Informal document GRSP-69-02
(69th GRSP, 17 - 21 May 2021,
agenda item 8)

Norwegian Safety Investigation Authority

Published December 2020

REPORT Road 2020/07

REPORT ON A HEAD-ON COLLISION BETWEEN A PASSENGER CAR AND A VAN ON THE E39 AT AUSTEFJORDEN, VOLDA, MØRE OG ROMSDAL ON 20 OCTOBER 2019

The Norwegian Safety Investigation Authority (NSIA) has compiled this report for the sole purpose of improving road transport safety. The object of any investigation is to identify faults or discrepancies which may endanger road transport safety, whether or not these are causal factors in the accident, and to make safety recommendations. It is not the NSIA's task to apportion blame or liability. Use of this report for any other purpose than for road transport safety shall be avoided.

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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REPORT ON ROAD TRAFFIC ACCIDENT

Date and time:	20 October 2019 at 09:03	
Scene of the accident:	Austefjorden in Volda, Møre og Romsdal county	
Road no, main section (hp), km:	E39, hp 32, m 2526	
Type of accident:	Head-on collision	
Vehicle type and combination:	Mercedes-Benz E-Class estate car 2011 model	Mercedes-Benz Vito van 2014 model
Type of transport operation:	Private transport	

NOTIFICATION OF THE ACCIDENT

The Norwegian Safety Investigation Authority (NSIA) was not notified about the accident, but became aware of it through the media. Because of its severity, the NSIA contacted the police. On Wednesday 23 October 2019, two accidents inspectors travelled to Volda to examine the vehicles. After the preliminary investigation, the NSIA decided to instigate a full investigation into the accident.

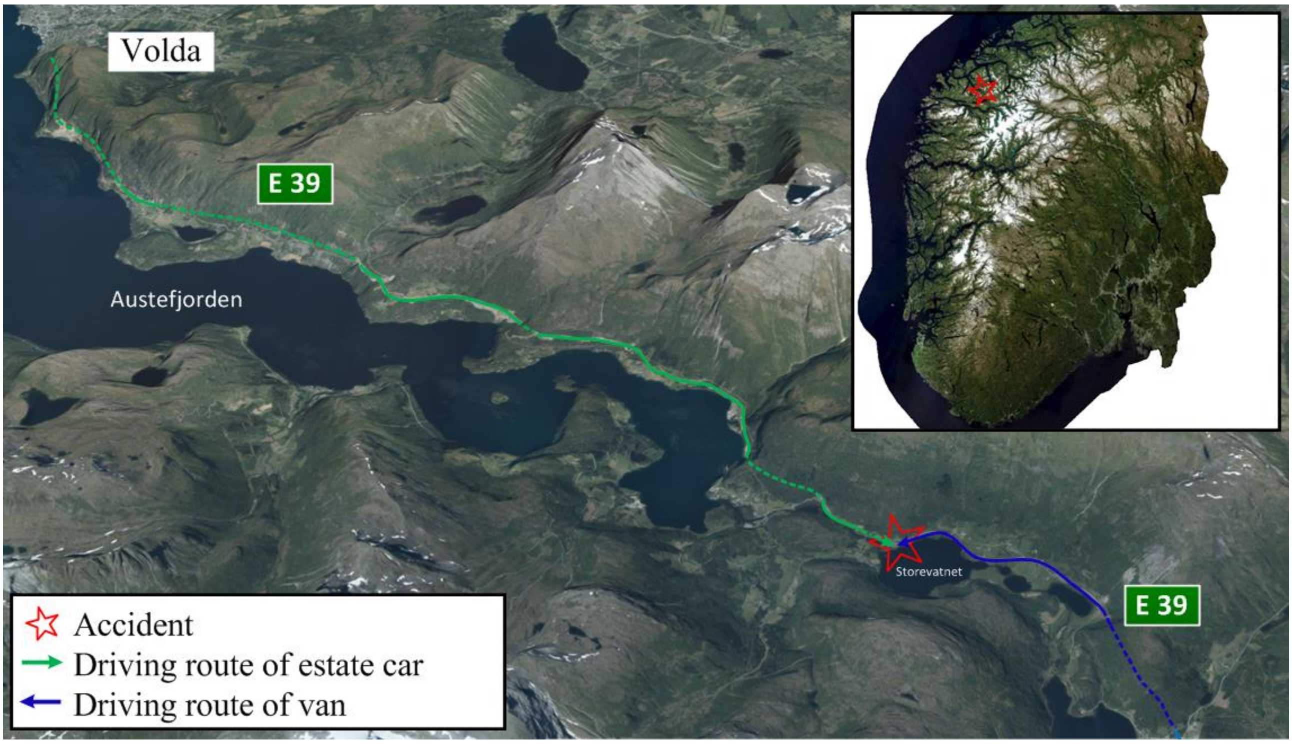

Figure 1: Overview of the accident site and the routes travelled by the vehicles. Map: © Norwegian Mapping Authority, NSIA

SUMMARY

On the morning of 20 October 2019, on the E39 northbound, immediately south of the Damfoss tunnel in Volda, a van with two persons on board lost its grip on the ice-covered road surface in a right-hand bend. The van crossed into the opposite lane and collided head-on with an estate car of approximately the same weight, fully laden with passengers.

Both vehicles are considered to have driven at a speed around the speed limit in the 80 km/h speed limit zone. The persons in the front seats of both vehicles sustained only minor injuries. The left rear seat passenger in the estate car was unsecured and died later from the injuries sustained in the collision. The middle rear seat passenger was secured by a seat belt and died instantly from extensive injuries. The right rear seat passenger was secured, but sustained critical abdominal injuries probably as a result of sliding under the seat belt during the collision.

It became clear after the accident that the van driver was driving without a driving licence. The NSIA maintains that driving without a licence is unacceptable from a road safety perspective. The NSIA also considers that the road conditions in the bend where the accident occurred did not meet the operating requirement for bare roadways, and that they were demanding and difficult to identify at the time of the accident. In the NSIA’s opinion, the road conditions at the scene were so bad that any driver would have found them challenging.

In its further investigations, the NSIA focused on the sequence of events and survival aspects of the accident, and why the injuries sustained by the rear seat passengers were so different and so much more severe than those suffered by the other passengers. The investigation concentrated on the safety equipment in the estate car’s different seats, and looked in particular at the safety level for the middle rear seat passenger.

The seat belt in the middle of the estate car’s rear seat had a narrower lap belt than all the other seat belts in the same vehicle, and was also the only belt without a pretensioner and force limiter. The seat belt’s shoulder belt was attached to a folding rear seat-back, rather than to the vehicle body like the other belts. The investigation showed that the back of the rear seat was severely deformed, despite being reinforced and well within the regulatory strength requirements described in UN-ECE R17.

The investigation showed that the split rear seat-back in the estate car was subject to a loading from luggage weighing 65 kg in total. In addition to this came the loading imposed by the middle rear seat passenger’s seat belt. Only a small rucksack and the middle head restraint entered the passenger compartment. The compartment cover beam was not fitted, and could not be fastened to the rear seat-back in any case. The NSIA considers that the compartment cover beam could have absorbed some of the loading, but that it is impossible to establish whether this would have changed the outcome for the middle passenger. It is the NSIA’s opinion that the luggage was sensibly packed. Heavy items were placed low against the seat-back, and the total weight was within what one might expect a rear seat-back to withstand, with or without the compartment cover beam fitted.

The NSIA’s investigation has caused it to be concerned that the regulations do not sufficiently provide for rear-seat passenger safety, and that no collision tests have been established to test this. The NSIA has also investigated several other car manufacturers’ middle rear seat belt arrangements, and considers these to be generally less well designed compared to other seat belts in the same vehicle.

The investigation has shown that the load in the boot should be secured, not just to prevent loose items from entering the passenger compartment, but also as means of preventing increased loading on the rear seat-back. This is an important passive safety measure for all persons in the passenger compartment, but especially for the middle passenger in rear seats with a split seat-back. The NSIA issues one safety recommendation based on this investigation.

1. FACTUAL INFORMATION

1.1 Sequence of events

On Sunday 20 October 2019 at about 06:00, a van with two persons on board left Førde heading north towards Ørsta. At 08:40, an estate car with five persons on board left Volda and drove south towards Oslo.

At 09:00, the area south of the Damfoss tunnel had clear weather with ground mist, high relative humidity and air temperature of about 0°C. These weather conditions had created a film of ice across the whole roadway in the shadowy area south of the Damfoss tunnel.

When the van was in the last right-hand bend before the tunnel, it lost its grip. The driver braked, but the van skidded straight ahead and into the opposite lane. The estate car had just come out of the tunnel on its southward journey. Its driver barely had time to take in that the van was crossing over into his lane, when the vehicles collided head-on. Both vehicles were of roughly the same weight and collided head-on with a small angle between them. Both drivers have assessed the speedometers in their own vehicles to be around 70-80 km/h before the accident, and within the speed limit, which was 80 km/h along this section.

The drivers and front seat passengers in both vehicles sustained only minor injuries. In the rear seat of the estate car, one person was killed instantly, one died later and a third person suffered life-threatening injuries.

Figure 2: Final positions - northbound van and southbound passenger car photographed at 11:48. Photo: The police

1.2 Personal injuries

Seven persons were involved in the accident; two persons in the van and five persons in the estate car. All those involved were of normal height and weight. Table 1 describes where each person was sitting, and the personal injuries sustained.

Table 1: Summary of where each person was sitting in the vehicles and their injuries. Source: NSIA

Vehicle	Seat	Gender, age	Injuries
Estate car	Driver	Man, 53 years	Fracture in left heel, neck pain.
	Right front seat passenger	Man, 26 years	Pain in both knees, injuries to right wrist.
	Left rear seat passenger	Woman, 29 years	Extensive head injuries. Died later in hospital.
	Middle rear seat passenger	Woman, 62 years	Instantaneous fatal dislocation and spinal injury between neck and head. No visible head injuries. Several fractured ribs. Fractured left leg and thigh. Extensive and potentially life-threatening abdominal injuries. Extensive injury to left side of neck. Three spinous process fractures on the left-hand side in the neck/shoulder area.
	Right rear seat passenger	Woman, 26 years	Critical abdominal injuries. Fractured ribs on left side. Pelvic pain.
Van	Driver	Man, 23 years	Fractured right thumb. Pain relief at the accident site.
	Passenger	Man, 24 years	Pain.

1.3 Survival aspects

1.3.1 Notification and rescue efforts

The operations centre was notified of the accident at 09:03. Two available ambulances and a police patrol deployed from Volda. The air ambulance was also called out. When the police patrol arrived at the accident site at 09:21, the ambulances were already there.

When the first ambulance arrived at the site, CPR was being administered to one of the passengers. In total, three ambulance helicopters deployed and assisted with evacuating patients. The fire service responded with a command vehicle and crew vehicle. One person was flown to Ålesund Hospital, four persons to Haukeland University Hospital, and two persons were taken by ambulance to Volda Hospital.

1.3.2 Survival aspects and safety equipment in the vehicles

1.3.2.1 *Introduction*

Both vehicles were transported to the NSIA's premises for examination after the accident. The passenger compartments in both vehicles had survival space[1] in all seat locations. The vehicles were equipped with safety equipment as illustrated in Figure 3.

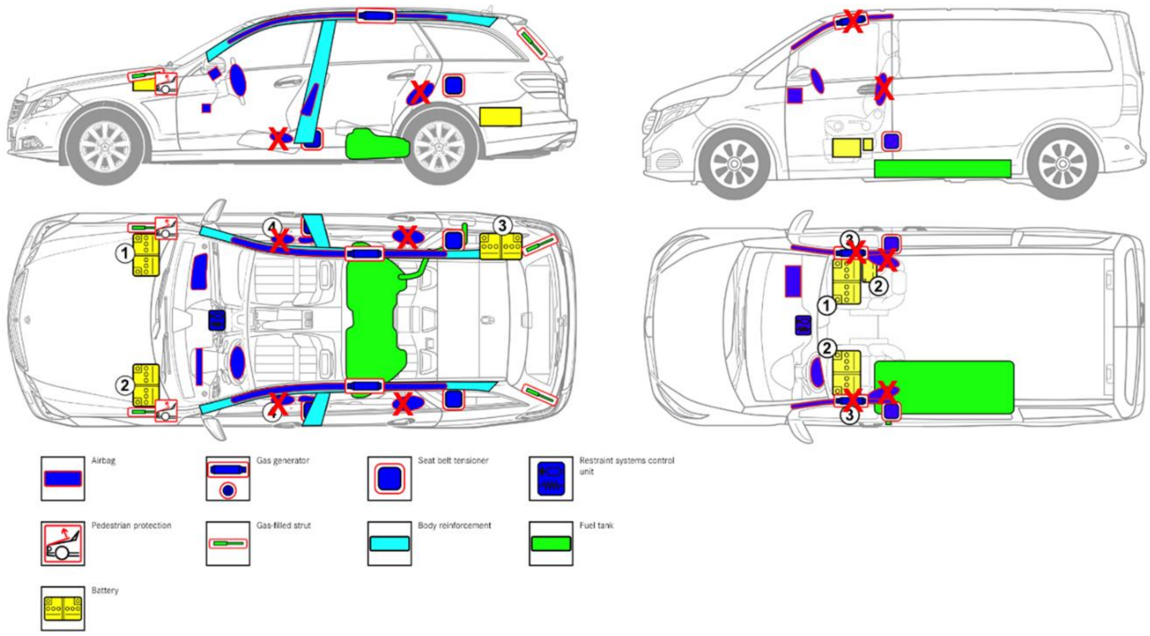

Figure 3: Diagram showing body reinforcement, airbags and seat belts with pretensioners in the estate car (left) and van (right). Safety equipment that was not installed is marked with a red cross. Illustration: «Euro Rescue» / NSIA

1.3.2.2 *The estate car*

There was a total of seven air bags in the estate car. Three of these were activated in the collision; the front and knee airbags on the driver's side, and the right front passenger's dashboard airbag. Four of the five persons in the car were secured with seat belts at the moment of impact. The seat belts were investigated by the NSIA and are described in more detail in Section 1.13.1.

1.3.2.3 *The van*

There was a total of two airbags in the van. Both the front airbag on the driver's side and the right front seat passenger's dashboard airbag were activated in the collision. The van had no side curtain airbags or chest airbags; these are optional extras. There were three-point seat belts with belt pretensioners and force limiters for the driver's seat and right-hand passenger side. Both persons in the van were wearing seat belts, and both belt pretensioners and force limiters were activated in the collision.

[1] The remaining space available to the driver and passengers inside a car after deformation or indentation of the vehicle body in a collision.

1.4 Vehicle damage

1.4.1 External and internal deformations, marks and points of impact in the estate car

The front of the estate car had external deformations and had crumpled by approx. 73 cm on average across its whole width. The passenger compartment was intact and all doors could be opened and closed. The windscreen was the only broken window. The driver's seat was originally 30 cm away from the back seat and was displaced forward and upward, but was still firmly attached to its front anchorage. The right passenger seat was originally 40 cm away from the back seat and was loose and displaced further forward. The rear seat-back consisted of two parts, and the larger part (the 60 part) was displaced approx. 20 cm forward from the normal position at the middle rear seat. The distance between the rear seat-back, and the forward part of the rear seat squab, was approx. 45 cm. The NSIA removed the upholstery from the rear seat-back and examined it in detail, see Section 1.13.4. There were scorch marks on the right rear seat squab, and a dent under the rear seat squab, see Figure 4.

The middle head restraint was stuck in the roof, pins first, immediately behind the driver's seat, but was not ripped or damaged. At the middle of the rear side of the seat-back was what appeared to be a spot of paint, but this is not related to the accident.

Figure 4: External/internal deformations, marks and points of impact in the estate car Illustration/photo: NSIA

1.4.2 External and internal deformations and points of impact in the van

Externally, the crumple zones in the front of the van had crumpled by approx. 40 cm. The right impact cushion had completely crumpled. There was little deformation internally, and a full partition separated the load in the cargo space from the passenger compartment. Pretensioners and force limiters were activated on both seat belts.

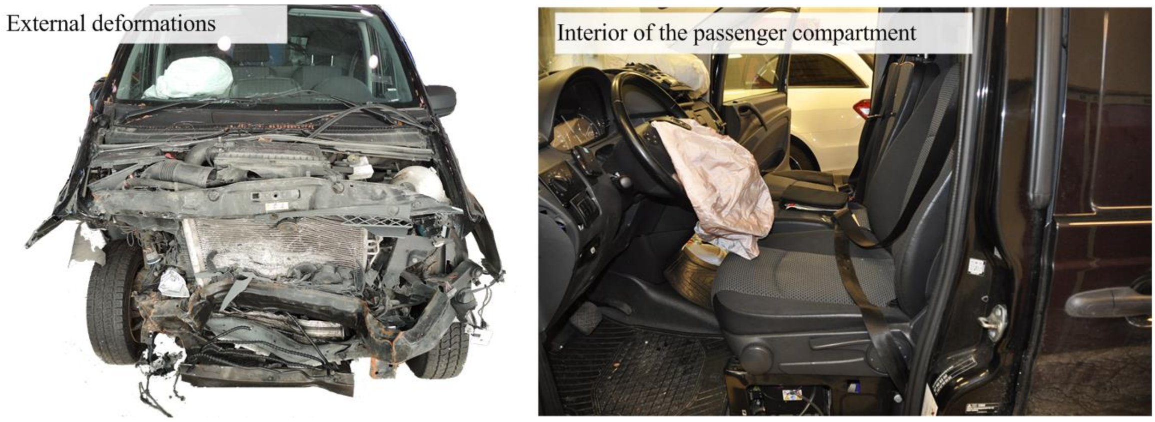

Figure 5: External deformations on the van and the interior of the passenger compartment. Illustration/photo: NSIA

1.5 Other damage

The accident did not cause any significant damage to infrastructure etc.

1.6 The site of the accident

Trace marks and damage at the scene were documented by the police and the Norwegian Public Roads Administration (NPRA) on the day of the accident, and the NSIA has based its work on this information. Traces from the van's tyres on the road surface were documented at an early stage. These traces gradually disappeared when the ice film melted as the sun rose, see Figure 6. Smashed covers and remnants from the engine compartments of both vehicles lay concentrated in a V shape beside the final position of both vehicles. No impact points or traces were found on the asphalt that could confirm where on the roadway the collision happened, but there were indications that the point of collision was ±1 metre from the final position.

Figure 6: Temporary traces left by the van on the roadway, photographed at 10:04. Photo: The police

Figure 7: Spread of plastic covers and remnants from the head-on collision Photo: The police

1.7 Road users

1.7.1 Driver and passengers in the estate car

The driver of the estate car was a 53-year-old man with Norwegian nationality. He held a driving licence with Classes BE/CE/DE and was living in Sweden.

The right front seat passenger was a 26-year-old man. A 29-year-old woman was in the left rear seat. A 62-year-old woman was in the middle rear seat, and a 26-year-old woman occupied the right rear seat.

1.7.2 Driver and passenger in the van

The driver of the van was a 23-year-old man with Swedish nationality. He had undergone and documented completion of the compulsory training (riskutbildning) for Class B in Sweden, which includes driving on a slippery driving track, but had not taken the driving test.

The right front seat passenger in the van was a 24-year-old man.

1.8 Vehicle and load

1.8.1 Mercedes-Benz E-Class estate car 2011

1.8.1.1 *General information*

The estate car was a Swedish-registered Mercedes-Benz E-Class estate car, 2011 model. The net weight of the vehicle was 1,850 kg, and the maximum permissible weight was 2,420 kg.

The vehicle had studless winter tyres, with 7 mm tread depth all round. Its last periodic roadworthiness test was carried out in Sweden on 22 February 2019. The NPRA examined the vehicle after the accident and found no faults or defects that could have contributed to the accident.

1.8.1.2 *Load and securing*

The vehicle's weight was estimated to have been approx. 2,200 kg at the time of the accident, approx. 220 kg below the maximum permissible weight. The weight of the luggage in the boot was calculated at approx. 65 kg. The luggage consisted of five suitcases/bags that weighed between 6.2 and 11.6 kg, and seven smaller bags, rucksacks and handbags weighing 2–4 kg.

Those involved explained that the heaviest suitcases and bags were placed lowest down and closest to the rear seat-back, and the rest were spread out as low as possible on the luggage floor. One suitcase was packed last and placed at the back of the boot on the right, along with a small rucksack. It was stated that no luggage was placed higher than the seat-back.

Two suitcases and one bag had external damage after the collision. All luggage, except for the 2.9 kg rucksack that was loaded last, remained in the boot following the collision. The rucksack was lying on the floor behind the right passenger seat after the collision.

The compartment cover beam, which can be fitted with a net stretching up to the roof and a fabric cover that can be drawn over the luggage, was not in place at the time of the accident. This is analysed in Section 2.5.3.3.

Figure 8: Luggage that was placed in the estate car's boot. Photo: NSIA

1.8.1.3 *Collision tests on similar models*

Several collision tests (NCAP – New Car Assessment Programme tests) were carried out on a corresponding 2010 model (saloon version). In Europe, this model was awarded 5 out of 5 stars in 2010 (Euro NCAP, 2010). A similar model was also tested by NHTSA in the USA in 2009, where it was awarded 4 out of 5 stars in a head-on collision test (NHTSA, 2009).

1.8.2 Mercedes-Benz Vito 2014

The van was a Mercedes-Benz Vito, 2014 model. The van's net weight was 1,830 kg and the maximum permissible weight was 2,800 kg. It had studless winter tyres, with tread depth between 6.2 and 8.5 mm. A periodic roadworthiness test was last carried out on 18 October 2018. The NPRA examined the vehicle after the accident. No faults or defects were found that could have contributed to the accident. The vehicle had a load of approx. 130 kg in its cargo space, which was separated from the passenger compartment by a protective wall. The vehicle's weight was estimated to be approx. 2,100 kg at the time of the accident.

1.9 Weather and driving conditions

At the time of the accident, the roadway at the accident site was still in the shadow of the mountains to the south-east. Sun conditions at the accident site are shown in Figure 9.

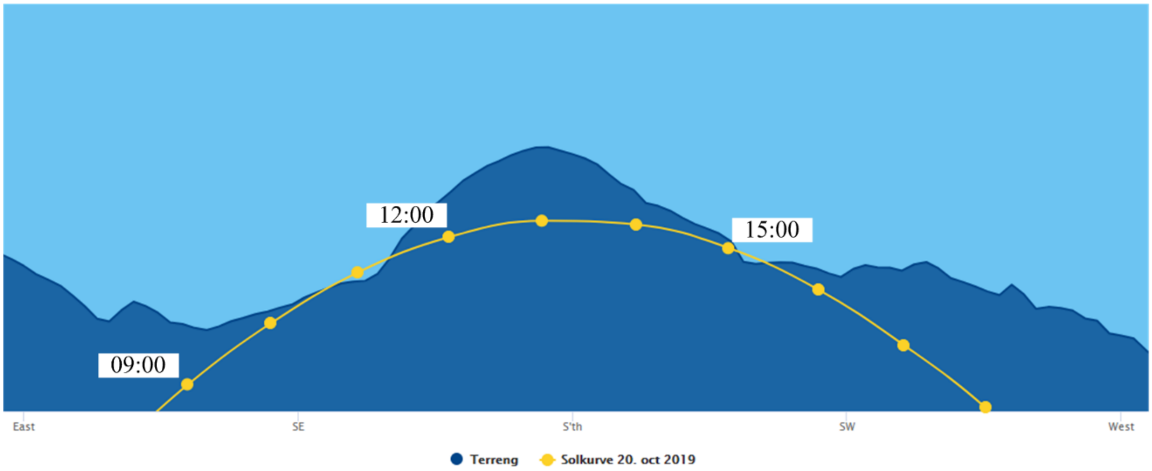

Figure 9: Sun conditions at Kvivsvegen, looking SE towards the mountains. Source: Suncurves

At the time of the accident, the area had mist from Storvatnet lake, and there was hoar frost on the ground beside the road. Both the persons involved and the response personnel at the scene described the road conditions as very slippery. Descriptions of the road surface at the accident site included 'like a skating rink', and it was so slippery that several of them had to hold on to one another to avoid falling.

There was light cloud cover, no precipitation, and the air temperature in Volda in the early hours of Sunday 20 October 2019 was above zero. During the night and up to 09:00, the cloud cover at altitude cleared. The nearest weather station to the accident site that measured roadway temperature was E39 Kvivsvegen, approx. 3.5 km from the site. This showed that the road temperature was below 0 °C, the dew point was higher than the road temperature and the air temperature was around 0 °C at the time of the accident, see Figure 10. It is well-known that in these weather conditions a film of ice is likely to form on the road surface as the moisture freezes.

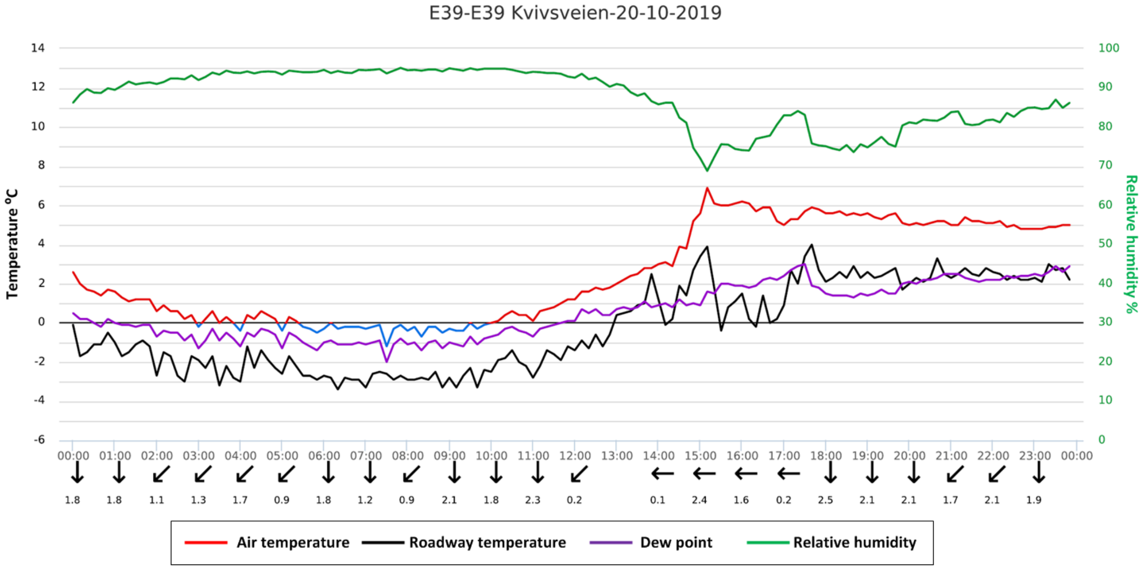

Figure 10: Measurements from the E39 Kvivsvegen weather station for 20 October 2019. Source: NPRA

1.9.1 Operation of the road

NPRA has reported that the operating contractor inspected the section of road in question on the night before the accident, and concluded that, based on the road conditions at the time, there was no need for any measures. The NSIA examination has not established when the ice film formed on the bend where the accident happened.

The operating contractor measured friction approx. 1.5 hours after the accident. The measurements were on the road from Volda towards the accident site, at 10:30. The friction measuring concluded outside the Damfoss tunnel, approx. 50–60 m from the accident site. The friction at that point was measured at µ = 0,3, with standard deviation of ± 0,157. At the time of this measurement the sun had just risen above the mountains to the south, and the sun had been shining on the road.

The NSIA describes the requirements for road operation in more detail in Section 1.14.1

1.10 Road conditions

1.10.1 General information

The accident happened on the E39, which at the site of the accident is a priority road with a general speed limit of 80 km/h. The horizontal curve radius in the bend where the accident happened was 250 m. Road width was within the limits specified in Manual N100 *Road and street design*.

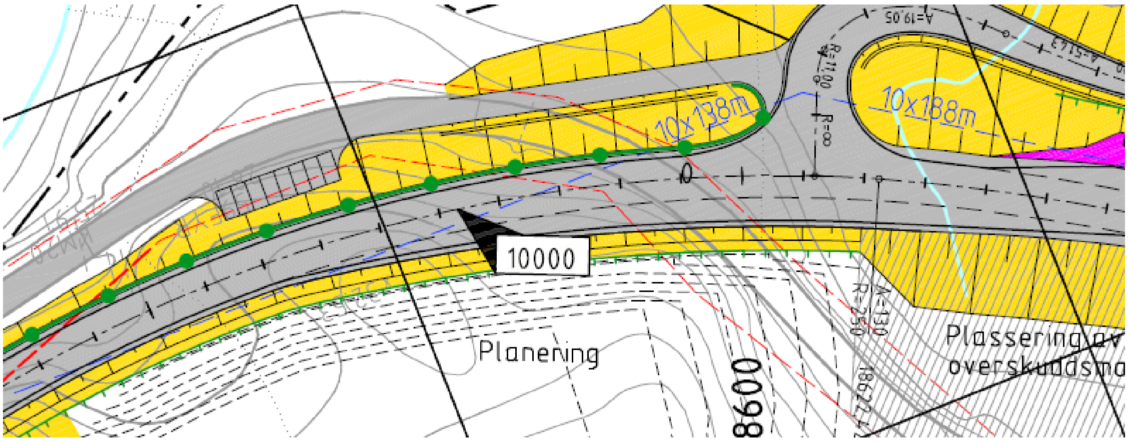

Figure 11: Map of the bend where the accident happened and the nearside passing bay by the exit road. Illustration: NPRA

The NPRA measured the camber of the road to 6.1% in the inner lane in the area where the van probably lost its grip. N100 stipulates that the camber through a bend on road type H1 with a radius of 250 m shall be 8%, which was the plan for this bend. The NPRA has informed the NSIA that, according to the road designers, the camber was reduced to 6% during development, in order to provide room for a nearside passing bay in the planned road junction area immediately south of the tunnel.

1.11 Technical registration systems

During the investigation, the NSIA took possession of both vehicles' airbag modules, but has not succeeded in downloading data from them in the course of the investigation.

1.12 Medical factors

Blood samples were collected from both drivers after the accident. There was no evidence of alcohol or other substances that might have impaired either driver's competence prior to the accident.

After the accident, a forensic autopsy was carried out on the middle rear seat passenger in the estate car. Her injuries were assessed as extensive. With the assistance of a forensic medical consultant, the NSIA carried out a detailed assessment of the mechanics of the injuries suffered by the passenger.

The passenger in the left rear seat died. The passenger was not subjected to a post mortem examination, but this person's injuries have been considered in conjunction with technical findings in the estate car.

1.13 Special investigations

1.13.1 <u>The seat belts in the estate car</u>

The NSIA examined all the seat belts in the estate car, see Figure 13. The seat belts were examined for scorch marks, wave patterns, activated pretensioners and extraction of the force limiter.

The main functions of a pretensioner and force limiter are to tighten the seat belt around the body as soon as possible during a collision, and then let out the seat belt with the force limiter so that the load on the body does not become too great. Seat belts with pretensioner and force limiters have proved to have a positive effect compared with seat belts without these functions (Andrzej Uchowski, 2011).

The seat belts in the front seats of the estate car were equipped with pretensioners, and the force limiters were designed to work in combination with the front airbags.

The seat belts on the right and left rear seats had pretensioners and force limiters in the retractor, see Figure 12. The pretensioner consisted of a bar that tightens the retractor using a pyrotechnic charge. The force limiter lets out the seat belt by one turn of the retractor at a given mechanical overload.

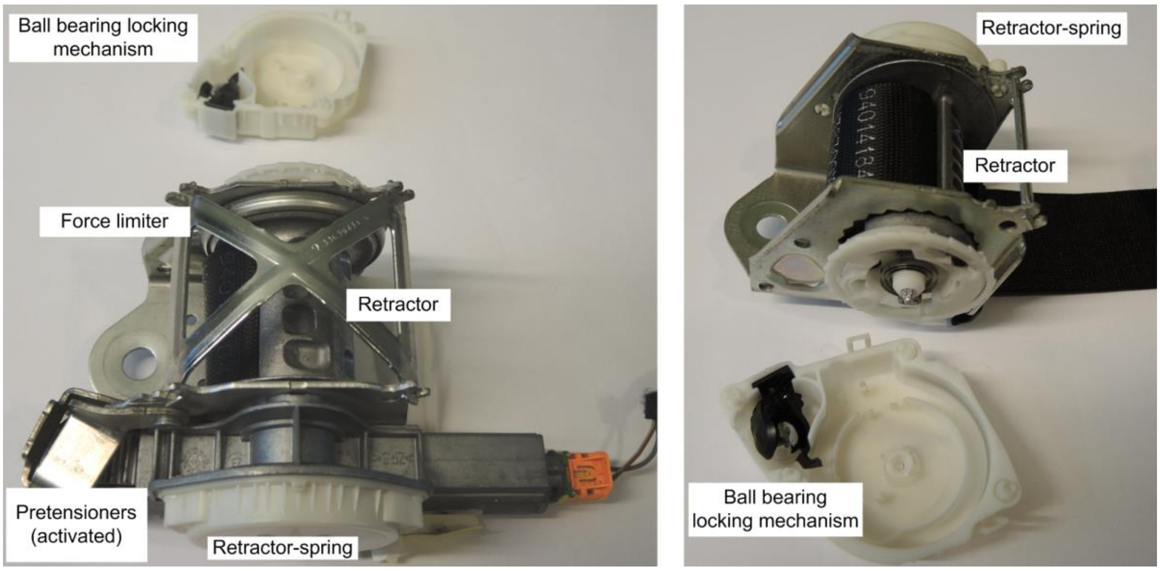

Figure 12: Rear seat belt functions at the sides (left) and the rear middle seat belt (right). Illustration: NSIA

The seat belt in the middle rear seat did not have a pretensioner and force limiter, and it locked with a ball bearing locking mechanism. The belt was anchored to two points on the body of the vehicle beneath the seat squab and to one point integrated into the front side of the rear seat-back. This seat belt was the only seat belt where the shoulder belt was not anchored to the vehicle's body, B or C pillar. The passive safety of the middle rear seat is described in more detail in Section 1.13.2, and all the seats are analysed in Section 2.4.

Table 2: Scorch marks, wave patterns and extractions on the estate car's seat belts. Source: NSIA

Seat	Lap belt	Shoulder belt	Pretensioner/force limiter
Driver's seat	Scorch mark by buckle	Scorch mark by B pillar	Activated / 10 cm extraction with jamming
Right front	Scorch mark by buckle	Scorch mark by B pillar	Activated / 24 cm extraction
Left rear seat	Not in use	Not in use	Activated (fastened)
Middle rear seat	Wave pattern along 20 cm, internal scorch mark	Small rip at top towards the retractor	Not available
Right rear seat	Wave pattern along 25 cm, internal scorch marks	Weak wave pattern at bottom, scorch mark by C pillar	Activated / 20 cm extraction

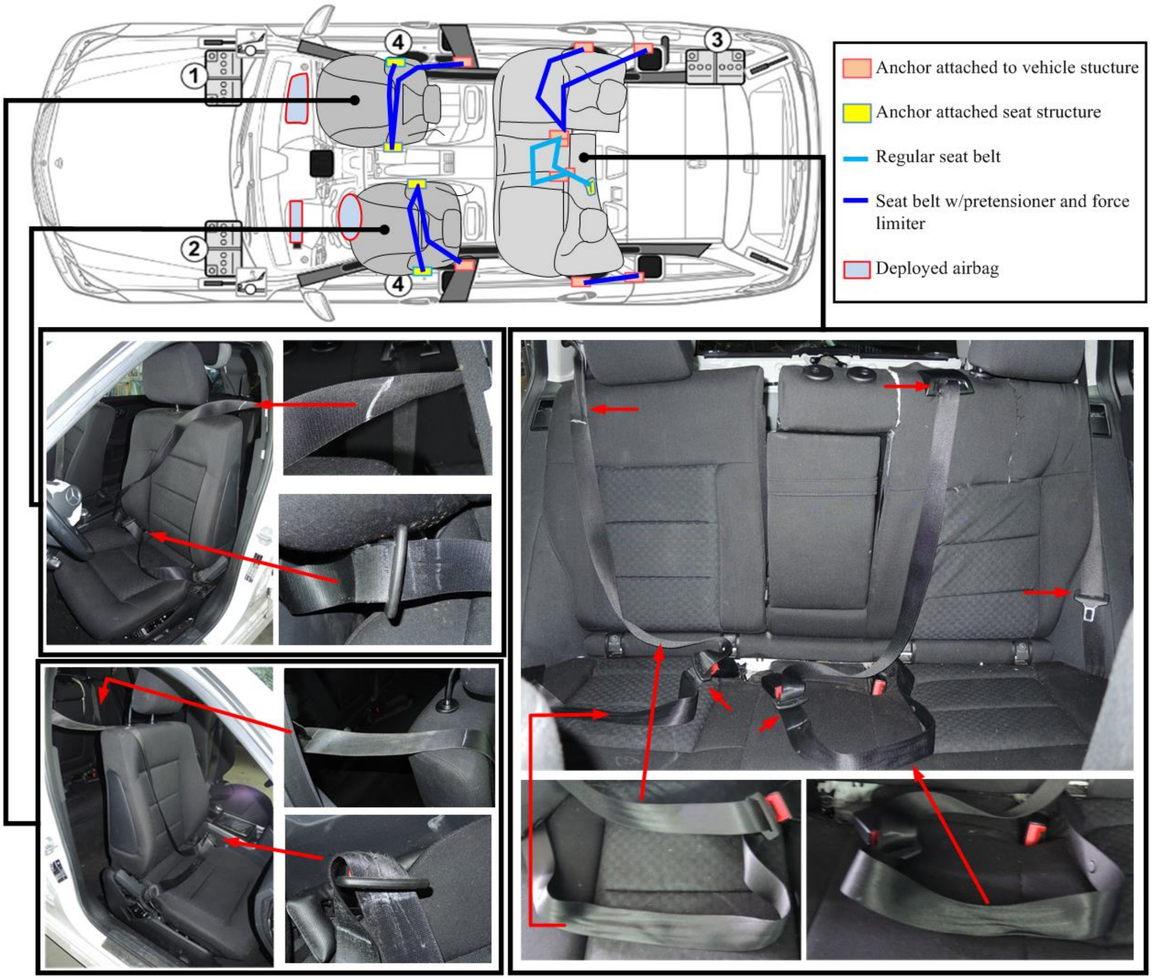

Figure 13: Scorch marks, extractions and wave patterns on the seat belts after collision. Illustration: NSIA

1.13.2 Examination of rear seat design in a similar estate car

The rear seat has split folding rear seats, also known as 60/40 seats (split by 60% and 40% of the seat width). The NSIA obtained a wreck of a similar estate car to examine the rear seat design and conduct various experiments. The rear seat structures are shown inFigure 14. The rear seat framework was constructed of sheet metal and u-profile struts.

All anchor points for the passenger seat belts on the right and left sides were attached to the vehicle's body.

The middle rear seat belt's lap belt anchorage was attached to the car's body, but the middle belt was the only belt where the shoulder belt was not attached to the body. The retractor for this seat was fitted on the front side of the 60-part of the seat-back, roughly in the middle, high up and in a metal housing behind approx. 2.5 cm of upholstery.

The 60-part's framework was constructed in two parts, where the framework from the outer edge towards the retractor had special reinforcement, marked yellow in Figure 14. The lateral strut at the top of the 60-part was divided in two at the retractor, with a small, profiled metal part in the gap. The reinforcement consisted of a diagonal strut, fitted at the bottom of the outer edge of the left seat, where it was linked to a torsion rod. It then led diagonally up towards the retractor for the middle seat belt.

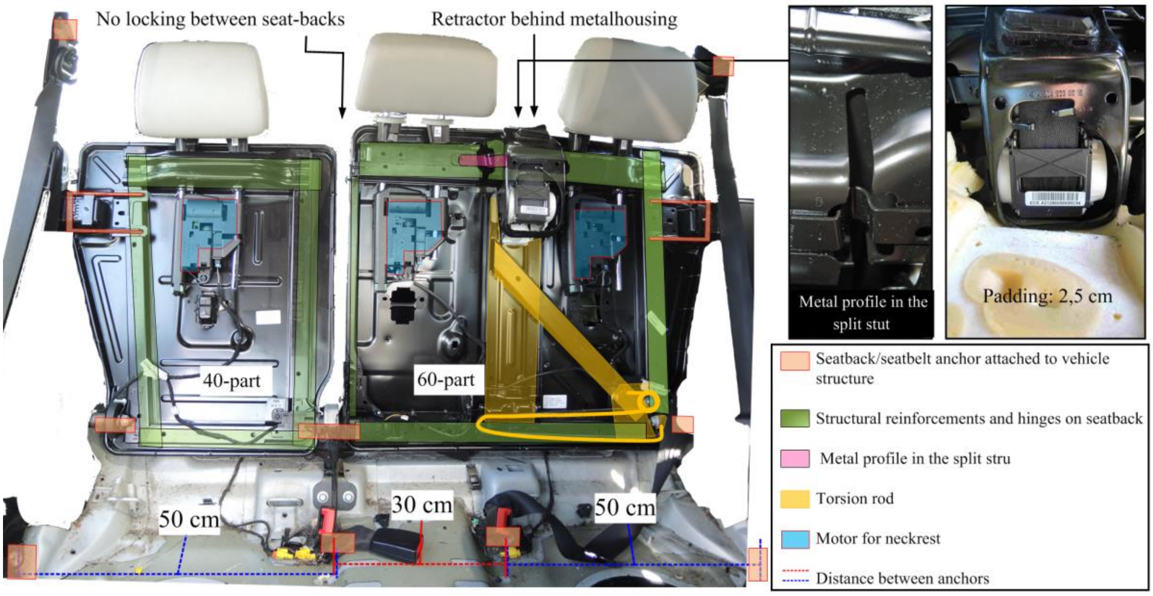

Figure 14: The rear seat structure and distances between the seat belt anchor points. Illustration: NSIA

The distance between the anchor points for the right and left rear passengers' lap belts was 50 cm – the same as for the front seats. The distance between the anchor points for the lap belt in the middle seat was 30 cm. The actual belt buckle stuck out above the seat squab, unlike the other belt buckles, see Figure 15.

In the locked position, the rear seat-back was at an angle of approx. 120 degrees to the floor. When the middle seat was pushed forward with the belt locked, the length of the belt increased because of the difference between the seat-back rotation point and the positioning of the anchor points, as shown in Figure 15.

Figure 15: Rear seat-back angle and extension of locked seat belt's length when the seat-back is moved forwards. Illustration: NSIA

The head restraint was locked on to the rear seat-back by a spring lock engaging in a notch in one of the headrest pins. The head restraint unlocked with a nudge of the hand along the pins.

1.13.3 Investigation of deformation and oscillation of rear seat-back in a similar estate car

The NSIA experimented with pulling the rear seat-back of the test car forward, before the upholstery was removed. In this experiment, shown in Figure 16, the seat was pulled forward 10–15 cm before being allowed to swing back to its original position when the pull was released.

To give an indication of the force required, a measuring weight was attached to the load strop that was fitted to the seat belt. The maximum load recorded was 300–400 kg, and the pull was released after approx. 0.4 seconds.

The experiment was filmed. It is very clear from the recording that the seat-back bent forward when the load was applied to the shoulder belt. When the pressure on the strop was released, the seat-back sprang back, but before it came to rest it rocked to and fro before it reverted to a roughly upright position, see Figure 16.

Pulling experiment, set-up   Sequence of oscillations from the video (0,4 - 1,6 seconds)

Figure 16: Set-up of the pulling experiment and sequence of oscillations from the video. The whole experiment lasted for around 2 seconds. Illustration: NSIA

The experiment clarified for the NSIA that a momentary application of force generated by the weight of a person fastened in a seat belt during a collision can also deform the seat-back and create tensions in the rear seat-back. In this experiment, the seat-back was not visibly deformed, which indicates that the force the accident vehicle was subjected to, was significantly higher.

1.13.4 Investigation of the back seat of the estate car involved in the accident

The NSIA removed the upholstery from the rear seat-back of the estate car involved in the accident in order to examine deformations, twisting and metal fractures. Both parts of the seat-back were deformed, but the 60-part was most deformed.

The 60-part was at its most deformed from the retractor in the middle and out towards the C pillar. Fractures were found in the strut at the top, by the retractor, and the small metal profile in the gap was completely stretched out, see Figure 17. Twisting and stretching was found at all three anchor points that attached the seat-back to the body of the vehicle, especially by the buckle against the C pillar.

Figure 17: Deformations, twisting and metal fractures on the seat-back's 60-part. Illustration: NSIA

1.13.5 Rear seat-back designs for a selection of other manufacturers

During the investigation, the NSIA obtained access to several medium-sized passenger cars (2011–2014 models) with a seat belt integrated into the rear seat-back. Several rear seat-backs were examined by removing the upholstery, see Figure 18.

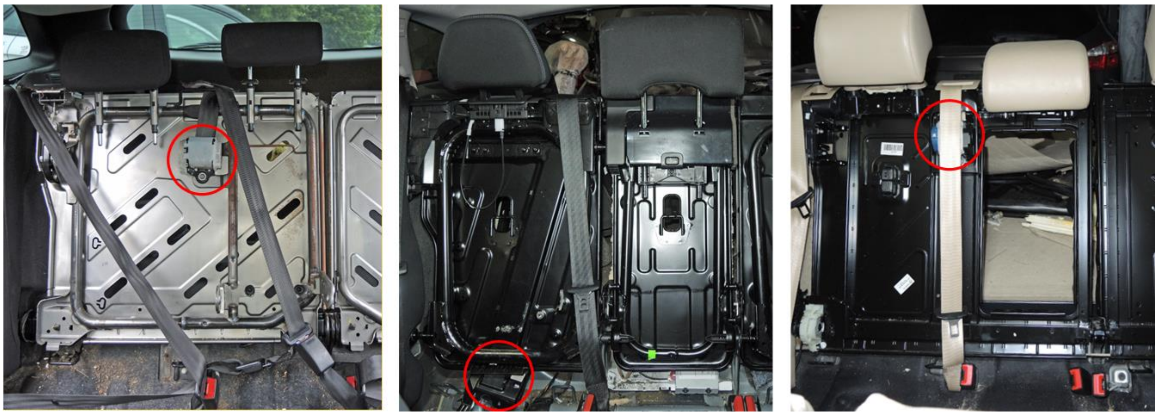

Figure 18: Design of seat belt integrated into rear seat-back for several manufacturers. The retractors are marked by red circles. Illustration: NSIA

All seat-backs that were examined consisted of welded sheet metal and a frame. The frames were either made of round tubes or u-profile struts. Reinforcement of the rear seat-back towards the retractor for the middle seat varied, and the retractors were of different types. Many retractors were fitted at the front edge, with or without a metal housing; others were floor-mounted and had a pretensioner and force limiter. The width of the seat belt across the pelvis in the rear middle seat was consistently narrower than for the other seat belts in the same vehicle.

1.14 Laws and regulations

1.14.1 Road operating requirement at the accident site

The section of road at the accident site was operated by Veidekke in winter operating class B (low) under contract ‘1500 Ålesund 2014-2019’. The winter preparedness period in this contract started in October and lasted until the end of April every year.

The contract specifies that in winter operating class B (low), salt shall be used to prevent slippery road conditions during transition periods between the road being bare and being slippery as a result of ice or hoar frost.

The Norwegian Public Roads Administration has specified that the friction requirement for bare road on this section was μ = 04 or higher. Approved driving conditions were that the wheel ruts should be free of ice and snow (bare) for at least 2/3 of the width of the lane. In this operating class, the time requirement for re-establishing approved driving conditions after a weather event was 5 hours.

1.14.2 Requirements relating to vehicles

The estate car in this accident was EU type approved pursuant to European Directive 2007/46/EC. This Directive includes several UNECE Regulations that the estate car had to comply with in order to secure type approval. They are described below. In Norway, this approval scheme is recognised through the EEA Agreement and implemented in the Norwegian Car Regulations.

1.14.2.1 *European seat belt requirements*

In passenger cars, three-point seat belts are required for both front and back seats. UN-ECE R 14 requires the seat belt anchorages for both shoulder and lap belts to withstand

13.5 kN (or 1,376 kg). The seat belt requirements are specified in UN-ECE R 16. In passenger cars (M1), the requirement is for the seat belts to be of type Ar4M (A = three-point belt, r = retractor, 4 = emergency locking retractor, M = emergency locking retractor with multiple sensitivity).

1.14.2.2 *General European requirements for the strength of rear seat-backs*

Annex 9, in UN-ECE R 17 describes a strength test for split rear seat-backs. This requirement was introduced in 1998 and has applied to all new cars since 2002. The test requirements are a minimum requirement that apply to split rear seat backs in all types of vehicles. The test involves placing 2 suitcase-like 18 kg blocks in the boot 20 cm from the seat-back, and a 10 kg block up against the head restraint. It is then run on a test sled that simulates a head-on collision at 50 km/h, giving a maximum retardation of 20–28 G. The test is passed if none of the blocks in the boot penetrate the passenger compartment and the seat-back is not deformed by more than 100 mm in front of the R point and the head restraint not by more than 150 mm. The manufacturer defines the R point.

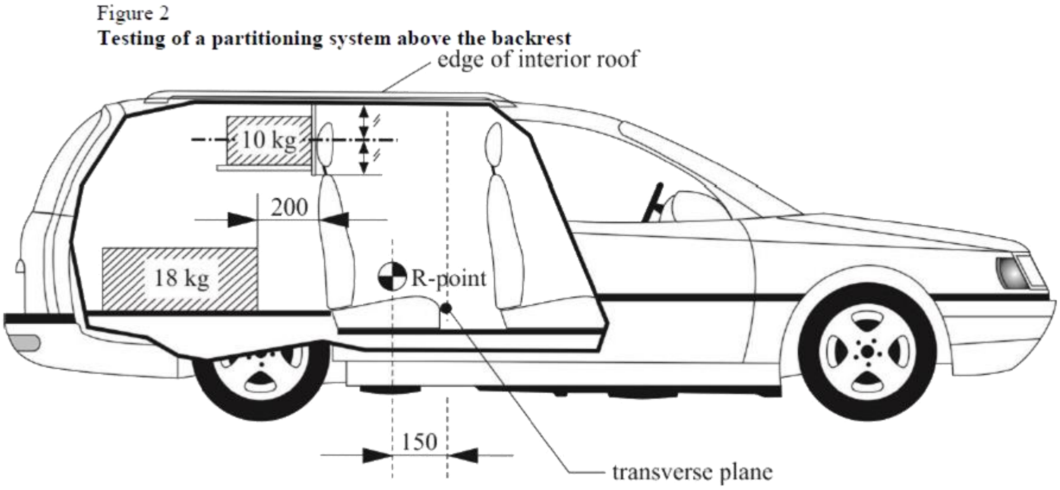

Figure 19: Test of seat-back with 2 x 18 kg luggage and 10 kg against the head restraint in a sled test at 50 km/h. The minimum requirement for forward deformation of the seat-back is described below. Source: UN-ECE R17

This test was carried out without crash-test dummies in the rear seat and does not describe how the seat belts in the rear seat shall be designed. No requirement is specified for the way in which a seat-back can or should be deformed, nor for oscillation of the seat-back.

The NSIA has been informed that a compartment cover beam fitted behind the seat-back is not a requirement for initial approval of passenger cars.

1.15 Authorities, organisations and leadership

1.15.1 NPRA

The National Public Roads Administration is an administrative agency under the authority of the Ministry of Transport. The agency is organised with two administrative levels: The Directorate of Public Roads and six professional divisions. The NPRA is responsible for the planning, construction, operation and maintenance of national roads, and for approval and supervisory activities relating to vehicles and road users. The NPRA also prepares regulations and guidelines for road design, operation and maintenance, road traffic, road user training and vehicles. The NPRA is not a member of Euro NCAP.

1.15.2 United Nations Economic Commission for Europe, UNECE

Through an agreement from 1958 and 1998, Norway is represented in the World Forum for Harmonization of Vehicle Regulations, WP29. The group has six reporting subgroups, each with its own special areas that prepare proposals for harmonized regulations. GRSP is one of these six expert groups, which develops proposals for regulations for passive safety. The Norwegian Public Roads Administration provides experts who represent Norway in this group. GRSP consists of over 80 experts from over 60 other member countries plus international interest organizations representing industry and consumers.

1.15.3 Euro NCAP

Euro NCAP (New Car Assessment Programme) is a non-state organisation that carries out collision tests on new passenger cars coming onto the market in Europe. All passenger cars are awarded points for the tests, there is special recognition for innovation, and the final evaluation is expressed as a star score where the maximum is five stars.

1.15.4 NHTSA

The National Highway Traffic Safety Administration (NHTSA) is an American federal agency that reports to the Department of Transportation. NHTSA’s responsibilities include the New Car Assessment Program (NCAP) in the USA.

1.15.5 Mercedes-Benz

Mercedes-Benz is a make of car manufactured by Daimler AG. The Norwegian importer for this make is Bertel O. Steen.

1.16 Other information

1.16.1 Report on rear seat safety

In 2002, four years after UN-ECE R 17 was supplemented with rear seat strength requirements, the European Association for the Co-ordination of Consumer Representation in Standardisation (ANEC) prepared a report aimed at influencing the regulations (ANEC, 2003). Sled tests were carried out with four suitcases with a total weight of 90 kg, which ANEC considered was a more realistic weight for the luggage.

Figure 20: The back seat in one of the test cars, before and after the ANEC test. Photo: ANEC

The results from this report were raised for consideration by the UN collaborative group in WP.29 (TRANS/WP.29/GRSP/34) 8 December 2003. More accident statistics were deemed to be required if changes to the regulations were to be considered:

> *'Several experts requested accident statistics to justify the amendment of Regulation No. 17. When this data is presented to the GRSP, the consideration of this item may be resumed.'*

1.16.2 <u>Report on factors that contribute to serious injuries and deaths among rear seat passengers in head-on collisions</u>

On 5 August 2019, the Insurance Institute for Highway Safety (IIHS) in the USA published a research report on factors that contribute to serious injuries and deaths among rear seat passengers in head-on collisions where the front seat occupants survived (Jessica Jermakian, 2019). Rear seat passengers comprised 8% of fatalities in the USA in 2016. The study was based on collisions involving cars less than 10 years old, and accidents that occurred in the period 2014–2015. The background to the study was that data from other accidents indicated that the safety advantage of sitting in the rear seat of newer vehicles had decreased over time.

In the discussion of this report, it was suggested that the rear seat passengers were killed or injured as a result of forces imparted by the three-point seat belts restraining them, while the front seat occupants survived. This indicated that there might be differences between the safety systems of the front seats and those of the rear seats. The report concluded that all new strategies for rear seat safety should take into account the specific needs the rear seat environment gives rise to and the corresponding safety challenges.

1.16.3 <u>Previous reports by the NSIA</u>

In the report on a head-on collision between a passenger car and a passenger van on the E6 at Slettnes in Storfjord in Troms on 24 September 2017, two safety recommendations were issued about internal safety in cars (SHK, 2019).

The first safety recommendation (ROAD No. 2019/01T) recommends that the NPRA establish regulations that ensure a physical barrier between the passenger compartment and the boot of a passenger car in cases where goods are loaded above the height of the rear seat-back. The second safety recommendation (ROAD No. 2019/02T) recommends that the NPRA, in collaboration with relevant partner organisations, intensify its work to improve road users' knowledge about and understanding of the importance of using safety equipment in cars correctly.

Much of this report is also based on knowledge gained from a larger thematic report on vehicle safety published by the NSIA (SHK, 2012).

While this investigation was being conducted, observations were made concerning the rear seat of a passenger car in another ongoing investigation. The accident involved a passenger car colliding with a stationary HGV at a speed of approx. 80 km/h (SHK, 2020). There were no persons in the back seat, but the rear seat structure gave way in the collision. The only item that could have been in the boot before the accident, was a 4-litre container of washer fluid that was lying in the passenger compartment after the collision. The seat cover in the rear seat was removed and the NSIA found that the retractor integrated into the rear seat-back had been displaced approx. 15 cm forwards.

Figure 21: Deformed rear seat structure from the accident involving a collision with a stationary HGV (SHK, 2020). Source: NSIA

1.17 Useful or efficient investigation methods

1.17.1 Euro Rescue

The car manufacturers prepare an ‘Emergency response guide’, a guide for the emergency services that describes the airbags, pretensioners, cutting zones for main power and reinforced bodywork. Descriptions of pyrotechnic pretensioners in this guide advise that the seat belt most probably also has a force limiter.

On 17 June 2020, Euro NCAP and the International Association of Fire and Rescue Services (CTIF) launched a free application, ‘Euro Rescue’ (Euro NCAP, 2020), where this guidance was made publicly available, see the figures below.

Figure 22: Tesla 3 (2018) has no pretensioners in the rear seat. Source: Euro Rescue

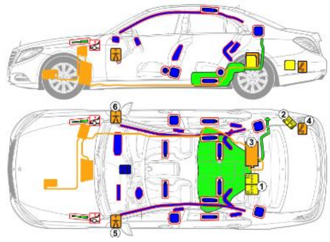

Figure 23: Mercedes-Benz S Class (2013) has pretensioners and airbags for the rear side seats. Source: Euro Rescue

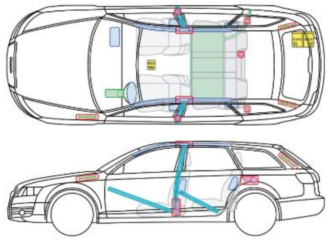

Figure 24: Audi A6 (2004-2012) has pretensioners for all rear seats. Source: Euro Rescue

The guide does not contain the complete safety design for each seat in the individual manufacturers' vehicles. The NSIA has briefly reviewed several makes, and the guide shows that the manufacturers have differing safety philosophies for seat belt installations. The type of seat belt used in the rear seats varies widely between the car manufacturers, as well as between models produced by the same manufacturer.

1.18 Implemented measures

The Norwegian Public Roads Administration has stated that in connection with this case, the accident has been reviewed with the current operator as an area they must be careful with in relation to icing on the road. Beyond this, no specific measures have been ordered through the contract, as the winter operating class B is adequate.

2. ANALYSIS

2.1 Introduction and limitation of scope

This investigation was initiated because of the extensive injuries sustained and the marked difference in the extent of injuries between the front and rear seat occupants in the estate car. There was survival space for all seats in the car, and this gave grounds for a closer examination of the mechanics of the injuries, as well as the car’s passive safety systems. The safety of all seats in the estate car in a collision is discussed, and the analysis goes on to focus on the passive safety of the middle rear seat. The discussion below includes regulatory requirements, collision tests and the level of safety in the industry.

In the analysis, the NSIA first discusses the sequence of events and the road conditions. The NSIA recognises that the road and weather conditions at the accident site were demanding. Nevertheless, the NSIA chose to limit its investigation of this aspect, and refers to previous investigations where operation and maintenance was the primary focus.

2.2 Assessment of the sequence of events

The final position of the vehicles gives a very good indication of their position on the roadway when the collision happened. This, in combination with the statements of the two drivers, shows that the van initially lost control because of low friction on the road and then crossed over into the opposite lane. The road conditions were demanding, and this is discussed further in Section 2.3. The speed of the vehicles at the time of the collision has not been possible to determine accurately. Based on information from the drivers, the vehicles' weight and deformations, assumed point of impact and end positions, NSIA considers that both vehicles have had a speed around the speed limit of 80 km/h at the time of the collision.

It became clear after the accident that the van driver was driving without a driving licence. The Swedish driver had completed his driver training, but had not taken the practical driving test. The NSIA maintains that driving without a licence is unacceptable from a road safety perspective. Nevertheless, the road conditions at the site were so demanding that the NSIA considers that other drivers would also have found it challenging to cope.

Both vehicle bodies had good inbuilt safety, and the collision forces in the relatively powerful impact were largely absorbed by intended deformations in both vehicles. Despite the speed being quite high, both drivers and front seat passengers sustained minor or no injuries. Their safety belts and airbags functioned as intended, and their survival space was intact after the collision.

In the rear seat of the estate car, two of the passengers died and the third was severely injured. There was survival space here too, so the investigation has focused on explaining how the extensive injuries sustained by these passengers occurred. The survival aspects of the individual seats in the estate car are discussed in more detail in Section 2.4.

2.3 The road conditions

Friction measurements made after the event are not suitable for assessing the friction under the van’s tyres when it lost road grip. The description and assessment of the friction conditions are therefore based on the sequence of events, descriptions provided by the police and witnesses, weather and climate measurements and pictures from the accident site.

The NSIA's overall assessment is that at the time of the accident, roadway friction was far below the operating requirement for a bare road, and that an ice film had formed in the bend. Wet ice generally has a friction coefficient of approx. 0.05–0.15μ, and in this friction range the critical speed for this bend, without braking, is assessed as between 60 and 80 km/h. The non-conformity in the camber of the bend is deemed to have been a minor contributory factor.

Heat radiation from the roadway in the section shaded by the mountains to the south, combined with the dissipation of cloud cover in the early hours, caused the ice film to form. The sub-zero temperature on the roadway, with the dew point higher than the road temperature, enabled the air to release moisture which froze on the roadway. Storvatnet lake contributed to increased air humidity in the area around the accident bend, and in the prevailing weather conditions, this may have contributed to the formation of an ice film across the whole roadway.

Overall, the NSIA assesses the road conditions in the accident bend as being demanding and difficult to identify. This is deemed to be the principal causal factor behind the accident.

The NSIA has previously investigated similar accidents where changes in driving conditions on a bare road played a part, especially the head-on collision at Veme in Ringerike in 2014 (SHK, 2015). That investigation illuminated the severe challenges faced by the road owner, contractor and road users alike. The NSIA considers that the road conditions arising at the time of the present accident represent a significant challenge to traffic safety.

2.4 Collision safety in the estate car

Both vehicles were relatively recent models, built in accordance with strict collision safety requirements. As the front seat occupants in both vehicles emerged relatively unscathed, the investigation has focused on safety in the estate car, principally in the rear seat.

2.4.1 External collision safety

The estate car was deformed across the whole of its front crumple zone when it collided with the van, which was of roughly equal weight. The car manufacturers test their vehicles in a head-on collision, so it is relevant to assess this accident in the light of collision tests carried out on a car of the same make. The relevant collision test was found only to have been carried out on a saloon version, but it has the same front as the estate car.

The head-on collision test for this make of car was carried out by NTHSA. The collision speed in the test was 56 km/h. Maximum acceleration on the two 85 kg test dummies was recorded as 46 G on the driver and 51.2 G on the passenger.

Deformation on the estate car in the accident was 73 cm. The investigation has shown that the effect of the crumple zone, combined with seat belts and airbags, may have been enough to keep the G forces on the persons in the front seats down to a level similar to that measured in the collision test, despite the collision speed in the accident being around 80 km/h .

2.4.2 Collision safety in the front seats

2.4.2.1 *Driver's seat*

In the driver's seat, the collision systems, with a combination of airbags and seat belts, functioned as intended. The driver suffered a fracture in his left heel, most probably from impact with the brake pedal. His injuries may have been limited by his shoulder belt jamming, which restricted its extension to 10 cm. A longer extension could have taken the driver closer to the steering wheel. The driver's seat was also subjected to forces from the passenger behind, without this causing injury to the driver. The seat belt's lap strap was anchored to two points on the driver's seat, which is seen as a positive factor.

2.4.2.2 *Front seat passenger*

The front seat passenger was also almost uninjured after the accident, even though the whole seat came loose and his knees hit the dashboard. The seat-back was impacted by the right rear seat passenger's knees and probably also by the 2.9 kg rucksack from the boot. However, these forces did not injure the front seat passenger. Here too, the seat belt's lap belt was attached to the seat. The passenger's knees hit the dashboard, but apart from that, the collision safety system functioned as intended.

2.4.3 Collision safety in the rear seats

2.4.3.1 *Left rear seat passenger*

The left passenger in the rear seat was unsecured during the collision. This person sustained serious head injuries from the impact with the B pillar when she was thrown forward and to the left in the collision. There was a side airbag/curtain on the left side, but it was not programmed to activate without a physical sensor signal from the left side of the car.

On newer cars, it is now more usual for side airbags to be programmed to activate in a pure head-on collision as well. The NSIA thinks that if the side airbag had activated, it might have protected the passenger from the B pillar, but the extent of injury has not been further assessed.

2.4.3.2 *Right rear seat passenger*

The NSIA has assessed the survival aspects for the right rear seat passenger based on marks on the seat belt, the seat and the injuries the passenger sustained in the collision.

Registered injuries indicate that the lower body slipped underneath the lap belt in the collision ('submarining'). The wave pattern on the lap belt and lower part of the shoulder belt showed signs of the belt having become twisted while it was tightening. This can happen if the seat belt is tightened against the soft abdominal region.

The passenger suffered severe abdominal injuries and several broken ribs on the left side. Her knees hit the passenger seat in front and there were scorch marks from trouser material on the seat squab and a dent beneath it, indicating that her lower body was forced down into the seat squab, see Figure 4. The pretensioner was activated and the force limiter allowed full extension of the seat belt, reducing the force. The force limiter in the seat belt is considered to have had an injury-limiting effect.

2.4.3.3 *Middle rear seat passenger*

The NSIA has assessed the survival aspect for the middle rear seat passenger based on marks on the seat belt, interior, the autopsy, other medical information and several reconstructions.

It has not been possible to establish exactly how the passenger was sitting in her belt before the collision, but leg and thigh fractures indicate that her knees impacted the driver's seat. This might have affected her body's direction of travel, before the lap belt decelerated her lower body. The wave pattern on the seat belt coincides with the extensive and potentially fatal abdominal injuries described in the autopsy report. This seat belt had the narrowest lap strap of all the seat belts, and is further analysed in Section 2.5.2.

The retractor was installed on the front edge of the upper part of the rear seat-back. The shoulder part of the seat belt moved with the upper part of the rear seat-back when it was deformed forwards during the collision. This may also have affected the direction of travel. The NSIA considers the fractures in the upper part of the passenger's back to be related to the tightening of the shoulder belt in this situation. The NSIA also considers that the metal housing around the retractor on the front of the seat-back, beneath the thin upholstery – as shown in Figure 14 – may have contributed to her injuries.

The autopsy did not reveal any visible external head injuries, but it did identify a severe neck injury. The NSIA has obtained a specialist medical opinion, in addition to the autopsy report, to help asses these injuries. They are described as unusual and very complex.

The NSIA considers that these injuries were so serious that they could not have been inflicted without a secondary blow to the head, in addition to the deceleration caused by the seat belt. Forces transferred via the head restraint, which came loose and was stuck in the roof after the accident, may have contributed to the injuries shown in the autopsy report. The upholstery on the head restraint may also explain the absence of external head injuries.

The head restraint showed no external damage or rips, and the NSIA has found no direct evidence to confirm whether the head restraint came loose because it was hit by luggage, or whether its own weight tore it loose when the seat-back was displaced forwards. The NSIA considers that both are possibilities.

2.5 Passive safety in the middle rear seat

2.5.1 Introduction

Traditionally, the middle rear seat is considered a safe seat, both because the collision forces in head-on collisions diminish moving back towards this seat, but also because it is further away from the outer sides and interior of the vehicle. However, the investigation has shown that while the strength requirements for middle seats are the same, the design of the rear seat-backs differs between car manufacturers.

The investigation found that Mercedes-Benz has designed a rear seat-back that is well within the requirements for rear seat-backs, as described in Section 2.6.

The NSIA has also analysed the middle passenger’s safety in respect of seat belt design, anchoring of the shoulder part of the seat belt, and how the design of the rear seat-back will affect the middle passenger’s safety in a high-speed collision.

2.5.2 Design of the middle rear seat belt

The middle rear seat belt was the only belt in the estate car that had no pretensioner and force limiter. The shoulder part was attached to the seat-back, and differs from all the other belts in not being anchored to the B or C pillar or the car’s body. The distance between the lap belt anchorages for the middle rear seat belt was narrower than in the seats on either side, and the belt buckle projected further out than on all the other seat belts, see Figure 15.

The NSIA examined the middle rear seat belts on several different passenger cars and saw several different solutions. It is the NSIA’s opinion that the narrow seat width for the lap belt may affect the forces around the hips when the belt is tightening to a greater extent than when anchorages are further apart and the belt buckle is in a lower position. The investigation has not proved that the middle belt should not be used by an adult, but the NSIA considers that the short distance between the lower anchorages can cause problems with positioning the belt and adjusting the seat belt optimally.

2.5.3 Folding rear seat-backs with integrated seat belt

2.5.3.1 *General information*

In a head-on collision, a rear seat-back will have to absorb collision forces from the front, resist luggage from behind and simultaneously secure the person in the seat belt that is attached to the seat-back. A split seat-back without locking is a practical solution (for transporting long objects), but its ability to create a solid barrier that secures both luggage and middle rear seat passenger is inherently weakened.

2.5.3.2 *Deformation of the rear seat-back resulting from a powerful, momentary force*

The NSIA’s pulling experiment indicated that when a momentary force was applied, the rear seat returned to its normal position almost without becoming deformed. The oscillation is deemed to be a natural consequence of the rear seat’s construction and anchor points, and the tensions that arise between the reinforced part and the anchorages when a loading is applied to the rear seat-back, see Figure 14.

The investigation has shown that the energy/force generated by the collision was much greater than in the experiment, as the seat-back was permanently deformed. The investigation has also shown that the movements in the rear seat-back were significant, and that this also affected the movements of the passenger in the collision.

2.5.3.3 *The effect of the luggage load on the rear seat-back*

The investigation has shown that the total weight of the luggage was 65 kg, consisting of a number of items, and these impacted both rear seat-backs during the collision. After the collision, the retractor for the middle belt was 20 cm ahead of its starting position. The NSIA believes that the 60-part of the rear seat-back probably deflected even further than its final position indicates, and that it was subjected to a combination of forces as the luggage pushed into the rear seat-back from behind, while the shoulder belt of the middle passenger was pulling the seat-back forwards.

The compartment cover beam was not fitted at the time of the accident. The cross-strut had both a fabric pull-over cover and a net that can be attached to the roof. However, the cross-strut cannot be attached to the rear seat-back so the passenger, and the luggage placed low on the floor would have exerted force directly on the seat-back, even if the cross-strut had been fitted.

The investigation showed that the rear seat-back succeeded in keeping almost all the luggage in place in the boot, but that it became significantly deformed as a result of the total loading. If the cross-strut had been fitted, it might have absorbed some of the load, but not all. The NSIA considers that the baggage was packed normally, with heavy items low down and close to the seat-back. The total weight of the luggage was within the expected tolerance of a rear seat-back, with or without the cross-strut fitted.

It is impossible to state definitively whether the cross-strut and luggage net would have altered the outcome of the accident. The NSIA refers to this and previous investigations and makes the general point that it is important to secure cargo in passenger cars, especially in estate cars without a solid partition between the seat-back and the passenger compartment.

The NSIA believes that the loading on the rear seat-back would in any case have been too great in this high-speed accident. The forces exerted by the luggage, combined with the forces absorbed by the seat belt structure, caused major deformation of the seat-back and, together, they contributed to the fatal injuries sustained by the middle rear seat passenger.

The investigation showed that the seat belts for the different seats vary in construction, and that safety in the middle rear seat is directly related to the ability of the rear seat-back to withstand the loading imposed by the middle passenger and the luggage in the boot. In this case, normally positioned but unsecured luggage, with an average weight of 13 kg per passenger, contributed to major deformation of the rear seat-back. The investigation has shown that a variety of structural solutions are used by the various car manufacturers, and this is considered in itself to contribute valuable knowledge to support ongoing efforts to improve passive safety in car rear seats.

2.6 Regulatory requirements for rear seats and rear middle seat belt installation

The rear seat-back in the estate car fulfilled the strength and deformation requirements specified in UN-ECE R17 (Annex 9) when it was approved. The strength requirements for the rear seat-back, described in Section 1.14.2.2, are validated by a test with no test dummies in the rear seat, and there are no specifications or requirement for how seat belts should be fitted to, or independently of, the seat-back. The test allows deformation, but does not consider oscillation of the seat-back.

Figure 25 illustrates a passenger in the middle rear seat with alternative anchorages for the shoulder belt; in the roof, and integrated into the rear seat-back. The approved deformation is also shown, in red.

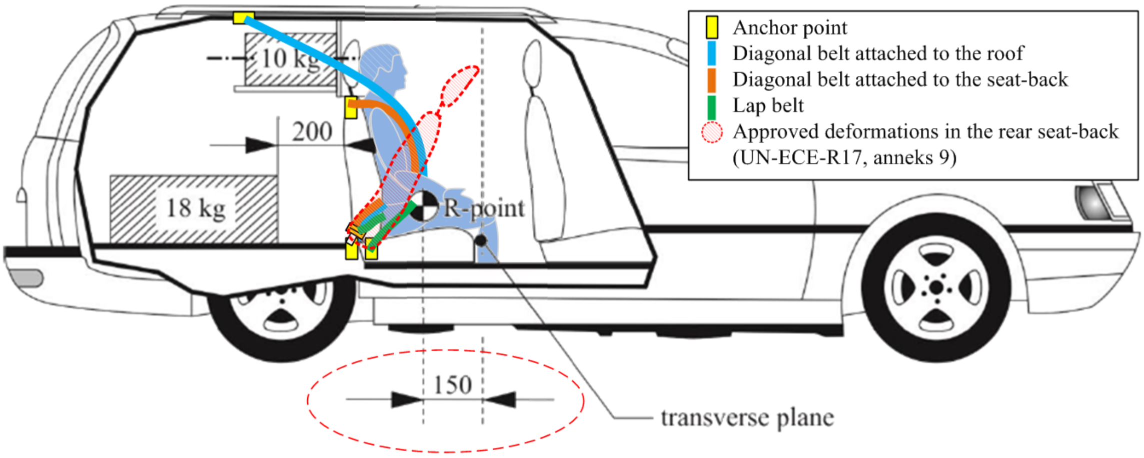

Figure 25: Strength requirements for rear seat-backs - showing middle rear passenger and seat belts with alternative shoulder belt anchorages. (Note: R-point is determined by the car manufacturer and will vary). Illustration: NSIA

In the context of this test, the alternative middle rear seat belt anchorages present different problems in relation to deformation of the rear seat-back. When the shoulder belt anchorage is in the roof, the rear seat-back must be strong enough for a deformation not to jam the passenger between the shoulder belt and the rear seat-back. When the shoulder belt anchorage is integrated into the rear seat-back, the movement of a secured passenger’s body will be determined by the movement of the rear seat-back and the configuration of the belt, described in Figure 15.

In the NSIA's opinion, this illustrates that the securing of a passenger in the middle rear seat is directly linked to how well the rear seat-back performs in the test, and the regulations may be defective in not specifying this. This accident illustrates that the test requirement may be too low, as the deformations in the rear seat-back would have been within the specified requirement.

A report by ANEC in 2002 suggested that a more realistic weight of luggage that a rear seat-back should be designed to withstand, would be four suitcases totalling 90 kg (ANEC, 2003). The NSIA agrees that more items and greater weight would make the test more realistic than at present. The NSIA also considers that the current test criteria have a major weakness in that they do not include specifications for securing of the rear seat passengers. In turn, this has led the car industry to adopt a variety of rear seat-back designs.

The 2019 report from the USA describes several factors that contribute to greater injuries and fatalities among rear seat passengers in head-on collisions (Jessica Jermakian, 2019). The NSIA considers that the findings in the report contribute to increased understanding of variations in practice and the challenges presented by passive safety in rear seats. The report describes several problems that bear similarities to the findings from this accident.

This investigation indicates that safety in the middle back seat is affected by the chosen seat belt design. It also shows that the shoulder belt, and the way in which the rear seat-back moves, are interdependent.

The investigation has shown that different car manufacturers have chosen different solutions. Based on observations and findings during this investigation, the NSIA finds that the test criteria in Annex A to UN-ECE R17 are inadequate for managing the risk posed by loose luggage impacting on a folding rear seat-back while a passenger is secured in a seat belt that is anchored to the same rear seat-back. The NSIA believes that the investigation gives grounds for reviewing these requirements, and submits a safety recommendation to the NPRA to this effect.

2.7 Collision tests and consumer information about rear seat safety

Euro NCAP's test programme for head-on collisions did not include a test protocol with an adult test dummy in the middle rear seat and loose luggage in the boot. The NSIA considers that a collision test of this nature would be useful for consumers, as it would motivate the car manufacturers to improve safety for middle rear seat passengers. A test dummy in the middle rear seat will also demonstrate more clearly than at present how luggage in the boot – even if it does not penetrate the passenger compartment – affects passenger safety.

During the investigation, quantification/classification of middle rear seat passenger safety has presented challenges, not least because very few collision tests exist. The NSIA considers that the combination of seemingly weak requirements and inadequate testing may mean that neither car manufacturers nor consumers are properly informed about how luggage in the boot affects safety in a head-on collision. Using 'Euro Rescue' (described in Section 1.17.1), the NSIA has been able to see the wide variation in types of seat belts fitted to rear seats, and considers that safety in general can be improved by paying more attention to this area.

In the final phase of this investigation The NSIA has been in dialogue with Euro NCAP. The Euro NCAP has recognized the findings and conclusion of this investigation and will include it in in the discussion for future protocol amendment.

2.8 The importance of correct use of safety equipment

This and previous investigations have shown that if seat belts are poorly positioned and adjusted on the body, serious injuries can result. It is important for the individual motorist to understand how seat belts should be positioned and adjusted around the body, and that correct fitting is essential if the car's safety systems are to function as intended. Usually, car user manuals also describe the correct use of safety equipment.

Seat belts are flexible in use, and some belts may be more difficult to position and adjust than others. There are several ways of positioning a seat belt incorrectly, which may mean that the belt tightens in the wrong way in a collision. The lap belt shall be positioned tightly across the hips so that the iliac crest absorbs the forces. This must be combined with correct placement of the shoulder belt, i.e. directly over the shoulder and tightly across the chest so that the passenger sits in a straight position against the seat-back and the seat belt can function optimally. This has been pointed out in several NSIA investigations. During the summer of 2020, an information video illustrating this issue has been produced in collaboration with Oslo University Hospital and published on the NSIA website (SHK, 2020). NSIA believes that this video should be used in teaching, including in the traffic instructor education.

This investigation has shown that the seat belts for the individual seats are constructed differently, and the safety in the middle rear seat is directly related to how well the rear seat-back resists the loading imposed by the passenger and the luggage in the boot.

It is also important to use any available load securing equipment in passenger cars, and factory-fitted safety equipment such as cross-struts behind the rear seat-back, grills or netting up to the roof will help to reduce the risk of injuries and loading on the rear seat-back. This investigation has shown that unsecured, but well positioned luggage with an average weight of 13 kg per passenger contributed to major deformations in the rear seat-back in a head-on collision at high speed.

The NSIA's investigations have shown a need to raise awareness of cargo securing. This is not just to prevent loose objects from entering the passenger compartment, but also to prevent increased loading on the rear seat-back. Proper cargo securing will improve the passive safety of all persons in the passenger compartment, but particularly the middle rear seat passenger in cars with a split seat-back.

In 2019, the NSIA submitted two safety recommendations to the NPRA (SHK, 2019) about correct use of seat belts and cargo securing in passenger cars. The NSIA still considers it important to disseminate information and knowledge about these matters, and is of the opinion that there is scope for improvement in strength requirements and industry standards.

3. CONCLUSION

3.1 Sequence of events

a) A van lost road grip in a right-hand bend in an 80 km/h zone, crossed over into the opposite lane and collided head-on with an estate car of roughly equal weight, fully laden with passengers.

b) Both cars are considered to have driven around the speed limit, and within the speed limit of 80 km/h.

c) An ice film had formed on the roadway, resulting in low friction.

d) The drivers and front seat passengers in both vehicles sustained only minor injuries.

e) The left rear seat passenger in the estate car was unsecured at the time of the accident and died later from injuries sustained in the collision.

f) The middle rear seat passenger was secured by a seat belt and died instantly from extensive injuries.

g) The right rear seat passenger was secured, but suffered critical abdominal injuries as a result of sliding under the seat belt in the collision.

3.2 Road conditions

a) The road conditions in the accident bend did not meet the operating requirement for bare road and were difficult to identify at the time of the accident.

b) The operating contractor inspected the road the night before the accident, and concluded that, based on the road conditions at the time, there was no need for measures.

3.3 Passive safety in the vehicles

a) The estate car and van had good collision safety for the driver and right front seat passenger.

b) The passive safety for the middle rear seat passenger in the estate car differed from the other seats as the lap belt was narrower, the seat belt had no pretensioner or force limiter, and the anchor point for the shoulder belt was fitted to the rear seat-back and not to the car's body.

c) Safety in the middle rear seat is directly related to how well the rear seat-back withstands the loading from a passenger and the luggage in the boot. In this case, unsecured but well-positioned luggage with an average weight of 13 kg per passenger contributed to major deformations of the rear seat-back.

d) The regulations that deal with testing of the strength of folding rear seats (UN-ECE R17) do not describe or take into account how a middle rear seat passenger is secured with a seat belt.

e) The car manufacturers design the safety equipment for the middle rear seat passenger in different ways, and there are no collision tests that deal with this issue.

3.4 Other results of the investigation

a) The driver of the van was driving without a driving licence, but had documented completion of the compulsory training (riskutbildning) for Class B in Sweden, which includes driving on a slippery driving track.

4. SAFETY RECOMMENDATIONS

The investigation of this accident has identified an area in which the NSIA deems it necessary to submit a safety recommendation for the purpose of improving road safety.[2]

Safety recommendation ROAD No 2020/10T

In the frontal collision in Volda on 20 October 2019, two people sitting in the back seat of the station wagon died and one person was seriously injured, while the people in the front seats of both cars survived the accident with only minor injuries. The investigation of the high-energy accident that occurred at around 70–80 km/h, has shown that the passive safety systems in the estate car were constructed differently, and that the safety in the middle rear seat was directly linked to how a split rear seat manages to withstand the load from passenger and luggage placed in the boot. In this case, unsecured but well-placed luggage contributed to large deformations on the rear seat back. The NSIA has assessed UN-ECE R17 (Annex 9) and the test requirements for the strength of rear seat-backs in the light of this accident, and believes that the test requirements do not adequately safeguard the safety of passengers in the middle rear seat.

The Norwegian Safety Investigation Authority recommends the Norwegian Public Roads Administration to make an assessment with the aim to improve the regulations for the safety of rear seat passengers and inform UN's Working Party on Passive Safety (GRSP) about this accident and the findings of the investigation.

The Norwegian Safety Investigation Authority

Lillestrøm, 16 December 2020

[2] The investigation report is submitted to the Ministry of Transport, which will take necessary steps to ensure that due consideration is given to the safety recommendations, cf. Section 14 of the Regulations of 30 June 2005 on Public Investigation and Notification of Traffic Accidents etc.

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