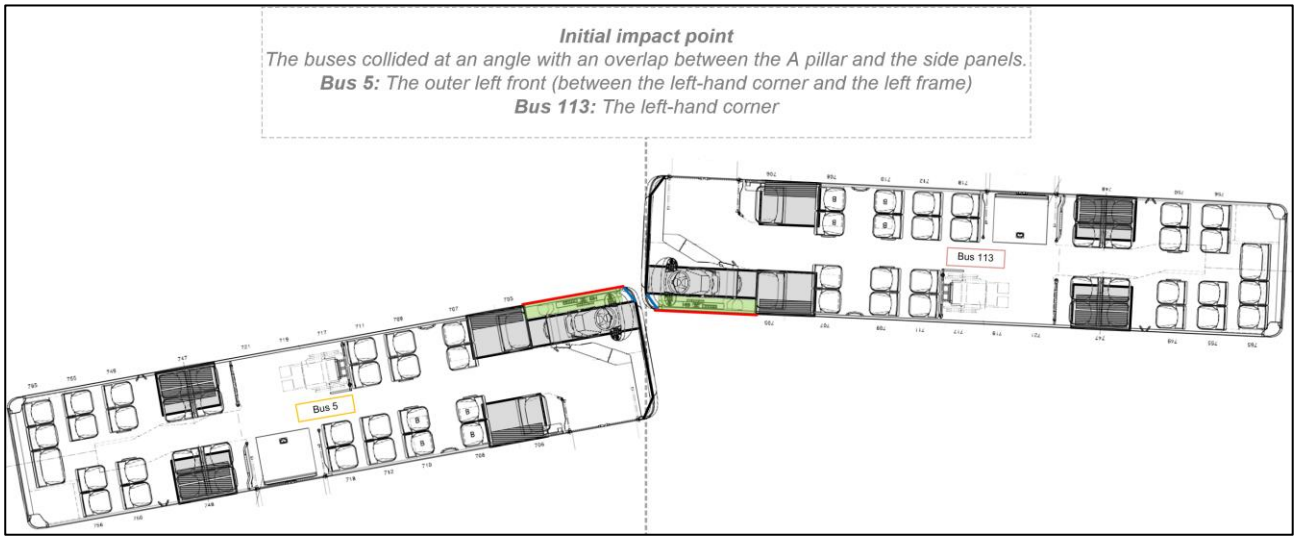

Figure 15: The buses' initial impact point. Illustration: NSIA

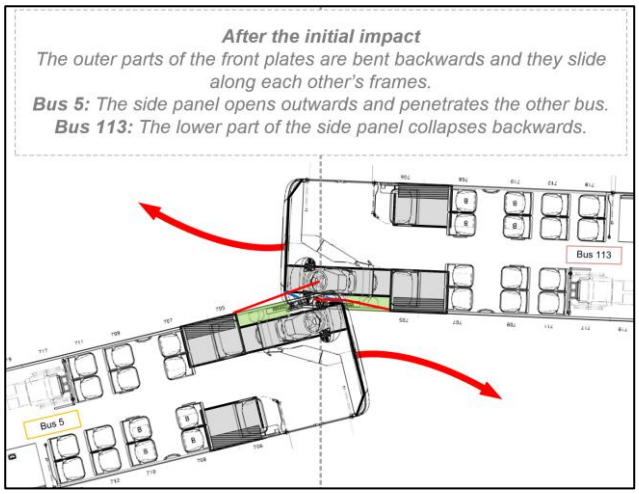

Figure 16: The buses' penetration after the initial impact. Illustration: NSIA

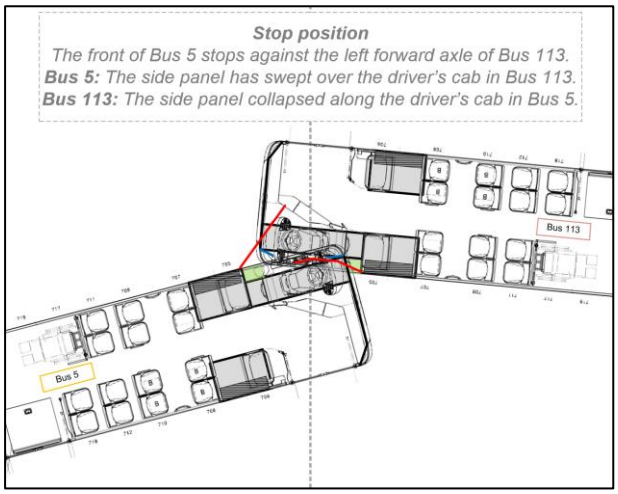

Figure 17: The buses' stop position in relation to each other. Illustration: NSIA

The collision highlights what the NSIA regards as a combination of unfortunate elements of the design of the buses' left-hand corners. The side panel with an A pillar and wall frame are of a robust design. This is a result of the bus's superstructure, which meets minimum requirements for rollover and impact tests to prevent collapse (described in UN Regulation No 66[15]). The left-hand frame of the buses was approx. 45 cm inside and under the left side panel. In this space (the service space) there was no shock absorbent or shock resistant structure except the outer part of the front plate, which collapsed on both buses.

As a result of the lack of a shock-absorbent or shock-resistant structure, the collision between the buses led to a collapse furthest down in the left-hand corner, and to the whole left side panel bending outwards. The NSIA believes that this played a decisive role in the side panel penetrating Bus 113, leading to the death of the driver.

The side panel of Bus 113 also penetrated Bus 5, but it penetrated alongside the driver's cab, and, as a result of the collapse in the lower part, it missed the driver. The driver of Bus 5 was nonetheless critically injured since other parts of the bus were pressed inwards at seat height.

The NSIA has reviewed the damage to the buses and the findings from the investigation together with the bus manufacturer MAN. However, the NSIA does not believe that the MAN buses represent a unique technical solution, but that the design and the lack of a shock-resistant structure on the front left-hand side of the buses represent a general technical challenge for several bus manufacturers. This is critical for the safety of bus drivers in head-on bus collisions with little overlap. Similar bus design challenges were also identified in the Nafstad (2017) and Tangen (2021) accidents.

The NSIA believes that, as employees, bus drivers should be better protected. In this connection, it is positive that new Norwegian requirements for head-on collision protection in new buses entered into force on 1 October 2023 through the Regulations relating to universal design of motor vehicles used for licensed transport etc. The requirement means that a metal plate weighing 1,500 kg attached to a pendular arm, strikes the front of a bus at around 30 km/h (55kJ).

However, the investigation has shown that the left-hand corner of buses has weaknesses in head-on collisions that occur with a small overlap, and that the weaknesses are not necessarily uncovered in a frontal impact test based on a flat impact against the front of the bus. When new buses are registered in Norway pursuant to the new requirements, the different manufacturers will

[15] UN Regulation No. 66 – Rev.1 – Strength of superstructure (buses)

take different approaches to satisfying the minimum requirements in the test. The NSIA does not know, however, whether the technical solutions only satisfy the frontal impact test or whether they can also address the weaknesses this investigation has revealed.

The regulations relating to the crashworthiness of buses are part of the EU regulations, and, pursuant to the EEA Agreement, Norway is obliged to accept buses that are approved based on the common European requirements. In the long term, the fact that the Minister of Transport has raised the issue at the EU level could form the basis for better frontal protection of buses, and the Norwegian regulatory amendment is a step in the right direction in terms of increasing safety. The bus sector's efforts to improve the safety of drivers is also an important contribution to the further work on increasing the crashworthiness of buses.

2.4 Further work

The NPRA's consultation paper[16] on the now implemented regulatory amendment stated that 'during the period from 2011 to 2020, 35 people have died in head-on collisions involving buses'. During the same period, a total of 1,314 fatalities were registered in road accidents in Norway. That means that head-on collisions in which a bus was one of the involved vehicles amounted to 2.66% of all fatal accidents during the period. Based on the information the NSIA has about head-on collisions since 2020, the proportion of fatalities in head-on collisions involving a bus does not seem to have decreased.

In light of the safety recommendation already issued by the NSIA in connection with two previous investigations and the ongoing work relating to the crashworthiness of buses under the auspices of the bus sector, the Ministry of Transport and the NPRA, the NSIA will not issue further safety recommendations in connection with this specific investigation.

However, head-on collisions where a bus is one of the involved vehicles account for 2–3 per cent of all road traffic fatalities. The NSIA therefore believes that more knowledge is needed about the overall challenges relating to the crashworthiness of buses and what impact this can have on other groups of road users in head-on collisions. The NSIA will therefore conduct further investigations into the crashworthiness of buses.

Norwegian Safety Investigation Authority
Lillestrøm, 13 December 2023

[16] *Annex 1 – Consultation paper: Consultation on the proposed regulations amending Regulations No 1438 of 3 December 2009 relating to universal design of motor vehicles used for licensed transport etc. (reference 21/ 238225-2) – in Norwegian only*