Investigation report

A 1/2004 Y Abridged translation
of the original Finnish report

A head-on collision involving a heavy vehicle combination and a charter coach on highway 4 at Konginkangas near the town of Äänekoski, Finland on 19.3.2004

The vehicle combination: Road tractor REY-481 and full trailer PZU-497

The charter coach: IUF-867

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SUMMARY

On Friday 19.3.2004 at 02:08, a traffic accident occurred at Konginkangas near the town of Äänekoski on highway[1] number 4. The trailer of a heavy vehicle combination (full trailer combination) on its way from Viitasaari to Helsinki, collided with a charter coach, used by Sunny Buses Ltd (Aurinkobussit Oy), on its way from Helsinki to Kuusamo. The full trailer combination was loaded with paper reels and Transpoint Oy Ab. owned it. There were 36 passengers on the coach at the time of the accident. The driver of the coach and 22 passengers perished in the accident. The rest of the passengers were seriously injured. The driver of the full trailer combination escaped uninjured.

The full trailer combination had left from Helsinki on 18.3.2004 at 20:33 for Viitasaari, loaded with case goods. Another of the same company's full trailer combinations, having departed from Rovaniemi, was loaded in Kemi with paper reels. Both vehicles arrived in Viitasaari during the night of 19.3.2004. The drivers exchanged pallets and trailers, whereafter the vehicles took off from Viitasaari for Helsinki and Rovaniemi, respectively, at about 01:30.

About half an hour after having departed from Viitasaari the vehicle heading towards Helsinki arrived in a place at Konginkangas where the road curves to the left in the driving direction. At this location, there is a northbound overtaking lane. In a downhill curve, about 550 metres before the point of the collision, the trailer of the vehicle began to fishtail (travel with a side-to-side motion) and approximately 150 metres before the point of impact the trailer's rear swung beyond the right hand shoulder of the road into a snow drift down the slope in such a way that the rear wheels were travelling, at most, at a distance of four metres from the edge of the asphalt. The trailer rose back onto the road and the entire vehicle drifted into the left. The driver tried to steer the vehicle back into its own lane, but the trailer continued in the left lane, which was being used by the oncoming coach.

The coach, travelling in its own lane, collided almost head-on with the centre front wall of the trailer. Due to the force of impact, the front part of the coach was crushed. The trailer's detached front wall penetrated nearly halfway into the cabin of the coach, pushed by the trailer's load of paper reels (about 800 kg each).

The full trailer combination continued forward for approximately 25 metres after the collision and the trailer pushed the coach backwards down the slope of the road. The tractor was slowed down by the impact and thrown to the left in the driving direction. Finally, it heavily impacted the left side of the coach. After the impact, the tractor was thrown into the left hand ditch in the driving direction. The trailer, which remained coupled to the truck, stayed on the road next to the coach in the same lane as the coach. According to the tachographs of both vehicles, the full trailer combination and the coach were travelling at approximately 70 km/h at the time of the collision.

The investigation revealed, among other things, that both drivers had valid driver's licences and that neither alcohol nor any other intoxicant was present. The route planning of both vehicles was done in such a manner that it was not possible to complete the trips by following the prescribed

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[1] Highway = Main Road (Class I)

speed limits or regulations on driving hours and rest periods. No such technical faults that would have contributed to the cause of the accident were detected in either vehicle. The gross combination weight of the tractor-trailer exceeded the maximum permissible weight by approximately 4 100 kg. The excessive load was not determined to have played a crucial part in the accident.

The road at the accident site was extremely slippery as the surface of the road had frozen after a local rain shower. Both vehicles exceeded the 80 km/h winter speed limit and, taking into account the slipperiness of the road, travelled at too high situational speeds. The maintenance contractor of the road had not received information about the approaching rain shower.

The investigation commission carried out re-enactive road test runs at the accident site and based on the results, computer simulations were made to establish the causes for the loss of control of the vehicle combination.

The investigation commission determined the causes of the accident by using a methodology that was developed for road and cross-country traffic accident investigation commissions. Direct causal factors were found in the way the full trailer combination and the coach were controlled. Indirect causal factors were found in the vehicles, the traffic situation and factors in the transport system. Additionally, factors contributing to the increase of injuries were found. A total of 32 causal factors were established, of which some were direct and others indirect. The direct cause of the accident, as regards the driver of the full trailer combination, was the loss of control of the vehicle. The selection of an unfavourable driving line, the high situational speed and the driver’s possibly reduced state of alertness were the most noticeable contributing factors. The direct cause, regarding the driver of the coach, was the detection error that delayed an evasive manoeuvre. The high speed in slippery conditions was noted as a contributing factor.

When it comes to the full trailer combination, the weak structure of the trailer’s body, the insufficient anchoring of the load and the high situational speed of the vehicle contributed to the number of fatal and serious injuries. As for the coach, the low crashworthiness of the front part of the coach, the fact that seat belts were not worn, the high situational speed and the large weight difference between the vehicles were noted as factors causing additional injuries.

The investigation commission made a total of 21 safety recommendations, of which 13 were directed to the Ministry of Transport and Communications. Additional recommendations were made to the Ministry of Trade and Industry, the Ministry of the Interior, the Ministry of Social Affairs and Health, the Ministry of Finance, the Finnish Vehicle Administration AKE, the Emergency Response Centre Administration, the Finnish Road Administration (Finnra) and to the Finnish Bus and Coach Association.

Concerning the improvement of safety of heavy traffic the investigation commission considers the following five recommendations the most important:

> The speed limiting devices for lorries shall be set at the vehiclewise maximum speed of 80 km/h.

Legislation should be changed so that, pursuant to the recorded tachograph data, the driver can be penalized for having exceeded the vehiclewise speed limit.

A successfully completed course of anticipatory driving for heavy traffic should be a prerequisite for being allowed to take a driving test for a coach or a vehicle combination licence.

The supervisor (or a supervisory entity) of the driver shall be made legally liable for his role in a possible violation or consequence.

The penalties and other consequences that are imposed for driving hour and rest period violations, working time legislation violations and for exceeding vehiclewise axle and bogie loads and gross vehicle weights should be made more severe. Penalties and consequences should bear real significance to the driver and to the haulier as well as to those in the transport chain who with their own actions, by giving inadequate or incorrect information, by using their right to direct work or by applying other such direct control, have contributed to the arising of an unlawful situation.

TO THE READER

This investigation report was written by following the table of contents used in international aviation accident investigations as well as the guidelines found in the Accident Investigation Board handbook. The report comprises four main parts. Part 1, EVENTS AND INVESTIGATIONS, consists of so-called factual information. In this part the investigation commission does not present its views on the events. In part 2, ANALYSIS, the commission analyses the facts presented in part 1 as well as causes and factors that contributed to the accident. The shortcomings and causes that came up in the accident investigation are briefly stated in part 3, CONCLUSIONS. The investigation commission lists its safety recommendations to various authorities and actors in part 4, SAFETY RECOMMENDATIONS.

FOREWORD

On Friday 19.3.2004 at 02:08, a traffic accident occurred at Konginkangas near the town of Äänekoski on highway 4. A heavy vehicle combination loaded with paper reels was on its way from Viitasaari to Helsinki. Its trailer (4-axle full trailer) collided with a charter coach which was on its way from Helsinki to Kuusamo. Transpoint Oy Ab owned the full trailer combination. The coach was owned by Nordea Rahoitus Suomi Oy, in the fleet of Pohjolan Turistiauto Oy and operated by Sunny Buses Ltd. The travel organizer Goingto Oy had chartered the coach and the passengers were mainly young snowboarders and downhill skiers from southern Finland. There were 48 seats on the coach and at the time of the accident there were 36 passengers onboard. The driver of the coach and 22 passengers perished in the accident and the remaining passengers were seriously injured. The driver of the full trailer combination escaped uninjured.

Investigations at the location commenced at 02:39 when a police patrol from the Äänekoski local district arrived at the scene, cordoned off the site and began to reroute traffic.

The Central Finland road and cross-country traffic accident investigation commission was informed of the accident at 03:06. Members of the commission, including Mr. Veikko Stolt and Mr. Esa Vainio, arrived at the scene at 04:00 and in cooperation with the Äänekoski police immediately began investigating the accident. Investigators from the Jyväskylä crime scene investigation unit initiated their own traffic accident inquiry at 05:20.

The person on call at the Accident Investigation Board Finland was informed of the accident a little later in the morning, at 04:20. The director of the Board, Mr. Tuomo Karppinen, and the chief accident investigator, Mr. Esko Lähteenmäki, travelled to the site, arriving at 09:45. Fire Chief Ari Vakkilainen arrived at the site at 11:00. At the accident site, Tuomo Karppinen and Veikko Stolt agreed on the setup of an investigation team, tasked to continue the investigation until the Government appointed a major accident investigation commission.

After the accident at 05:40, representatives from the Finnish Road Enterprise and the Keski-Suomi (Central Finland) Road Region measured the friction of the road with a friction-measuring device that the Road Enterprise project manager had in his car. The second measuring was done with the Jyväskylä airport friction-measuring vehicle at 07:13. A Finnish Air Force Support Squadron aircraft photographed the accident site from the air at 09:00.

By approximately 18:30, the accident site investigation was complete and the vehicles were towed away. The road was entirely closed for traffic between 02:40 and 18:30. During that time, a detour routed traffic through the centre of Konginkangas.

The coach was towed to a Finnish Air Force Support Squadron hangar in Tikkakoski for more detailed examination. On 31.3.2004, the coach was transferred from the hangar to the Seppälä area industrial park in Jyväskylä. The road tractor was driven to a vehicle inspection station in Jyväskylä to be examined, from where its owner picked it up on 24.3.2004. The trailer was towed to the Seppälä industrial park for detailed examinations. The swap body was released to its owner on 23.6.2004. From 11-12.12.2004 the investigation commission conducted re-enactive test runs at Konginkangas and at Jyväskylä airport in order to measure the stability of the vehicle combination.

On 24.3.2004 the Government appointed a major accident investigation commission. Chief Investigator Esko Lähteenmäki from the Accident Investigation Board Finland became the chair of the commission. The vice-chair was Chief Superintendent Veikko Stolt and the members of the commission were MSc Markku Haikonen from the Helsinki Polytechnic Stadia, MSc Ville Hämäläinen from the Accident Investigation Board Finland, Engineer Jorma Lähetkangas from the city of Kuopio, Motor Vehicle Inspector Esa Vainio from A-Katsastus Oy as well as Fire Chief Ari Vakkilainen from the Tampere Rescue Service Region. When MSc Ville Hämäläinen was unavailable to attend, Mr. Mikko Kallas, student of engineering, replaced him. Permanent representatives to the commission were Senior Physician Maaret Castrén from the Helsinki and Uusimaa Hospital District and Transport Technician Unto Pentinmäki from the Huittinen Adult Education Centre

The investigation commission interviewed the driver of the vehicle combination, the surviving coach passengers as well as eyewitnesses to the accident. In addition, representatives of both of the drivers' employers were interviewed.

Several companies and entities provided expert services for the investigation. The Finnish Meteorological Institute compiled a report on the prevailing weather conditions in the region at the time of the accident. The Finnish Road Administration (Finnra) commissioned road profile measurements at the accident site. The tachographs of both vehicles were examined at the National Bureau of Investigation's forensic laboratory as well as at VTT's (Technical Research Centre of Finland) Building Technology laboratory. The Occupational Safety and Health Inspectorate of Central Finland provided a statement on drivers' working and driving hour and rest period directives. Citec Information Oy Ab produced a video animation of the accident. Jyväskylä University of Applied Sciences carried out paper reel friction measurements. An expert from Nokian Renkaat Oyj analysed the tyres of both vehicles in detail. The trailer's shock absorbers were tested at Suomen Vaimennin Oy. The manufacturer inspected the wear and condition of the trailer's fifth wheel in Germany. Ms. Tarja Ojala, a researcher from Safety Futures Ky, assisted the commission in analysing the responsibilities and flaws in the transport system. Dr. Markku Partinen, docent in neurology, analysed the state of alertness of the driver of the full trailer combination. Professor Esko Keskinen from Turku University compiled a causal analysis.

For the purpose of re-enactive test runs, the commission rented the actual road tractor that was collided from Transpoint Oy as well as a full trailer which was like the one that was destroyed in the accident. Transpoint assigned a driver for the test runs. Turku University of Applied Sciences rented out and installed the measuring equipment used in the re-enactive test runs. MSc Risto Salminen was responsible for metrology and the test programme. He also participated in the data analysis. Chief engineer Olavi Koskinen from the Finnish Road Administration modelled the road profile at the accident site. MSc Tero Kiviniemi, representing VTT Industrial Systems and using MSC Adams simulation software, created a computer model of the full trailer combination. Thereafter, he examined the vehicle combination's behaviour on the modelled road profile by running simulations. Test run data were used to calibrate and verify the accuracy of the computer model.

The investigation commission examined structural factors of the trailer's body at the plant of the trailer's manufacturer Närko Oy.

The investigation commission met with authorities, experts, actors and companies within the transportation branch in order to listen to their views. These entities were, among others, the Ministry of Transport and Communications, the Finnish Vehicle Administration, the Finnish Road Administration, the Finnish Road Enterprise's Road Weather Centre, the rescue service, emergency medical services and hospital care, the heavy traffic surveillance group of the National Traffic Police Helsinki unit, Finnish Road Enterprise, Stora Enso Oyj, Finnish Transport and Logistics SKAL ry, Finnish Bus and Coach Association ry, Employers' Federation of Road Transport, Transport Workers' Union AKT ry, the international chauffeurs' union Finnish affiliate Rahtarit ry and the Traffic Safety Committee of Insurance Companies. Furthermore, issues relating to modes of operation and safety cultures within the heavy traffic branch were discussed with the transportation captains of Fortum Oyj and Oy Esso Ab.

On 16.6.2005 a draft of the safety recommendations was sent to all pertinent authorities for statement as prescribed by the Accident Investigation Act. These were the Ministry of Transport and Communications, the Ministry of the Interior, the Ministry of Social Affairs and Health, the Ministry of Finance, the Finnish Vehicle Administration, the Emergency Response Centre Administration and the Finnish Road Administration. Furthermore, transport business associations, actors and other interested parties were requested to submit comments on the recommendations. The due date for the statements and comments was 5.9.2005.

The parties submitting statements and comments had an opportunity to familiarize themselves with the entire draft inquiry report at the Accident Investigation Board's premises. Only one representative of the authorities came and looked at the draft report. However, all of them submitted their statements on the safety recommendations. In addition, most of the associations and actors commented on the recommendations.

The investigation report was completed on 18.10.2005.

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1 EVENTS AND INVESTIGATIONS

1.1 The accident

1.1.1 Events preceding the accident

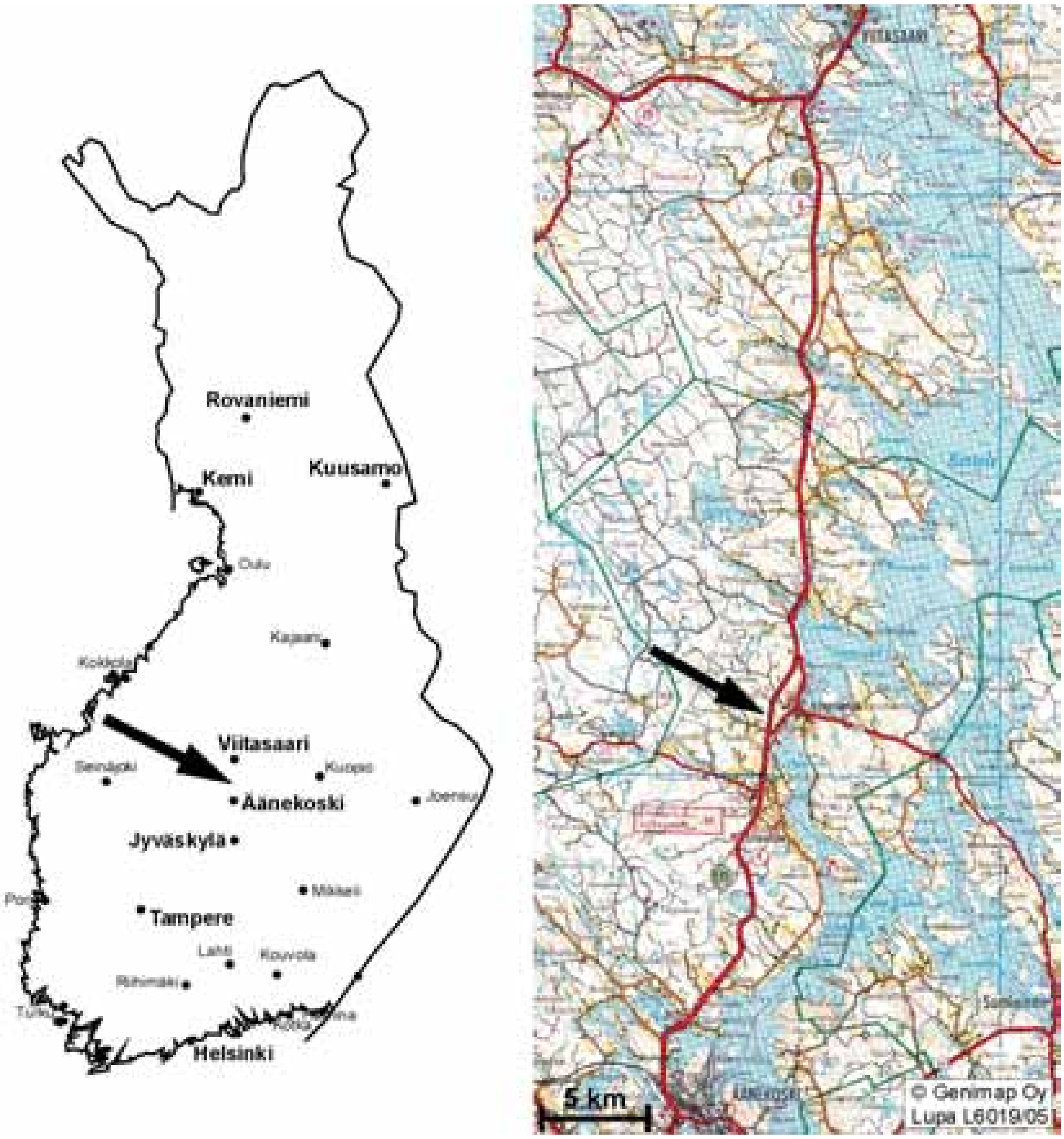

Figure 1. The accident site

The vehicle combination (full trailer combination, tractor-trailer) departed Helsinki for Viitasaari on Thursday 18.3.2004 at 20:33, loaded with case goods. Another tractor-trailer belonging to the same company, having departed from Rovaniemi, was loaded in Kemi with paper reels. Both vehicle combinations arrived in Viitasaari during the night of 19.3.2004 where the drivers exchanged swap bodies and trailers. The full trailer combinations set out from Viitasaari towards Helsinki and Rovaniemi, respectively, at about 01:30.

A chartered coach with 27 passengers onboard departed Helsinki for the Ruka ski resort in Kuusamo at 20:53. The coach picked up 6 passengers in Tampere at 22:48. The coach arrived in Hirvaskangas near Äänekoski at 01:02, picking up three additional passengers. After the break in Hirvaskangas, the coach continued towards Ruka at 01:42.

During the evening of 18.3.2004, the road surface temperature at the accident site was slightly above zero Celsius. At around 23:00 the road surface temperature dropped a few degrees below freezing. Sporadic light rain showers occurred in the night in Central Finland. The rain froze on the cold road surface, causing black ice.

1.1.2 Loss of control of the vehicle combination and the collision

Approximately half an hour after having departed from Viitasaari the vehicle combination arrived at Konginkangas, where the road curves to the left in the driving direction and simultaneously climbs up to the top of a hill. After passing the apex of the hill, the curve continues for another 400 m, whereafter it straightens out while descending to an open field area. There is a northbound overtaking lane at this point. In the downhill curve, the trailer began to fishtail and approximately 150 meters before the point of collision the trailer’s rear part was thrown beyond the right hand shoulder into a snowdrift down the slope resulting in the rear wheels travelling, at most, at four metres’ distance from the edge of the asphalt. The trailer rose back onto the road from the slope and the full trailer combination drifted into the left lane. The driver tried to steer the vehicle back into its own lane, but the trailer stayed in the oncoming traffic lane.

The oncoming coach, travelling in its own lane, collided almost dead centre into the front wall of the trailer. Due to the force of impact, the forward part of the coach was crushed. The trailer’s detached front wall penetrated nearly halfway into the cabin of the coach, pushed by the trailer’s load of paper reels (weighing about 800 kg each).

The full trailer combination continued to move forward for approximately 25 metres after the collision and the trailer pushed the coach backwards down the slope of the road. The truck was slowed down by the impact and was thrown to the left in the driving direction and subsequently heavily impacted into the left side of the coach. After the impact, the truck was thrown into the left hand ditch in the driving direction. The trailer, which remained coupled to the truck, stayed on the road next to the coach in the same lane as the coach.

The driver of the vehicle combination later explained that he only noticed that the road was slippery when the trailer began to fishtail.

According to the tachographs of both vehicles, the full trailer combination and the coach were travelling at approximately 70 km/h at the time of the collision.

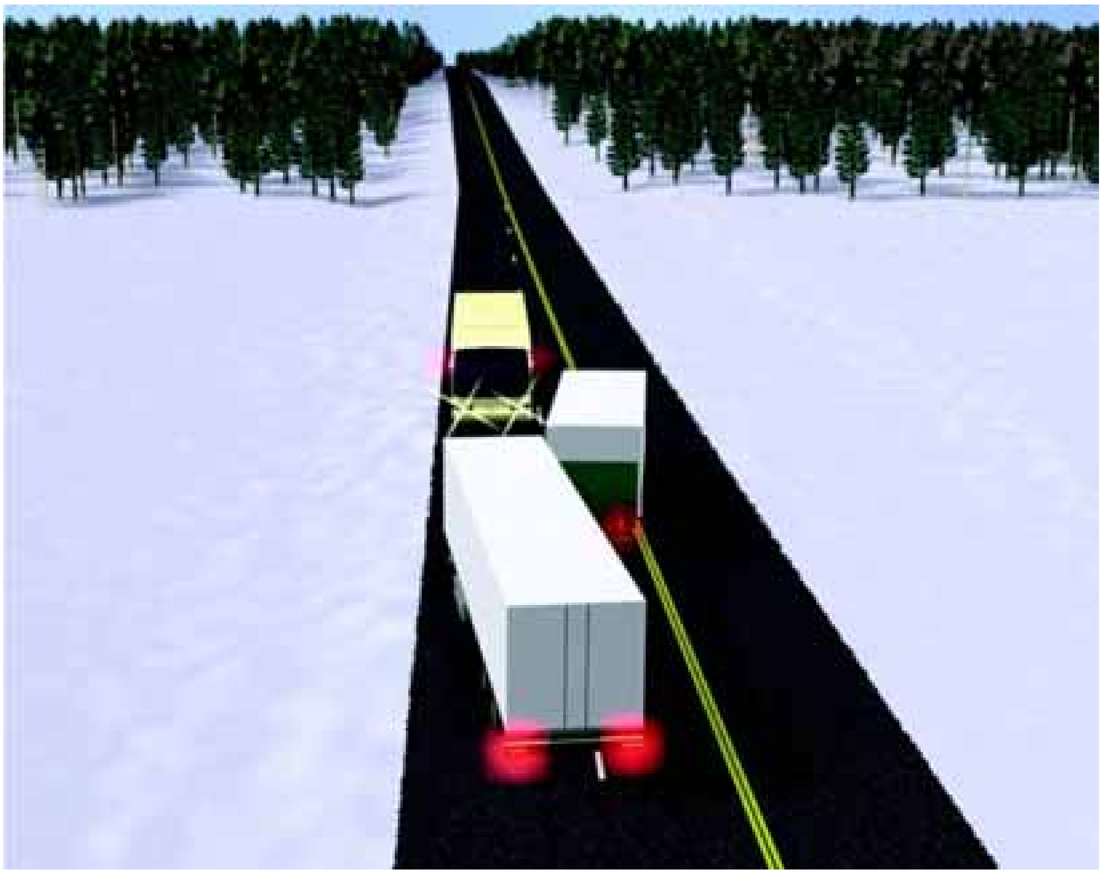

Figure 2. The investigation commission's view of the vehicles' relative positions immediately before impact.

1.2 Injuries to persons

Injuries	Drivers	Passengers
Fatal	1	22
Serious		14
Mild/no injuries	1	0

The average age of persons involved in the accident was 26 years. There were 24 women and 14 men. Twelve of the passengers on the coach were below the age of 20.

In addition to physical injuries, many victims sustained mental trauma requiring treatment.

1.3 The damage to vehicles

The back wall of the tractor's cabin was damaged. The front wall of the swap body and its left side were torn open. The front part of the trailer was destroyed.

The coach was damaged beyond repair.

1.4 Other damage

Some of the paper reels in the load were damaged. Passengers' belongings were damaged.

1.5 The drivers

Driver of the vehicle combination: Male, 39 years of age.

The driver had an ABECE driver's licence. He had been issued an AB driver's licence on 9.12.1982, a lorry licence on 18.7.1988 and by virtue of his work experience an ABECE licence on 16.8.1993, authorizing him to drive vehicle combinations. Ever since then he had been a full-time driver of heavy vehicles, annually logging approximately 115 000 kilometres. He had driven the vehicle involved in the accident for about 30 000 kilometres.

During the previous five years he had received one penal order for endangerment of traffic.

The driver of the coach: Male, 56 years of age.

The driver had an ABECEDE driver's licence. He had been issued an ABC licence on 6.9.1971 and an ABECE licence for vehicle combinations on 22.1.1975. After having been issued a coach driver's licence on 14.1.1976 he worked as bus driver in local traffic for seven years. Thereafter, he was hired by a charter coach company and drove a coach in Finland and in other European countries. He had 25 years of experience in driving buses and coaches, logging almost 100 000 kilometres annually.

During the previous five years he was issued two penal orders for endangerment of traffic.

1.6 The vehicles

1.6.1 The vehicle combination

The road tractor:

Make:	Scania
Model:	P124 GB-A-6X2/450+136
Serial number:	YS2P6X20031288685
Taken into use:	2.6.2003
Odometer reading:	179 970 km
Registration inspection:	23.4.2003
Length:	9.9 m
Width:	2.5 m

Wheelbase:	4.5 m
Bogie wheelbase:	1.36 m
Net Vehicle Weight:	10 500 kg
Carrying capacity:	15 500 kg
Gross Vehicle Weight:	26 000 kg
Maximum vehiclewise speed:	80 km/h

There were 17 paper reels in the tractor's load space. According to the waybill the laden weight was 13 403 kg.

The weighed total mass of the tractor was 28 320 kg and since its Gross Vehicle Weight (GVW) was 26 000 kg the GVW was exceeded by 2 320 kg.

Calculated axle loads:	1st axle 8 622 kg	2nd axle 11 880 kg	3rd axle 7 818 kg
Permissible axle loads:	1st axle 7 500 kg	2nd axle 11 500 kg	3rd axle 7 500 kg
Excessive axle loads:	1st axle 1 122 kg	2nd axle 380 kg	3rd axle 318 kg.

The road tractor was a three-axle lorry fitted with a day cabin, swap body equipment, tailgate hook lift and a towing coupling (trailer hitch). The second axle had twin wheels. The rear wheels turned hydraulically when the front wheel steering angle exceeded four degrees. The front had leaf spring suspension and the rear air suspension. The tractor had an electronic anti-lock pneumatic disc brake system (EBS). The secondary braking system comprised the trailer brake and an automatic exhaust brake. The tractor was fitted with a traction control system. Both the exhaust brake and the traction control were on at the time of the collision. The vehicle did not have an ambient temperature indicator. Both seats were fitted with three-point seat belts.

The swap body was a so-called VR (State Railroads) container, fitted with four retractable legs and manufactured by the body maker Fokor. It was of box van type, manufactured out of fibreglass and insulated. Twin doors were both in the front on the right hand side and in the back. The swap body was taken into use in 1988.

The trailer:

Make:	Närko
Model:	TP42L-UKRGS45-360
Serial number:	YF104DT4BXF018603
Taken into use:	4.1.1999
Regular inspection:	5.12.2003
Length:	13.57 m
Width:	2.60 m
Front bogie wheelbase:	1.36 m
Wheelbase:	6.52 m
Rear bogie wheelbase:	1.82 m
Net Vehicle Weight:	10 800 kg
Gross Vehicle Weight:	36 000 kg

There were 32 paper reels in the trailer. According to the waybill the laden weight was 24 985 kg.

Calculated axle loads:	front 16 463 kg	rear 19 322 kg
Permissible axle loads:	front 16 000 kg	rear 20 000 kg
Excessive axle loads:	front 463 kg	the permissible rear axle load was not exceeded.

The trailer's calculated total weight was 35 785 kg and since its GVW was 36 000 kg, the GVW of the trailer was not exceeded.

The four-axle trailer had fixed front and rear bogies, twin wheels, an air suspension and anti-lock pneumatic drum brakes (ABS). Axles 2 and 4 were fitted with wheel speed sensors. The body was enclosed with fibreglass as outer and inner linings. The trailer was insulated and fitted with a heater.

The trailer's axle alignment was laser-inspected approximately two weeks prior to the accident and the alignments were found to be straight and true.

The full trailer combination's length, Gross Combination Weight, coupling and the towed weight

The total length of the full trailer combination (tractor and full trailer) was 24.98 m. The maximum permissible length for a vehicle combination is 25.25 m.

The total weight of the tractor was 28 320 kg and the total weight of the trailer was 35 785 kg. Hence, the Gross Combination Weight (GCW) was 64 105 kg. The maximum permissible GCW for a vehicle combination is 60 000 kg. Therefore, the tractor-trailer vehicle exceeded the GCW limit by 4 105 kg.

The coupling of the vehicle combination conformed to the rules. The permissible towed weight, i.e. the maximum permissible GVW of the coupled trailer was 36 000 kg.

1.6.2 The coach

Make:	Volvo
Model:	B12M/620
Serial number:	YV3R9H51X1A000145
Chassis:	Carrus 9700
Taken into use:	14.6.2002
Odometer reading:	153 378 km
Registration inspection:	14.6.2002
Annual inspection:	7.3.2003
Length:	12.0 m
Width:	2.55 m
Wheelbase:	6.2 m
Net Vehicle Weight:	13 250 kg

Carrying capacity:	4 750 kg
Gross Vehicle Weight:	18 000 kg
Calculated weight at the time of the accident:	16 150 kg
Passenger seats:	48
Maximum vehiclewise speed:	100 km/h

The vehicle alteration inspection for changing from 46 seats to 48 seats had not been done.

Permissible axle loads: 1st axle 7 500 kg 2nd axle 11 500 kg.

Neither the GVW nor permissible axle loads were exceeded.

The chassis was manufactured of stainless steel. The vehicle had air suspension and anti-lock pneumatic drum brakes (ABS). The Volvo Engine Brake (VEB) was the secondary brake. The vehicle was fitted with a traction control system. The coach had an ambient temperature indicator and a system that could be switched on to warn of slippery road conditions. Due to the destruction it is unknown whether the system was turned on at the time of the accident. The seats were adjustable Carrus TS-2000 tourist coach seats. All seats had seat belts. The driver seat, the tour guide seat, the first row seats, the row of seats behind the middle door as well as the ones next to it on the left were fitted with three-point seat belts. All other seats had two-point seat belts.

1.7 Meteorological information

During the morning of 18.3.2004, a weak snow shower front moved to the east from Central Finland. After that, the weather was mostly overcast with local light drizzles. In the afternoon the cloud base broke at times but it was still mostly overcast. The ambient temperature varied between 0 and +2°C. Relative humidity remained for the most part above 90%. In the evening it was overcast but dry and the relative humidity remained high. The temperature hovered around zero.

During the evening preceding the accident two separate weather forecasts were issued for the Keski-Suomi (Central Finland) Road Region area. The Finnish Meteorological Institute forecast was issued at 21:00 and according to it the minimum temperature during the night would be -1°C with zero precipitation. The Foreca Oy forecast was issued at 20:39 wherein a minimum temperature of -3°C and a 5% chance of precipitation were predicted. According to the road weather centre, neither forecast warranted alerting the road maintenance contractor.

Scattered showers formed in the Bothnia region moving east-southeast, strengthening during the evening of Thursday 18.3.2004. The Finnish Meteorological Institute’s doppler weather radar pictures revealed that the showers passed over highway 4 at Konginkangas at around 01:30. The rain sprinkled the highway stretching about 10 km both north and south of the accident site. Scattered showers occurred elsewhere as well on the Jyväskylä-Äänekoski section of the highway. The precipitation only amounted to a few millimetres at the most. The temperature was close to zero but in many places, the road surface temperature fell a little below freezing. After the time of the accident (19.3.2004 at 02:08), the weather cleared up and the ambient temperature clearly fell below zero.

It is highly likely that the precipitation in the showers mostly materialized as wet snow. At the site of the accident, the showers were dissipating and slightly after the time of the accident, the rain petered out completely. As the showers were growing weaker the precipitation, here and there, may have been freezing rain.

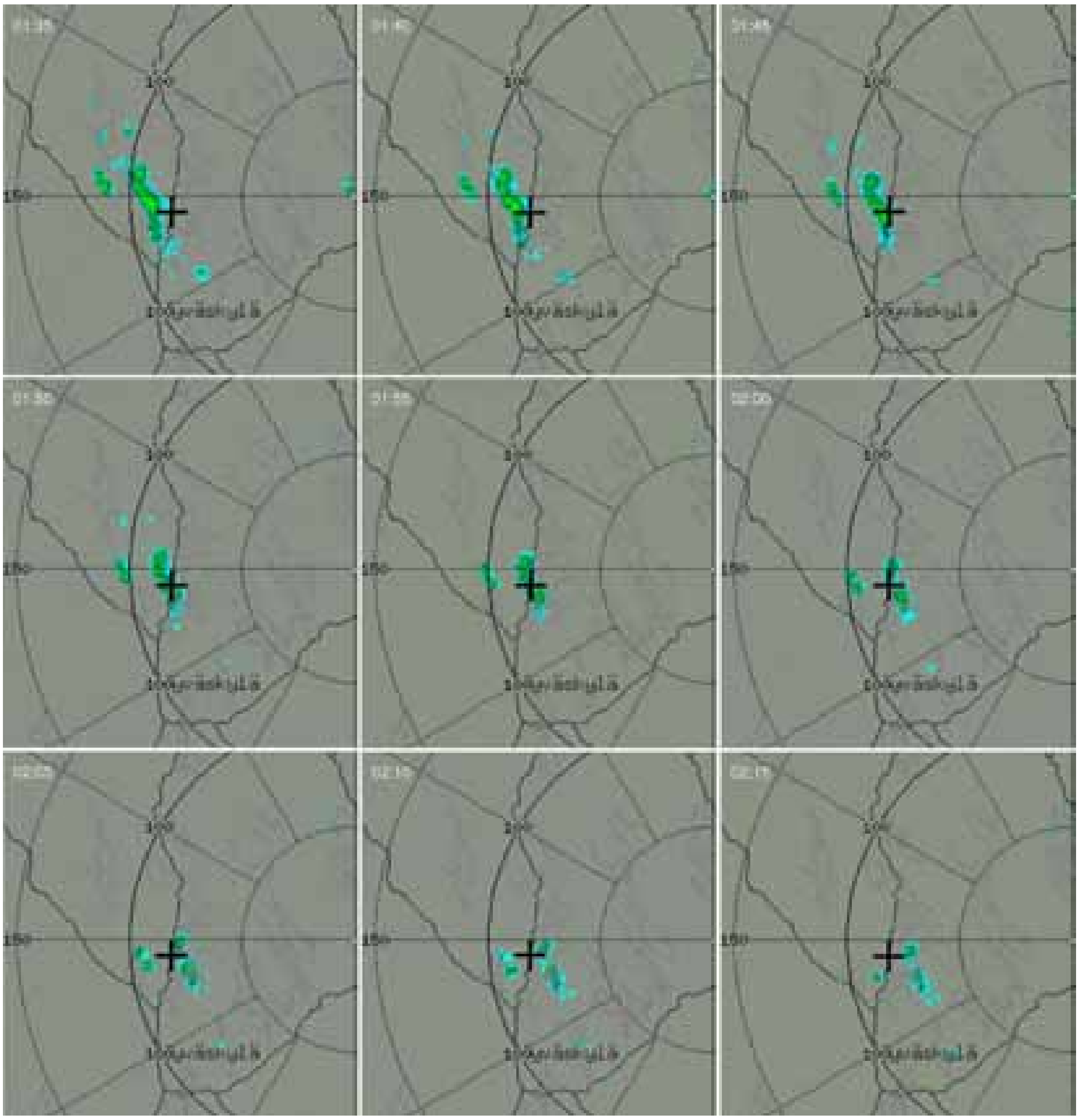

Figure 3. Partial doppler weather radar picture close-ups from the area where the accident happened. The cross marks the accident site.

Showers, partly wet snow or partly rain, had weakened but there was still enough precipitation to wet the road surface - at least in places. At the time of the accident, the road surface temperature was below dew point and, therefore, humidity was condensing on the road surface. Meteorologically speaking the road surface was either icy or frosty.

Due to a technical malfunction, the doppler weather radar picture was not updated at the Helsinki road weather centre between midnight and 04:00 and, hence, the road weather centre operator did not detect the approaching rain.

1.8 The road

1.8.1 Road geometry and surface condition

The accident took place on a long straight section of the road, in the northbound lane, where a northbound overtaking lane begins.

It was possible for the drivers to see each other's headlights from a distance of about one kilometre. Considering the relative speeds of the vehicles, they would have passed each other in approximately 25 seconds.

Looking from the driving direction of the full trailer combination there is a knoll before the accident site as well as a curve to the left on the top of a hill (R=1000 m). After the curve, a straight section of road begins at 360 m before the point of impact. The tractor-trailer approached the accident site from the north descending a relatively steep incline with a 5.9% longitudinal gradient. All in all the descent continues for about 650 m. In the driving direction of the coach immediately prior to the point of collision there is a slight downward slope with a 0.48% longitudinal gradient.

The camber of the road varied between the two lanes at the curve. The camber angle of the lane used by the full trailer combination varied between 1-3%. The angle of the lane used by the coach as well as the angle of the overtaking lane varied between 3-4%. All cambers, however, were correct, i.e. angled towards the inside of the turn. According to the road plan all lanes should have been built with a 3% camber towards the inside turn.

In the outermost lane of the curve, used by the full trailer combination, the pavement was visibly grooved and the lane was noticeably uneven.

Figure 4. The curve and the hill. The circle indicates the place where the driver lost control of his vehicle and the arrow denotes the point of collision.

The pavement of this section of the road was somewhat worn. As for grooves and smoothness, pursuant to the results of groove measurements taken on 3.4.2004, the surface was deemed partly good and partly satisfactory.

1.8.2 Winter maintenance of roads

(Abridged from the original Finnish text)

In Finland, the Finnish Road Administration (Finnra) is the authority responsible for public road maintenance. Practical road maintenance is implemented through regional contracts. An individual contract comprises a contiguous region encompassing approximately one thousand kilometres of roads to be maintained. The maintenance contracts are signed for several years at a time and Finnra selects the contractor through competitive bidding.

Finnra has set up a unified service level classification for winter road maintenance. Any given road's maintenance service class is determined by taking into account the traffic volume, the functional class of the road and the regional climate.

The roads are divided into five maintenance classes:

- Class Is: All roads with an Average Daily Traffic (ADT) of > 6 000 vehicles/day
- Class I: All main roads[2] with an ADT of 3 000–6 000 as well as regional highways and connecting roads with an ADT of 4 000–6 000
- Class Ib: All class I main roads with an ADT of < 3 000; class II main roads with an ADT of 1 000–3 000 as well as regional highways and connecting roads with an ADT of 1 500–4 000
- Class II: All class II main roads with an ADT of < 1 000; regional highways with an ADT of 200–1 500 as well as such connecting roads with an ADT of 350–1 500
- Class III: Regional highways with an ADT of < 200 as well as connecting roads with an ADT of < 350.

Finnra has established maintenance class-specific quality requirements for different maintenance procedures as well as time constraints for urgently required maintenance. At night between 22:00–05:00, the maintenance contractor is generally allowed to implement maintenance procedures as per one maintenance class below the required normal level of the given section. The contractor is required to monitor and report on the maintenance quality, which is also monitored by Finnra representatives through spot checks. If the contractor underperforms in maintenance quality, he will be issued appropriate sanctions as stipulated in the maintenance contract.

Timely de-icing of roads in wintry conditions is the most difficult and time-critical task since roads become slippery in many different ways:

- the wet road surface freezes during thermal radiation

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[2] Main roads are divided into two classes: class I and class II (not to be confused with the maintenance class).

- moisture in the air condenses on the otherwise dry surface of the road forming frost or hoar frost
- the temperature rapidly rises after a very cold spell forming frost on the road
- rain freezes on a cold road surface
- supercooled rain (freezing rain) turns into black ice once it hits the road surface
- snowfall makes the surface slippery.

When it comes to traffic safety, the most effective way to maintain winter roads is to prevent slipperiness from even forming. This can only be done by anti-icing (preventive salt spreading) in favourable weather conditions by which ice is prevented from forming and snow from sticking to the road surface. However, environmental factors restrict the use of salt in anti-icing.

The initiation of anti-icing depends on reliable weather forecasting. Finnra has set up a road weather information system for monitoring and forecasting purposes.

1.8.3 Weather and road conditions monitoring and the initiation of road maintenance

Weather development is monitored by Finnra’s automatic road weather stations, road weather cameras and by doppler weather radars covering the entire area of Finland. There are some 350 road weather stations and ca. 250 road weather cameras in Finland. They primarily cover the main roads and relay information to Finnra’s road weather centres as well as to Suomen Kelitieto Oy (Finnish Road Weather Information Ltd), who serves other contractors. Furthermore, weather and road weather forecasting as well as doppler weather radar and weather satellite imagery are outsourced. Finnra’s road weather centres along with Suomen Kelitieto Oy monitor the development of weather and anticipate the need for road maintenance. During the winter, the road weather centres are manned 24/7. When the prevailing weather or its anticipated development warrants commencement of maintenance activities, the road weather centre supervisor issues a weather alert to the road maintenance contractor. The weather alert initiates the relevant maintenance activities. During normal working hours, the contractor’s staff monitors the weather and the road weather conditions and acts on its own initiative.

Calls pertaining to traffic conditions from drivers or from the authorities are automatically directed via the “Road User's Phone Service 0200-2100” to Finnra’s Traffic Management Centre (TMC) in Tampere. Once contacted, the TMC evaluates the severity and traffic impact of the situation and categorizes it as one of the following message types:

- Request for action
- Information to the maintenance contractor
- Query

The TMC immediately relays the information to the appropriate regional contractor. Once the contractor receives a “Request for action” or “Information to the maintenance conractor”-message, he is obligated to decide on the course of action without delay and to inform the TCM of his intention. When necessary, the contractor must go to the site to evaluate the situation.

1.8.4 Road maintenance at the accident site

(Abridged from the original Finnish text)

The section of the road where the accident took place was in winter maintenance class I, based on traffic volume. The Finnish Road Enterprise maintained the road. The road weather centre in Helsinki monitored the development of weather conditions in Central Finland. The road weather stations nearest to the accident site were approximately 25 km to the south in Äänekoski and 11 km to the north in Konginkangas. The closest road weather camera was located ca. 15 km south of the accident site.

In the evening before the accident, the road surface was entirely bare and mostly dry. In places snowfall in the morning had left the road wet. The road surface temperature was a couple of degrees above zero. From 20:00-21:00 in the evening, the Finnish Road Enterprise spread a brine solution on the road areas that the snowfall in the morning had left wet. Brine was spread on a stretch of about 500 metres on the downhill section of the road on which the full trailer combination travelled. At that time the accident site itself was dry and, hence, was left untreated. The weather forecast called for subzero temperatures at night.

The accident occurred at 02:08. After the accident, at 02:34, the Central Finland emergency response centre requested de-icing for the accident area. Brine was spread on the area at 04:22, i.e. 1h 48min after the call. The road clearing equipment was stationed in Suolahti and, as per winter road management quality requirements, de-icing had to be completed within two hours of notification.

1.8.5 Measuring of the road surface friction

On Thursday, 18.3.2004, at around 23:00 the road surface temperature fell a couple of degrees below zero. On the night of the accident, there were some scattered showers in Central Finland. The rain froze as it hit the cold surface of the road.

After the accident at 05:40, representatives from the Finnish Road Enterprise and the Keski-Suomi (Central Finland) Road Region measured the friction of the pavement with a friction-measuring device that the Road Enterprise project manager had in his car. The friction coefficient at the site of the accident varied between 0.19 and 0.21.

The second friction measurement was conducted with the Jyväskylä airport friction-measuring vehicle at 07:13. The lowest figure was 0.2 and the highest 0.6. The large variation resulted from the de-icing of the road that was done after the accident. After the accident, brine was spread between 04:22-04:40 on the section of the road that the full trailer combination had used.

1.8.6 Traffic volume on the section of road

The average daily traffic (ADT) on the section of road in question is 4 320 vehicles/day, of which heavy traffic constitutes 16%. The weekday ADT is 4 016, of which 19% is heavy traffic.

The automatic traffic detector 14.5 km south of the accident site recorded the traffic volume on 19.3.2004 between 01:00 and 02:00. During that interval, 54 vehicles passed the detector, 37 of which were heavy vehicles and 17 were either cars or vans. Of these, 27 heavy vehicles and 10 cars were northbound whereas 9 heavy vehicles and 8 cars were southbound. The average speed of the heavy vehicles was 84.9 km/h, varying between 82-98 km/h. The average speed of cars and vans was 91.4 km/h, varying between 67-100 km/h. There was an 80 km/h winter speed limit on that section of the road.

1.8.7 Accident history of the site

The following lists the accidents reported to the police from 1999-2003 on the section one kilometre to the north and one kilometre to the south of the accident site:

- Four elk collisions at dusk and in the dark. Bare road surface. No injured persons
- Two instances of driving off the road to the right on a straight section of the road. Icy pavement. No injured persons
- Two overtaking accidents in which vehicles headed in the same direction hit each other. Icy pavement. No injured persons
- One instance of driving off the road to the left on a straight section of the road. Icy pavement. No injured persons
- One instance of driving off the road to the right in a left hand curve. Bare and dry road surface. No injured persons
- Rear-ending a braking vehicle in front. Slushy road. No injured persons.

There were altogether 11 accidents translating into an average rate of 1.1 accidents/road kilometre/year. The average accident rate on highway 4 in the Keski-Suomi Road Region is 0.97.

1.9 The recording equipment

(Abridged from the original Finnish text)

Both vehicles were fitted with tachographs as road event data registration devices. Tachographs are mandatory in lorries and buses and they record the driving hours and rest periods as well as the speed of the vehicle on a waxed paper disc, in the form of a graph. The discs are personal and the drivers insert them into the tachographs at the beginning of their shifts. Both discs were clearly readable.

Neither vehicle’s ABS nor EBS brake recorders registered any brake system malfunctions.

1.10 Inspection of the accident site and the vehicles

1.10.1 Inspection of the accident site

The accident took place on highway 4, approximately 650 m to the north of Konginkangas' south exit. The Road Data Bank address of the site is 4/312/3,590. Due to the northbound overtaking lane beginning just at the accident site, the road is not a full three-lane road. The pavement width at the point of impact is 10.3 m. The accident happened on an approximately 5 km long straight section of road which has a few hills. The sight distance at the site is approximately one kilometre. The point of collision is located in an area surrounded by an open field. The terrain on both sides of the road is level and the contours of the side slopes are wide and quite gentle. The road runs ca. 1.5 m above the level of the field and the ditches are fairly shallow. Snow was ploughed beyond the edge of the asphalt and the snow banks were approximately 20-30 cm high and partially thawed by the sun. Snow depth in the field was 40-50 cm.

Figure 5. Aerial photograph of the accident. (Photo: Hannu Vallas)

When the site was inspected at around 10:00, there were no tyre marks on the asphalt surface. The point of impact was designated by a drag mark on the road, made by the coach's batteries and which lead to the other side of the road from the point of collision. Furthermore, the coach's detached front door and parts of the sunroof lay on the slope at the point of impact. Parts of mirrors were scattered on both sides of the road. On the slope in front of the point of impact and in front of the coach there were three paper reels as well as two side door panels that had been ripped loose from the left side of the trailer. One of the door panels had split into two. Six paper reels were resting on the road between the trailer and the coach.

Judging by the collision marks, the coach had been travelling in its own lane. However, it was impossible to determine its exact distance from the edge of the pavement at the time of the collision.

1.10.2 Inspection of the vehicles

The road tractor and the swap body

The road tractor lay in the ditch approximately eight metres behind the coach, cabin forward. The rear of the tractor was at the edge of the asphalt. The front wall of the swap body was broken, pressed by the paper reels. The collision guards at the front of the swap body base had given way and as a result, the swap body had plunged forward. The paper reels had also bent the back wall of the cabin inwards.

Figure 6. The tractor from the right.

The left rear side of the swap body had blood marks as well as abrasion marks made by the coach's broken window. As the paper reels hit the left sidewall, they produced an almost 1 m high vertical rupture at the spot of the abrasion marks, 0.9 m from the rear corner. Furthermore, there were impact marks on the left side of the chassis in the lower structures and in the rear corner as well as at the end of the rear bumper. The rear bumper struts were bent to the right.

The drawbar had scuffed the left side of the trailer hitch. In addition, the side flanges on the drawbar were slightly bent.

The trailer

The trailer was beside the coach in the coach's lane. The coupling between the trailer and the tractor had not disconnected. The front end of the drawbar was slightly bent to the left. The aluminium beams on the trailer's right hand side underride barrier had been bent and detached at the rear. The outermost right wheels on the rear bogie were packed with snow.

Figure 7. The trailer from the front.

The front wall of the body was torn loose. Only a 35-90 cm high strip was still attached to the upper side of the front wall. The front part of the trailer's frame had impact marks. The front bogie's left wheels and tyres were badly damaged. The first axle was completely loose and the second one was partially loose. The frame of the front bogie was bent and the left splashguard had come loose and was stuck to the front of the coach. The vertical steel beams in the front corners of the body as well as the body sill of the left side doors had come loose. The right side wall was damaged for about 2 metres' distance. Of the five door panels on the left hand side the first two had come loose and the remaining three had opened.

The coach

The vehicle combination had pushed the coach approximately 12 m backwards from the point of impact. The coach ended up on the right hand side slope of the road in the driving direction with the crushed front of the cabin remaining at the edge of the asphalt.

The frame structure was crushed all the way down to the front axle. The front axle had shifted rearwards and turned in such a way that the left front wheel was further back than the right wheel. The frame beams behind the front axle were badly damaged. The worst damage extended to the back wall of the front luggage compartment. The left front tyre deflated in the collision. The front floor was crushed for about a five metres' distance. The right hand side front wall had bulged outward all the way to the cabin compartment's middle door. The left side had completely split open for a distance of about five metres. Measuring from the frame beams the impact shortened the coach by 2.1 m on the left and 1.9 m on the right. Furthermore, on the left hand sidewall of the cabin compartment in front of the rear wheel there was an arched impact mark ca. 1.2 m long and 0.4 m high. The chassis was bent inwards and the outer side panel of the coach was torn at this spot.

Figure 8. The coach from the front.

The paper reels pushed a large portion of the trailer's front wall down to 1.5 m from the coach's toilet inside the cabin compartment. The toilet was on the right side in the middle of the cabin. Five paper reels had penetrated the coach. From the middle door on the coach's cabin compartment retained its original form. There were several seats on the ground between the coach and the trailer. At least some of the seats had been thrown outside during the rescue effort. The back row seats and one pair of seats in front of them on the left as well as three pairs of seats on the right remained in place. All other seats had come loose.

1.11 Breathalyser test, forensic toxicology investigations and the coroner's inquest

A breathalyser test was performed on the coach driver, showing zero blood alcohol. Both the tractor-trailer driver's and the coach driver's blood were analysed for alcohol and for medicinal substances. The samples contained neither alcohol nor medicinal substances. Autopsy was performed on everyone who perished in the accident.

1.12 Fire

There was no fire.

1.13 Survival aspects

The driver of the coach as well as 22 passengers died as a result of their injuries. Of the 14 surviving passengers, all received various degrees of injuries. The penetration of the trailer's front wall and paper reels into the cabin compartment increased the number of casualties and exacerbated the severity of the injuries. The toilet in the middle of the cabin compartment stopped the progress of the trailer's front wall and prevented the paper reels from advancing into the rear of the cabin. The passengers also sustained injuries from having been thrust into the cabin's inner structures as well as from the high forces of deceleration (g forces) that prevailed during the collision. Every seat in the coach had a seat belt but no one used them.

The driver of the full trailer combination wore his seat belt and, hence, sustained no physical injuries in the accident.

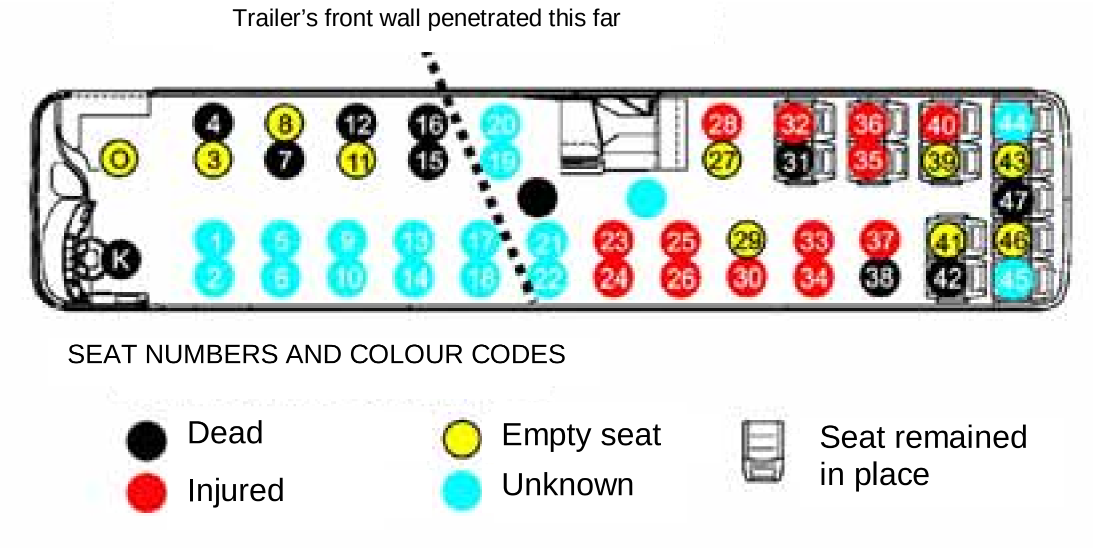

Figure 9. The position of passengers inside the coach at the time of impact.

1.14 Action taken by the authorities and rescue activities

1.14.1 Operation of the emergency response centre at the time of the alert

(Abridged from the original Finnish text)

The mission of the emergency response centre (ERC) is to receive emergency calls and to forward them to rescue, ambulance and police units.

Police, rescue and ambulance transport authorities have issued operational guidelines to the ERC. Regional alarm procedures, i.e. response plans, have been drafted for the ERC areas in preparation for different types of accidents. The ERC operator must establish the nature of the emergency and its location and then dispatch the rescue units as per the appropriate response plan within 90 seconds of the beginning of the emergency call. In addition to the response plans, the ERC must abide by the requests and orders of the rescue authorities while they are performing their tasks.

On the night of the accident, there were three ERC operators as well as a shift commander on duty at the ERC of Central Finland (Keski-Suomen hätäkeskus, henceforth KEHÄ). The shift commander and one of the ERC operators were trained police officers and the rest of the operators were ERC operator-certified.

The driver of the vehicle combination involved in the accident called KEHÄ at 02:08:46 and reported that a coach had collided into the fishtailing trailer of his vehicle combination. The paper reels in his cargo had penetrated the coach. The caller believed that at least the driver of the coach had died in the accident.

At 02:10:50, the KEHÄ operator concluded that the accident was of the type: “Traffic accident, major” in accordance with the Konginkangas area response plan and dispatched the required four rescue units as well as four ambulance units. They were alerted 2 min

4 s after the accident. Three of the dispatched rescue units came from Konginkangas and one from Äänekoski. Three ambulance units came from Äänekoski and one from Viitasaari. The units were told that the accident involved a collision between a “heavy vehicle combination” and a coach.

At 02:11:50 a driver of another heavy vehicle combination, having arrived at the accident site from the direction of Jyväskylä, was the second one to place an emergency call to KEHÄ about the accident. From his call it became evident that there were approximately forty passengers on the coach and that only the rear portion of the coach remained intact. KEHÄ advised the caller to organize the directing and warning of traffic to prevent additional accidents until the authorities arrived and took over.

After this, on the order of a fire chief participating in the rescue operation and in addition to the response plan, KEHÄ dispatched seven more ambulance units and seven rescue units. The last units were alerted more than thirty minutes after the accident. KEHÄ also attempted to dispatch rescue helicopters from Oulu and Varkaus but due to poor flying weather and lack of crew, they were not available.

KEHÄ also notified the police, the Central Finland central hospital, Äänekoski health centre as well as certain other authorities of the accident and relayed messages between different actors during the rescue operation.

1.14.2 Rescue activities at the accident site

(Abridged from the original Finnish text)

Clearance

Passers-by, requested by KEHÄ, took care of warning and directing traffic at the site until the rescue and police authorities arrived.

The fire chief representing the Äänekoski rescue unit, who was the first to arrive at the scene at 02:21:45, assumed command over rescue and clearance activities.

Prior to the arrival of the fire fighters two coach passengers had exited the coach on their own.

Upon arriving at the scene of the accident, the fire fighters set up general lighting and initiated the vehicle extrication to rescue the victims. As the clearance operation proceeded, fire fighters carried passengers out of the coach as soon as they managed to extract them. There were no self-ambulatory passengers left on the coach when the clearance operation began. Due to the force of impact, passengers had been thrown against the seats in front of them. At this point, the structural integrity of the seats was compromised so that they partially came loose and the seat backs bent forward, pinning the passengers in their seats. The extrication of trapped passengers had to be started from the back of the coach. Clearance entailed first detaching the seat and then extracting the trapped passenger. Only after this was done, could the following seat and its occupant be freed.

The front wall of the trailer as well as five paper reels had pushed into the front part of the cabin of the coach. Eight persons were buried under them. It was impossible to move the paper reels by manpower alone. These were removed with the help of a hydraulic crane once the other casualties had been extricated from the coach.

1.14.3 Medical rescue activities

(Abridged from the original Finnish text)

General features of emergency medical services and the ambulance transport

A fire foreman from Äänekoski rescue department rode in the first care-level[3] ambulance arriving at the scene. He was also a certified practical nurse and he assumed responsibility over medical care at 02:21:40 while enroute to the accident site. He also designated himself as the on-scene medical commander. He arrived at the site within about 20 minutes of the time of the accident.

The on-scene medical commander, using the public authority network VIRVE, ordered all dispatched ambulance units to report to him. All in all 11 ambulances arrived at the site. Three of these were care-level ambulances and the rest of them (eight) were basic-level ambulances. The on-scene medical commander instructed each ambulance to transport only one seriously injured patient in addition to one less seriously injured patient. Two ambulance units disregarded the instruction and acted arbitrarily by simultaneously transporting three severely injured patients.

The first ambulance arrived at 02:29:07 and the last one at 03:25:07. Transportation of the first three patients to the hospital got underway at 03:17:02. Each ambulance remained approximately thirty minutes at the site before being able to transport casualties. The hold-up was often caused by the fact that it was an extremely slow process to extricate casualties from the coach.

An initial assessment protocol was prepared for each patient at the site of the accident. Most of the protocols were inadequate in detail as regards the patients' medical assessments and describing the medical care provided. The on-scene medical commander had to prioritise the transportation of casualties because he estimated that he had more victims requiring transport than ambulances. No on-scene treatment facility was established. This was because victim extrication proceeded so slowly that every patient requiring urgent care could promptly be placed in an ambulance. The drive to the central hospital took about 45 minutes.

Thirteen patients were transported to the Central Finland central hospital. One patient got into a car and went to the Äänekoski health centre, from where she came by taxi to the central hospital at 06:40.

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[3] An ambulance staffed and equipped to provide emergency medical services (i.e. an EMS ambulance)

After about 30 minutes from the time of the accident Äänekoski health centre dispatched its response team to the scene, comprising one doctor and two nurses. The team arrived approximately one hour after the accident, transported by a personnel transport vehicle from Äänekoski rescue department.

The central hospital dispatched a medical team 55 minutes after the accident happened, transported by one of Jyväskylä rescue department's vehicles. An EMS doctor was a member of the team and he met up with two ambulances coming from the accident site at a pre-agreed location enroute to the hospital. The ambulances were transporting two severely injured patients and the doctor administered emergency care to the patients. One of the ambulance units never got word of the possibility of receiving physician services enroute, even though their patient was in serious condition. The medical team arrived at the site approximately two hours after the accident. By that time, all of the patients had already been taken to the hospital.

The first patients arrived at the hospital approximately two hours after the accident and the last one ca. 2.5 hours after the accident.

The level of ambulance units

The level of an ambulance unit is determined by the training level of its personnel and equipment. Pursuant to section 3 of the Ambulance Service Decree, basic-level ambulance transport represents the kind of care and transportation during which the patient can be monitored and cared for in such a manner that while being transported, his condition will not unexpectedly worsen and when required, simple life-saving treatment can be initiated. Section 4 of the same Decree lays down that care-level ambulance transportation must provide the capacity to initiate intensive care treatment and that the patient must be able to be transported in such a manner that his vital bodily functions can be secured.

One of the Äänekoski ambulance units was a care-level unit and the other three units had ambulance drivers capable of administering medical care. The rest of the dispatched units were basic-level ambulances.

1.14.4 Rescue service communications

(Abridged from the original Finnish text)

The public authority network (Viranomaisradioverkko, VIRVE) is a digital nationwide authority network, based on terrestrial trunked radio technology. State and municipal authorities are the users of the network. The network enables the programming of wireless network call groups to the data terminal equipment of different authorities.

KEHÄ dispatched all units through VIRVE. Rescue units were dispatched by using their regional PELANTO call group. Ambulances were dispatched by using each region's own SAKU ANTO call group.

The on-scene medical commander directed all ambulances to change over to the call group ÄÄNEKOSKI. All radio traffic relating to medical care and ambulance transport was conducted in this call group.

VIRVE communications worked well in tasking and in the phase when rescue and ambulance units were on their way to the site of the accident. When several units using VIRVE had arrived at the site, radio traffic got jammed in the ÄÄNEKOSKI call group. For example, it was difficult for the fire chief, who was the first to arrive at the scene and subsequently assumed rescue command, to get through. Similarly, it was difficult for the rescue foreman on his way to the site from Viitasaari to make radio contact with the Äänekoski fire chief on duty. The on-scene medical commander could not make radio contact with the central hospital’s medical team in the INFO call group. Neither could the medical team get through to the accident site.

The central hospital’s medical team was not equipped with its own VIRVE mobile terminal. KEHÄ assigned two call groups to the unit transporting the central hospital’s medical team. The call groups were KS SAKU INFO (ambulance) and KS PEL INFO (rescue). The medical team did not have access to the ÄÄNEKOSKI call group which was used at the accident site and this is why the team could not communicate at all with the accident site while enroute. Despite valiant effort, the Jyväskylä rescue department vehicle personnel, transporting the medical team, did not succeed in making radio contacts to the call group KS SAKU INFO either.

Neither Äänekoski health centre nor its response team had VIRVE data terminals.

1.14.5 Operation of medical establishments

(Abridged from the original Finnish text)

Central Finland central hospital

During on-call hours 9-10 physicians representing different fields, 8-9 nurses and a ward secretary normally man the Emergency Room.

KEHÄ alerted the central hospital’s on-call surgeon at 02:20:20. The surgeon called the hospital’s medical director who immediately sounded the maximum possible major accident alarm, i.e. the full alarm. An emergency operations centre was established at the hospital, from where the hospital staff was alerted. All in all 214 personnel participated in emergency operations, 199 of whom were called in from home. Of the alerted, 20 were doctors and 114 nurses. It took approximately 25 minutes for them to arrive at the hospital and they remained on duty for 8 hours on average.

Activities commenced in accordance with the contingency major accident plan. The observation ward, the intensive care unit, the operating theatre’s recovery room and the ER were cleared of patients. They were transferred to other wards. The central hospital alerted the Jyväskylä health centre hospital to operational preparedness to get ready for possible patient transfers. Three summoned security guards secured the on-call area from trespassers.

The central hospital's medical care teams were established in line with the major accident plan. Each team comprised one or two doctors, two nurses, one auxiliary nurse and an orderly. Prior to the arrival of the patients ten surgical teams were established, each of which was led by a trauma surgeon. The operating theatres, too, were ready in time to receive the patients. The first patient arrived in the hospital at 04:07 and the following 12 patients arrived within 42 minutes thereafter. The medical director assigned the teams for each patient. The patient who had gone to the Äänekoski health centre on her own initiative arrived in the central hospital by taxi at around 07:15.

The major accident alarm was called off at 09:30 on 19.3.2004.

Establishing the medical team and its activity

As per the major accident plan, the central hospital must prepare to dispatch a medical team to the accident site in executive assistance. The medical team comprises one on-call doctor and two on duty nurses. Since the rescue authorities were not aware of the existence of such a team, they did not request one to the site. The hospital decided to dispatch the team to the accident site on its own initiative.

Public information at the hospital

A communications centre, led by the chief medical director, was established alongside the hospital switchboard. Not many phone calls were placed in the initial phase. All in all the hospital switchboard did not really receive any more calls than on the same weekday seven days before. The health care district promptly published a bulletin in Finnish and in English on its website. The bulletin was updated twice a day. The web pages received a total of 48 910 hits. The hospital arranged the first briefing on 19.3.2004 at 04:30. Nobody came to this event. The following briefings were held at 06:00, 12:00 and at 15:00. A press conference, organized jointly by the police and the health care district, was held on 21.3.2004 at 15:00.

Three phone numbers were set up for family member enquiries. They received altogether 370 phone calls. Some of the phone calls were referred to crisis centres at the callers' domiciles and some to Jyväskylä Mobile, which is an entity providing crisis support.

Äänekoski health centre

There is no night time on-call system at Äänekoski health centre. Requested by rescue authorities, KEHÄ alerted the health centre at 02:35:40 and activities commenced as per their preparedness plan. All in all six doctors, 15 nurses, 10 auxiliary nurses, four ward assistants and one nurse's assistant came to work at the health centre.

One patient was brought to the health centre from the site of the accident by private car at around 02:40. She was examined at the health centre and later on transferred to the central hospital at 06:40.

Pursuant to health centre regulations a first aid team led by a doctor is to be furnished for dispatching to an accident site by taxi. At 02:50:27, KEHÄ requested a team to go to the site as soon as possible. A senior physician and two on-call nurses formed the health centre's first aid team, which Äänekoski rescue department picked up on its way to the scene of the accident. When the first aid team arrived, only one patient was left at the site.

Jyväskylä health centre

After having received the accident alarm from the central hospital, Jyväskylä Health Centre alerted the chief resident, the assistant chief resident and his deputy. The health centre prepared to take patients from the central hospital in order to make more room at the hospital for casualties. However, in the end there was no need for patient transfers.

Voluntary Rescue Service

At 02:42, KEHÄ alerted the Voluntary Rescue Service, the VAPEPA, whose duty officer dispatched the VAPEPA's first aid teams in Äänekoski, Suolahti, Jyväskylä, Laukaa and Konnevesi.

The first VAPEPA chief arrived at the accident site at 03:20. He was informed that there was no more need for additional medical assistance and that the first aid teams could return to base. The teams continued on to the central hospital to assist there.

Jyväskylä Mobile

Jyväskylä Mobile is an organization dealing in social services. It was alerted through the Finnish Red Cross (FRC) at 04:23. Eleven Mobile staff arrived at the hospital and they provided support to the victims' family members as well as to one person involved in the accident. Mobile acted in accordance with the central hospital major accident plan. After 06:00, Mobile staff left the hospital.

1.14.6 Police activities

(Abridged from the original Finnish text)

On the night of the accident, seven police patrols were on duty around the province of Central Finland. Three of these were in the state local district of Jyväskylä. The Jämsä, Keuruu, Saarijärvi and Äänekoski state local districts had one patrol each on duty.

The Äänekoski state local district police patrol received an accident alarm from KEHÄ at 02:15. The patrol immediately took off from the Viitasaari police department for the accident site, approximately 33 km away. One of the police officers in the patrol was the state local district's police team leader.

While the patrol was enroute, KEHÄ informed them that the situation at the accident site was serious and that the likelihood for additional collisions was high. The team leader then immediately called in two off-duty police officers from the Äänekoski police department to the accident site. Furthermore, he requested KEHÄ to dispatch one additional on-duty patrol to the site. KEHÄ assigned the task to the Saarijärvi state local district police patrol, which departed Saarijärvi for the accident site, which was ca. 55 kilometres away.

The Äänekoski state local district police patrol arrived at the accident site at 02:39. At that time, two ambulances and rescue units had already arrived. The team leader designated the VIRVE police channels. The police and the rescue authorities communicated verbally with each other at the accident site.

After having assessed the situation and having determined the accident to be a major accident, the team leader called in additional police officers from the Äänekoski police department. One of the very first things he did was to organize a detour around the incident. He also directed KEHÄ to issue a traffic bulletin as well as to alert the road and cross-country traffic accident investigation commission.

For approximately 14 hours, 25 police officers worked at the accident site on different duties. Six police officers and two guards worked at the Äänekoski police department. The Jyväskylä police department had about ten police officers working in various tasks related to the incident.

The Äänekoski state local district police department conducted the preliminary accident investigation, receiving executive assistance from several other police departments in Finland.

1.15 Detailed inspections

1.15.1 Technical inspection of the vehicle combination

The road tractor

A test run for measuring the brake force and the fitting of the brakes was made on 24.3.2004. According to the results, the brakes were in proper working condition. Based on the investigation and test runs the vehicle’s steering controls were in working order and no excessive play was detected in the axles.

The first and second axle tyre dimensions were 315/80R22.5 with a load index of 156. The third axle tyre dimension was 385/65R22.5 with a load index of 160. The second axle had twin wheels. The tyres conformed to the registration. The tyres on the first and third axle were summer (tread) tyres. The second axle had retreaded block pattern profile tyres. Tread depths varied between 8-14 mm and the tyres were evenly worn. The outermost left tyre on the second axle was inflated to 6.2 bar. The other tyres varied between 7.1-8.4 bar. The rated tyre pressure for the ones in question is 8.5 bar. Apart from the tyre pressures, the tyres and tyre combinations conformed to regulations and directives.

The trailer

The trailer was no longer street legal after the accident. All of the trailer's brake drums were removed for inspection. The condition of the brake linings, brake drums and wheel bearings was inspected. In addition, the brake shoe expander camshaft, s-cams and roller followers were inspected. They conformed to specifications. The range and freedom of brake lever movement on every wheel was inspected. Some extended lever ranges were detected but the brakes were found to be in working order. The automatic regulating lever on the rear axle's right brake was loose. The brake on that wheel did not properly self-adjust and the brake lining was far from the surface of the drum lining. Furthermore, it was uncertain whether that regulating lever ever returned to its original position because it snagged with the frame side lever holder. The two rear axles were tested on a brake dynamometer and, even in spite of the abovementioned deficiencies, the brakes were found to be working properly.

The brake force on the third axle measured 14.5 kN on the left and 14.0 kN on the right. Correspondingly, the brake force on the fourth axle was 11.0 kN on the left and 16.0 kN on the right. The fourth axle brake force variance exceeded the 30% vehicle inspection norm variance by one percentage point. In the periodic vehicle inspection on 5.12.2003, the brakes were working properly.

Since support struts broke in the collision, the forward front bogie axle was detached. The rear axle on the bogie turned to the right after the left support strut bracket broke loose from the frame of the bogie. The left rebound limiter wire snapped. The entire bogie frame was bent on the right hand side in such a manner that the centre of the bogie was 50 mm lower compared to the front and the rear of the frame.

The rear bogie's front axle rebound limiter wires were partially cut. Judging by paint and appearance, the left support beam on the rear axle had recently been replaced, same as the left air spring bellow. The colour of the right side shock absorber also differed from the others.

All shock absorbers were removed and they were inspected in a Suomen Vaimennin Oy test device. All four shock absorbers on the front bogie were damaged in the collision. Based on the inspection and the test run it was thought that the front bogie shock absorbers were working properly prior to the accident. The rear bogie's front axle shock absorbers were in proper condition. The rear axle's left shock absorber was damaged - probably in the collision. The right shock absorber was of the wrong type; it was too short and too weak.

The fifth wheel was disconnected and dismantled. The parts were delivered to the importer (H.Kraatz Oy), who in turn forwarded them to the manufacturer (BPW Bergische Achsen) in Germany for inspection. Due to deformation, the fifth wheel could not be exactly gauged. However, since the wear ring grooves were not excessively worn, the manufacturer inferred that the axial and radial clearances on the fifth wheel conformed to the manufacturer's standards. Based on wear groove profiles the manufacturer deduced that the fifth wheel was functioning properly at the time of the accident.

The dimension of all of the tyres was 275/70R22.5 and their load index was sufficient (148). All axles were fitted with twin wheels. The tyres conformed to the registration. In addition to the block pattern profile tyres, axles one and three had summer tread tyres on the right hand side. The tyres on axle number two were not retreaded, whereas all other tyres had been retreaded. The right hand side tyres on the first axle were the most worn and their tread depths varied between 4-8 mm measured from edge to edge. The tread depths of the other tyres varied between 9-15 mm and they were evenly worn. Every tyre on the left hand side of the front bogie had deflated in the collision. The other tyres were inflated at 5.7-8.2 bar. The rated pressure for the tyres in question is 8.0 bar. Apart from the tyre pressures, the tyres and tyre combinations conformed to regulations and directives. A separate annex details the tyre combination.

For the most part the front wall of the body was detached, pressed by the paper reels, and was thrust into the cabin compartment of the coach. The marks left by the windscreen wipers and the holes left by their axles were still visible on the outside surface of the front wall. The front wall was bent by the paper reels.

The outer edge lights (5W) on the upper corners of the body front wall remained intact. Their filaments were stretched and distorted, from which it can be concluded that the filaments were hot at the time of the impact, i.e. the lamps were on. The lower corner perimeter lights were destroyed but when tested, the electric connection worked all the way to the bulb housing.

1.15.2 Examination of the trailer's body

Oy Närko Ab manufactured the trailer frame and body involved in the accident. The body was separately built and subsequently attached to the trailer frame. The body was of the enclosed box van type. In addition to the back doors, there were five opening door panels at the front on the left side. The sidewalls and the roof were constructed out of aluminium beam-reinforced polystyrene sheets, sandwiched in thin fibreglass sheets. The thickness of the sidewall structure was 45 mm and it was fastened to the body floor by aluminium beam. The doors had sliding hinges.

The front wall was 80 mm thick and, in addition to polystyrene, the structure contained a 15 mm thick plywood sheet. The wall was sandwiched in fibreglass. The front wall was fastened to the floor and to the sidewalls with aluminium and steel beams. Furthermore, adhesive, rivets and screws were used. The roof and the back door frames were likewise fastened to the frame.

Apart from its top section, the front wall of the trailer detached in the accident. The aluminium and steel beams that joined the front and side walls ripped away from the walls. The aluminium beam joining the front wall and the floor was torn loose. The right hand sidewall was damaged for about a 2 metres' distance. Of the five door panels on the left hand side the first two detached and the remaining three opened.

There were anchoring points spaced at every 120 cm on the body floor. The anchoring points were rated at 20 kN. There were two longitudinally positioned slotted load anchoring rails on the walls at the heights of 90 cm and 180 cm, respectively. Furthermore, there were five vertical beams for anchoring perpendicular barriers in the rear half of the body.

1.15.3 Technical inspection of the coach

When the coach's brakes were inspected, brake lining thicknesses were determined through the inspection windows. The thickness varied between 6-7 mm. Furthermore, it was noted that all brake shoes remained close to the drum linings. Brake linkage movement was within the normal range.

The steering controls and the front axle were partially destroyed in the impact. Parts were scattered around and were visually inspected. The investigation did not uncover any steering malfunctions preceding the accident.

The dimension of the tyres on all of the axles was 315/80R22.5, with the load index of 156. The tyres conformed to the registration. The front tyres were new summer tyres. The rear tyres were recently retreaded block pattern profile tyres. Tread depths averaged at around 15 mm. The left front tyre had deflated in the collision. The outermost left rear tyre was inflated at 5.4 bar and the other tyre pressures varied between 6.5-7.6 bar. The rated tyre pressure for the tyres in question is 8.5 bar. Apart from the tyre pressures, the tyres conformed to regulations and directives.

Inspection of the cabin compartment and the seats

The impact compressed the coach by approximately two metres. In addition, the cabin floor was crushed for a distance of about five metres. The right hand side wall was buckled outwards from the front all the way back to the cabin compartment's middle door. Four out of six windows on the right hand side were broken. The left side was completely split open for about five metres and only the rear left window was left unbroken. The cabin compartment was intact from the middle door on. Also the toilet, which was right in front of the middle door, remained more or less intact.

All five back row seats remained in place. The three pairs of seats farthest back on the right side of the cabin compartment and the pair of seats farthest back on the left were in place. All of the other 17 pairs of seats, as well as the driver's and the tour guide's seat, had come loose. The seats at the front on the right hand side were detached and pushed back by the paper reels all the way to the middle of the cabin. All other detached seats had been thrown out of the coach during the rescue effort.

The inspection of the seats revealed that approximately down to the middle door the seats on the left hand side had sustained heavy damage and that the paper reels had caused most of the damage. From the middle door onwards, the seats were mainly damaged by inertia forces caused by passengers being thrown against the seats from behind.

All of the seats had seat belts but there was no evidence of them having been worn at the time of the accident.

According to rescue personnel, many seats remained in place, albeit partially bent over. The aisle side brackets of these seat legs had torn apart but the window side brackets remained intact. The aisle side fastenings had broken in three different ways. Six pairs of seat legs detached when their fastening panel welding disintegrated. The panel, however, remained fastened to a floor beam. The aisle side floor panel bolts of five seats pulled through the fastening beam. The third way seats came loose was when the fastening beam tore loose from the floor structure. Seats that had detached this way were mainly found in the front of the vehicle where the floor itself was demolished. The wall anchorage withstood the accident quite well. Only after the wall itself disintegrated did the wall anchorage give way.

The coach chassis manufacturer built the seats. They had been previously tested and certified for anchorage strength and seat structure flexibility. VTT Automation (Technical Research Centre of Finland) ran the tests and the Finnish Vehicle Administration certified the results. The test results were in compliance with ECE regulation 80-01 as well as with relevant EU Directives. As the vehicles were being exported, however, some countries did not accept the aforementioned approvals. Hence, the tests were rerun by VTT under the supervision of the British VCA (Vehicle Certification Agency). Based on these test results, the seats were certified to comply with ECE regulation 80R as well as with EU Directive 74/408.

One of the tests entailed the inspection of the seat anchorage strength and of the two-point seat belt (ECE regulation 14-04, section 6.4.3 ”Test in configuration of a lap belt”). The test requires that seat belt brackets must withstand the tractive force of 2 130 daN when the weight of the seat is calculated at 6.6 x 50 kg. During the test every seat belt bracket is simultaneously subjected to a tractive force of 2 170 daN. The seat belt and seat leg anchorages held but the join between the seat frame and the leg’s upper part bent.

1.15.4 Examination of tachograph discs

Both of the vehicles’ tachograph discs were first visually inspected and subsequently examined by microscope at the National Bureau of Investigation forensic laboratory and at the VTT Building Technology laboratory. Both tachographs were correctly calibrated and had accurately recorded the driving speeds. The following times of day represent tachograph clock times.

The investigation commission requested a statement on the vehicles’ event history preceding the accident as well as driving speeds used both before and at the time of the accident.

The tractor’s tachograph was a BLU-8-125 DUAL. The name of the driver, the route designator “Helsinki”, the date 18.3.2004, the odometer reading 179 555 and the licence plate number REY-481 were written on the face of the disc.

Figure 10. The tractor’s tachograph disc.

Figure 11. The coach’s tachograph disc.

The coach’s tachograph was a BLU-8-125 DUAL. The name of the driver, the route designator “Vantaa”, the date 18.3.2004, the odometer reading 152 972 and the licence plate number IUF-867 were written on the face of the disc.

Legs preceding the accident which were recorded on the vehicles’ tachograph discs

The vehicle combination

Time	**Event**
19:33	Disc insertion
19:34–20:33	Several short legs (0.1–1.1 km)
20:33	Start
22:45	Stop
22:53	Start
01:20	Stop
01:20–01:37	Two short legs
01:37	Start
02:08	Collision

The coach

Time	**Event**
20:19	Disc insertion and start

20:31	Stop
20:35	Start
20:44	Stop
20:53	Start
22:48	Stop
23:03	Start
01:02	Stop
01:42	Start
02:05	Collision

During the final minutes preceding the collision the full trailer combination was mostly travelling at 80-90 km/h. Approximately four minutes before impact the speed peaked at 94 km/h. A little less than two minutes before impact the speed was 65 km/h at the slowest. The speed of the full trailer combination reached 91 km/h 350 m before impact. During the following 8-10 seconds, its speed decreased to 65-70 km/h. During the final 10 seconds before impact and for the distance of 170 m, the tachograph recorded a see-saw graph between 60-70 km/h, which is typical when ABS brakes are powerfully applied. After this, speed seems to have stabilized at 60-70 km/h. The tachograph recorded the speed at impact at 61 km/h. However, due to the ABS brake-generated speed indication error the actual speed was probably around 70 km/h.

The coach’s speed during the final minutes before the collision was mostly 90-100 km/h. At approximately 4.5 minutes before impact, the speed peaked at 113 km/h. During the final seconds before impact, the coach’s brakes were heavily applied. According to the tachograph, the braking had slowed the vehicle from 90 km/h to 60 km/h. However, due to the ABS brake-generated speed indication error the actual speed was around 70 km/h.

VTT’s report on the tachograph discs notes that maximum and minimum speeds as well as nearly constant speeds can be very accurately deciphered and in these instances, the graph error is ±1 km/h at the most. When the vehicle accelerates or decelerates the resultant speed and time graphs on the disc are almost vertical and this makes deciphering more complicated. When the width of the graph trace corresponds to 15 s and the trace edges as well as the disc surface appear rough on the microscope, it is generally impossible to achieve great accuracy when the forces of deceleration are decoded after hard braking. Because of this, an error can amount to several seconds, and a few seconds’ worth of error in reading accuracy can result in even a 100% error on deceleration, calculated on the basis of time and speed data.

1.15.5 Drivers’ working hours, driving and rest periods

Regulations concerning drivers’ working hours and periods of rest are uniform within the European Union and in the European Economic Area. They are defined in the Council Regulation (EEC) No 3820/85 of 20.12.1985 on the harmonization of certain social legislation relating to road transport. Provisions have been issued in the Road Traffic Act (267/1981) regarding its entry into force in Finland. Furthermore, drivers’ working hours are regulated by collective agreements signed by employers' organizations and trade unions as well as by the Working Hours Act (605/1996).

The authorities conduct roadside checks and monitor working and driving hours by inspecting tachograph discs.

When transport companies are inspected, control also extends to the information in the company's duty roster. The daily driving time is not to exceed nine hours. It may be extended twice in any one week to 10 hours. Driving time constitutes all the time, which is devoted to road transport activities, including stops caused by other traffic. Regardless of whether they occur on the road or elsewhere, breaks and rest periods, loading and unloading, repair and scheduled maintenance do not make up driving time.

The total driving hours within two weeks is not to exceed ninety hours. Hence, driving time is only regulated in cycles of 24 hours and two weeks.

This inquiry analysed the following:

- Information on the tachographs and the duty roster related to the driver of the full trailer combination involved in the accident
- Information on Transpoint Oy Ab drivers' tachographs on the Rovaniemi–Viitasaari–Rovaniemi section related to the haulier's Helsinki–Rovaniemi–Helsinki trunk route
- Information on the tachographs and the duty roster related to the driver of the coach involved in the accident
- Information on Sunny Buses Ltd drivers' tachographs on Helsinki-northern Finland-Helsinki chartered round trips.

The driver of the full trailer combination

The lorry driver's tachograph was inspected for the week of the accident and for the last working day of the week preceding the accident. The data revealed that regulations governing driving and working hours and rest periods were not, in all parts, followed to the letter. However, the duty roster showed that the driver had taken his daily and weekly rests.

The driving shift on the night of the accident was the driver's fourth consecutive night shift. According to the driver, prior to his shift on the night of the accident he had slept between ca. 08:30-13:30. He had also had a regular meal at home at around 17:00.

Driving hour and rest period data of the night of the accident:

Breaks had been shorter than prescribed. After driving for 4.5 hours, the 45 minute break had not been taken, nor was this break taken in 15 minute segments during the drive. The driver had taken an eight minute break from 22:45-22:53. By the time of the accident, the aggregated driving time was 5 h 10 min.

The driver had started working at the terminal at around 19:30 and, hence, he had logged 6 h 38 min of continuous working time by the time of the accident. The time exceeded the maximum uninterrupted working time of 5.5 hours as specified in the collective agreement.

Helsinki-Viitasaari-Helsinki leg tachograph disc inspection from March 2004

The Uusimaa District Administration for Occupational Safety and Health inspected several drivers' tachograph discs from March 2004 to establish how Transpoint Oy Ab was following working hour regulations on the route in question. Altogether 16 discs were inspected. The average distance covered during a driver's shift on this leg was approximately 750 km.

Tachograph disc inspection revealed that:

- Six discs exposed driving times exceeding 10 hours. The maximum permissible daily driving time is 10 hours.
- Six discs revealed that an uninterrupted 45 minute break or a 45 minute break taken in segments lasting at least 15 minutes each, as required for each 4.5 hours' driving time, had not been taken at all. Ten discs showed that the break had not completely been taken.
- Judging by the tachograph discs, the drivers would for the most part drive as fast as the speed limiter would allow (90 km/h) and even faster on downhill sections.

Driving hour and rest period information on the Rovaniemi-Viitasaari-Rovaniemi leg on 8.-11.3. and 18.-19.3.2004

The inspection of four working days discs of the driver of the northern leg revealed that:

- The average daily driving distance was 925 km
- The maximum daily driving time was exceeded by 1-2.5 hours
- The tachograph's mode switch had not been used according to instructions
- Other work, such as paper reel loading at the paper mill as well as swap body and trailer exchanging at Viitasaari, had been done during times which were designated as breaks
- Judging by the tachograph discs, the drivers would mostly drive as fast as the speed limiter would allow and on downhill sections, even faster than the limited speed
- The average speed on the leg was 82-85 km/h.

The coach driver

The investigation of the week of and the week preceding the accident revealed that the coach driver had followed the regulations governing driving and working hours and rest periods. According to his family members, he slept during the day and had a meal at around 16:00 prior to leaving home for his shift.

The driver had not always used the tachograph's mode switch. Some of the breaks were only recorded in the driving log.

In addition, the tachograph discs show the following:

- Apart from the day of the accident, the daily driving distances had been short and the average speeds low
- On the day of the accident, the average speed was approximately 87 km/h. On the motorway section, the driver had driven at the speed limiter maximum at around 104 km/h. On the Tampere-Jyväskylä section the speed varied between 80-100 km/h
- At the time of the accident, the driver had covered the distance of 406 km and had aggregated 5 h 46 min working hours, of which 4 h 38 min were driving time. He had taken his first break, lasting 40 min, at Äänekoski. During the break three additional passengers got onboard
- The distance from the site of the accident to the destination at Ruka was ca. 505 km. At an average speed of 80 km/h, this distance would have been covered in about 6 h 20 min.

Long-distance chartered coach traffic

The investigation commission examined how the regulations on driving and working hours and rest periods are adhered to in long-distance chartered coach traffic.

The following approaches in the chartered traffic between southern and northern Finland were found in the material provided by Sunny Buses Ltd:

- The driver picks up the passengers and drives north. Kuusamo (about 910 km) and Rovaniemi (about 840 km) were used as examples
- The driver picks up the passengers and drives to Oulu (about 610 km), from where another driver continues to the north
- When going, for instance, to Ylläs (about 970 km), there are two chauffeurs taking turns driving.

1.15.6 Test runs and simulations

Test runs

The investigation commission organized re-enactive test runs on 11-12.12.2004 at Konginkangas and at Jyväskylä airport. The vehicle combination consisted of the tractor involved in the accident and a trailer similar to the one in the collision. The load comprised 33 600 kg of paper reels, i.e. nearly the same amount as in the original full trailer combination in the accident.

Sensors in the tractor and in the trailer measured roll, roll rate, yaw rate and lateral acceleration. Furthermore, the tractor’s track rod was fitted with a steering angle sensor and the trailer had a sensor measuring the front bogie angle. The drawbar had sensors measuring the force of traction, compression and the drawbar angle.

Test run data were used to calibrate and verify the accuracy of the simulated computer models and the simulations.

The first day's runs involved the section of the road where the driver lost control of his vehicle. The purpose of this test was to establish the road geometry-generated impulses to the vehicle combination as well as forces on the drawbar between the tractor and the trailer. The runs were repeated several times using different speeds, manners of driving and driving lines. The test runs were conducted using both rated tyre pressures as well as those measured on the vehicle combination after the accident.

The second day test runs were driven on a taxiway at Jyväskylä airport. The main purpose of these tests was to measure the tractor-trailer's road stability. The test was done on a slalom track where the vehicle was subject to lateral acceleration forces. The test runs were conducted using both rated tyre pressures as well as those measured on the vehicle combination at the time of the accident.

Simulations

Answers to questions related to the vehicle combination's road stability were sought by conducting computer simulations. While approximate answers were found to some of the questions on how different factors affected the behaviour of the full trailer combination, other questions remained unanswered.

The simulation study sought answers to the following questions:

1. *What was the direct cause of the trailer's fishtailing?*
   The simulation proved that loss of control was not inevitable on the section of the road in very slippery conditions even at the speeds which were analysed from the tachograph discs. The simulation also proved that a slight extra driving line deviation from the normal curve radius pushes the friction demand of the tyres on the tractor's drive axle and on the trailer to the critical level.
2. *What factors prevented the driver from halting the fishtailing?*
   The investigation revealed that it takes correct and correctly timed control input to regain control of a fishtailing trailer. No unambiguous answers were found as to what the correct control inputs would have been and to their correct timing.
3. *How was the onset of the accident affected by:*
   a) the excessive load?
   The investigation revealed that the excessive load weakened the vehicle combination's stability and, thus, possibly contributed to loss of control (see: subpara 2.1 Analysis).
   b) the driving speed?
   The simulation proved that by reducing driving speed by e.g. 10 km/h from that which was recorded on the tachograph, one could significantly diminish the friction demand to maintain control of the tractor-trailer. A lower speed would even allow for an extra driving line change without resulting in loss of control (see: subpara 2.1 Analysis).
4. *Was there a causal link between the low tyre pressures and the accident?*
   The investigation proved that lower-than-rated tyre pressures reduce tyre wall and tread profile rigidity. However, the test results do not justify stating that lower tyre

pressures would have had a significant detrimental effect to the road stability of the full trailer combination.

5. *Was there a factor in the camber of the road or in some other characteristic inherent to the road that:*
   a) contributed to the loss of control?
   The investigation found two spots on the road profile that clearly jolted the tractor-trailer towards the outside curve (see: figures 19 and 20).
   b) *prevented the driver from regaining control of the full trailer combination?*
   No answer could be found to this question.
6. *Could the vehicle combination have been straightened out by increasing speed in these conditions?*
   Judging by the results of the investigation it is highly unlikely that a deliberate increase in speed would have straightened out the tractor-trailer.
7. *Would the application of the trailer brake have brought the vehicle combination under control?*
   The investigation could not provide an unambiguous answer to this question.
8. *What was the effect of engine braking?*
   The effect of engine braking was marginal.
9. *How did the cutting to the apex of the turn right after the top of the hill affect the situation?*
   An orthodox cutting to the apex, increasing the radius of the curve, has no negative effects per se. However, if the straightening out from the turn is done by jerky steering input or if one has to straighten out earlier than intended, it is possible that the curve radius momentarily decreases from that of the normal driving line.

   The test runs on a smooth, groove-free road produced an increase in lateral acceleration when the mid-turn driving line was tightened by means of choosing different driving lines and by employing different manners of driving.

   The simulation also showed an increase in friction demand while performing the same manoeuvres. Compare: Answer to question number 1.
10. *What was the effect of the speed on the top of the hill to the behaviour of the vehicle (e.g. 60, 70, 80 and 89 km/h)?*
    See the answer to question 3b
11. *What was the significance of the slipperiness of the pavement?*
    By driving in the centre of the lane and by using the speeds recorded on the tachograph the greatest significance of the road adhesion was considered to be on the uphill section. At that point, the obvious slipperiness should have been detected in the wheelspin of the drive wheels on the incline section. This means that if the friction was sufficient for the vehicle to climb the incline, then it must have also been sufficient to successfully negotiate the turn.

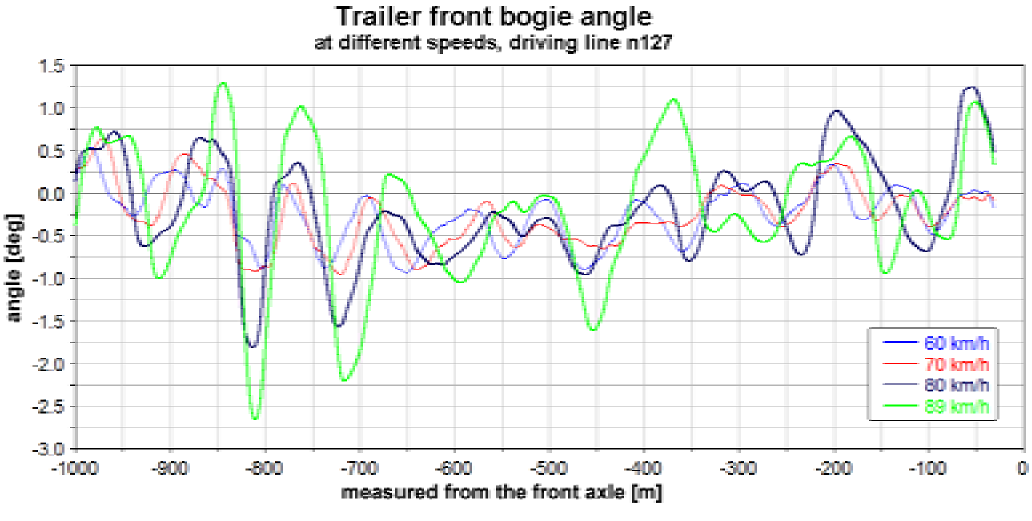
The behaviour of the full trailer combination based on test runs and simulations

VTT Industrial Systems compiled the simulation report. Turku University of Applied Sciences analysed the measured results and provided a statement. Data from both reports were used in analysing the loss of control of the vehicle combination.

Test run and simulation data did not provide answers to all of the questions posed by the investigation commission. Only approximate answers could be found to some of the questions related to how different factors affected the behaviour of the full trailer combination.

Results from the road profile of the examined area show that there were two spots that generated road-induced impulses, which disturbed the tractor-trailer's motion. The first one of these was at the onset of the apex of the curve at about 750 m (measured from the point of impact) before the top of the hill. The second spot was at around 575 m at the end of the apex of the curve.

Judging by the results the trailer became increasingly unstable as speed increased; figure 12. The most noticeable change occurred when speed increased from 80 km/h to 89 km/h.



VTT Tuotteet ja tuotanto

Figure 12. The angle of the trailer's front bogie in relation to the frame at different speeds. The plots clearly show how the trailer's oscillation grows in proportion to the increase in speed. On the driving line n127, the vehicle combination tracks on the left edge of its lane.

The so-called RA (Rearward Amplification) is a commonly used control value in studies concerning vehicle combination behaviour. The RA can be calculated to both lateral acceleration and to yaw rate.

The lateral acceleration RA indicates the ratio between the maximum lateral acceleration of the last axis of the trailer and the maximum lateral acceleration of the front axis of the tractor, measured in a driving situation. When RA is greater than 1, the tractor's front axle steer inputs are amplified in the trailer. When RA is smaller than 1, the tractor's steer inputs are dampened in the trailer (see: figure 20). Henceforth the term RA refers to the lateral acceleration RA.

Based on simulations it can be stated that the excessive load at the time of the accident destabilized the full trailer combination compared to that of a legally permissible load. The difference in RA, denoting the trailer's stability, was 6.5% at the maximum point. Only an increase in RA does not cause an accident but the vehicle's rearward amplification strengthens. If the driver makes a steer input at a critical steering input frequency and at an unfavourable spot, the risk of losing control increases.

Simulation data analysis, including ancillary diagrams, is presented in subpara “2.1 Loss of control of the vehicle combination”.

Brake lag and forces on the drawbar

The tractor used in the re-enactive test run had electronic anti-lock pneumatic brakes (EBS). The trailer had pneumatic anti-lock brakes (ABS), just like the collided trailer.

During the test runs both the brake lag and the release lag were measured (i.e. how much later the trailer begins to brake in comparison to the tractor and how much later the trailer stops braking after the release of the brake pedal). During the test runs (figure 13) brake modulation was light, as is generally customary in slippery conditions. When the measurement was taken the trailer’s brake chamber pressure was 0.7-1.0 bar. Timed from the instance when the brake chamber pressure exceeded 0.3 bar, the front axle brake lag measured at 1 s and the rear axle brake lag at 1.5 s, respectively. At the onset of braking, drawbar force pushed the tractor, at about 2 kN. The trailer brake release lag was 1.4-1.8 s. During the braking and the release the force on the drawbar was tractive, at about 2 kN.

Depending on the manner of braking on the downhill section prior to the accident site, forces on the drawbar varied. These forces, however, were very small (the scale of 2 000N, ca 200kp). The calculated lateral force (the so-called jackknifing effect) was only about 20N (ca. 2kp) because the maximum drawbar angle was only 0.4 degrees.

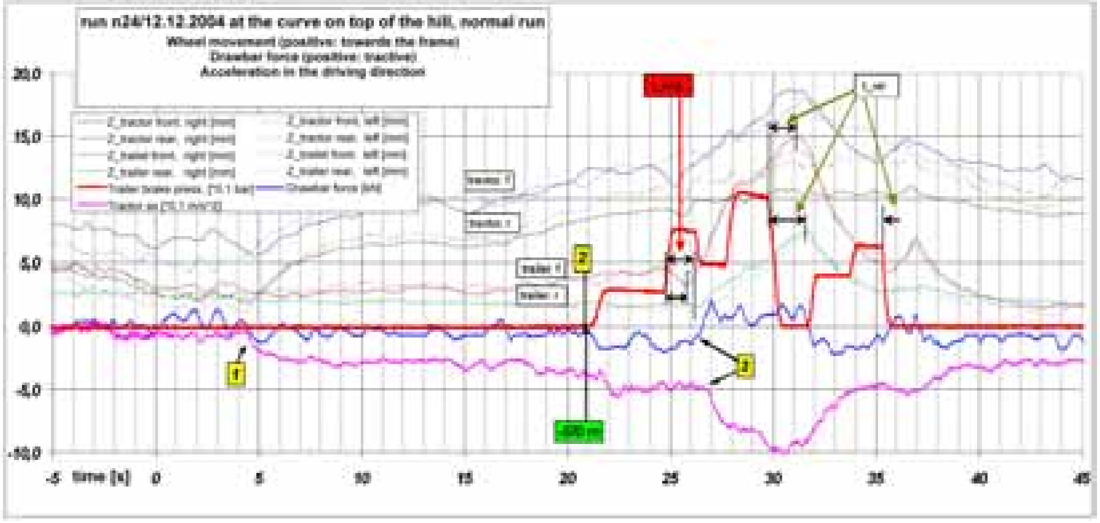


Figure 13. Measured brake lags and forces on the drawbar during test runs on 12.12.2004.

The test driver’s observations on the behaviour of the vehicle combination

The driver who performed the test runs on 11-12.12.2004 submitted a written report on the effect of tyre pressure changes on the handling of the tractor-trailer. Furthermore, he reported on the effect of a steering bogie on the controllability of the vehicle.

Changing the tyre pressures from those specified to the ones measured after the accident was hardly noticed in normal highway handling where the driver always tries to avoid sudden steer inputs and powerful braking. The difference was noticed at the slalom track when the “tractor-trailer continued to heave as if the shock absorbers were broken”. After the tyre pressures were lowered, the vehicle’s acceleration from standstill seemed to suffer.

This was the first time the test driver had driven a truck fitted with a system in which the rear axle wheels turn automatically once the front wheel steering angle exceeds four degrees. The driver noticed no difference in highway handling between a steering rear axle and a straight rear axle.

1.16 Organizations and management

The following depicts the companies’ organizations and management, based on the reports of the respective managements.

1.16.1 Transpoint Oy Ab

(Abridged from the original Finnish text)

In 2003, the haulier transported 2 million tons of freight, consisting of 2.6 million consignments. The company employed 1 103 personnel. Its operational fleet comprises ca. 185 company-owned lorries and 335 contract haulier lorries. With these lorries the company mainly transports parcel shipments in Finland in so-called VR (State Railways) swap bodies (ca. 1 000) and in trailers (ca. 450). Business is built on scheduled interterminal trunk route transports as well as on pickups and deliveries in cargo terminal areas.

The activities of Transpoint Oy Ab are divided into six profit centres, i.e. areas. In addition to these, the company has an international transportation department. The area directors, the sales director and the managing director form the management group.

1.16.2 Oy Sunny Buses Ltd

(Abridged from the original Finnish text)

Sunny Buses Ltd belongs to Pohjolan Turistiauto concern, the third biggest private coach and bus conglomerate in Finland. One of the owners is the managing director of both the Pohjolan Turistiauto concern and Sunny Buses Ltd. The company’s fleet comprises 400 coaches and 550 personnel. In 2002, the conglomerate transported 15 million passengers and logged a total of 15 million kilometres.

There are 35 coaches under the flag of Sunny Buses Ltd, three of which belong to the company itself. The other coaches are leased from the conglomerate's other companies. The average age of a coach is approximately 3.5 years. Sunny Buses Ltd employs 35 personnel, of whom 25 are full-time drivers. There are 10 persons in administrative and maintenance tasks and they, too, are permanent employees. The company employs a few temporary and part-time drivers. In 2002 Sunny Buses Ltd transported ca. 350 000 passengers and logged some 2 million kilometres.

The managing director, the administrative director and the financial director form the conglomerate's management group. When required, the Vantaa-based local director of Sunny Buses' Ltd also participates in managing affairs along with the conglomerate management.

1.17 Other information

1.17.1 Forces of deceleration in the vehicles at the time of impact

Based on the analysis of the tachograph discs it was noted that both the tractor-trailer and the coach were travelling at ca. 70 km/h immediately before impact. The weight of the tractor was ca. 28 320 kg and the weight of the trailer ca. 35 785 kg. The coach's weight was around 16 150 kg. At the time of impact, the tractor was at an estimated angle of 15º to the right in relation to the coach and the trailer. Based on accident site investigations, it was noted that the front of the trailer and the coach hit each other almost completely head-on. The impact was calculated as being inelastic. The resultant speed after the impact, 41 km/h in the direction of the velocity vector of the tractor-trailer, was calculated according to the law of inertia by taking into account the tractor's position in relation to the coach and the trailer. The collision altered the coach's speed by 111 km/h and the tractor-trailer's by 29 km/h, respectively.

The fact that the front part of the coach was crushed for about 2 m was taken into account as the average deceleration was being calculated. At the time of impact, the trailer's front bogie was going sideways and its outermost left wheels compressed for a total of ca. 30 cm. Moreover, when one takes into account the distance travelled by both vehicles during the course of the collision, the average deceleration of the vehicle combination was calculated at 5.4 g (53 m/s^2). The time elapsed during the collision was 0.15 s. The average deceleration of the coach was calculated at 21 g (208 m/s^2). However, momentary forces of acceleration during the event were greater.

1.17.2 Load anchoring

The road tractor

There were 17 paper reels in the cargo space, 10 of which were side by side on the floor. The right hand side row of reels was propped against the front wall. Due to reel diameters, there was no space for a fully parallel fit, meaning that the left hand reels were about 10 cm off the front wall. Furthermore, the reels leaned on the side walls as well as on each other. There were no load anchoring points on the floor.

The top row reels in the front were positioned along the longitudinal centreline of the trailer. The reels were secured to each other as a group with a tie-down strap, which was rated at 2 000 daN. The first reel was buttressed against the front wall. Additionally, a strap extended from the anchor rail on the left wall across the middle reel to the anchor point on the right hand side door. The two following reels were right behind the two at the front, side by side, and were slightly diagonally secured with a tie-down strap. The two reels at the rear were side by side and secured with a strap from behind. The rated strength of the two tie-down straps in the rear was 1 000 daN. No anchoring was in place to block forward forces.

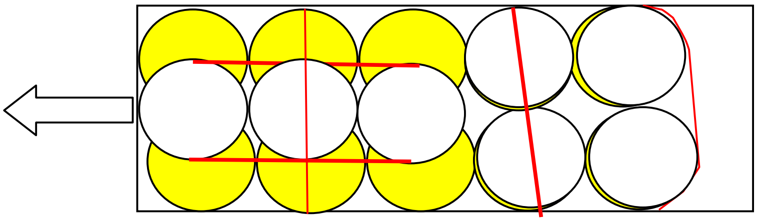


Figure 14. Load anchoring in the tractor viewed from above. The arrow indicates the tractor's heading. The yellow reels are at floor level and the white ones are on top of them.

The trailer

There were a total of 32 paper reels stacked in the cargo space, 20 of which were at floor level side by side in two rows. The right hand side row was propped against the front wall. Due to the size of the reels, the left hand side row was 10 cm off the front wall. Furthermore, the reels leaned on the side walls as well as on each other. Two perpendicular barriers resting on the reels buttressed the last two pairs of reels. Tie-down straps to floor anchor points secured the last pair of reels.

There were 12 reels, the first pair side by side, on top of the reels on the floor. The right hand side reel was buttressed against the front wall and, as on the floor, the left hand side reel was 10 cm off the front wall. The following three reels were positioned along the longitudinal centreline of the trailer. A tie-down strap extended across the middle reel from load anchor points on the wall to ones on the door. This also secured the doors. The following six reels were in side by side pairs and the last one, the twelfth, on the centreline of the cargo space. A tie-down strap hooked to the wall rail blocked the rearward movement of the last reel. The rated strength of the straps was 1 000 daN. In addition to the straps there were three perpendicular barriers resting on top of the reels securing them. No anchoring was in place to block forward forces.

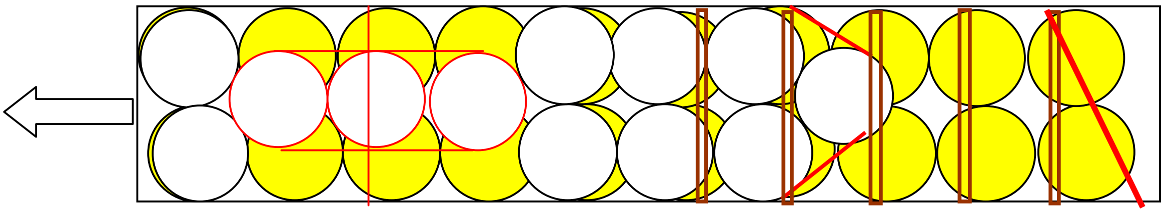


Figure 15. Load anchoring in the trailer viewed from above. The arrow indicates the trailer's heading. The yellow reels are at floor level and the white ones are on top of them.

1.17.3 Police traffic surveillance

(Abridged from the original Finnish text)

Pursuant to the Act on Police Administration, it is the task of the local police and the National Traffic Police to carry out traffic surveillance. The Decree on Police Administration provides the traffic safety tasks of the National Traffic Police in detail. Pursuant to the Decree, the National Traffic Police are to track the development of traffic safety, develop methods of surveillance, carry out vehicle checks and driver checks on the main roads. The police are also to monitor heavy traffic and the transport of dangerous goods as well as drivers' compliance to driving hour and rest period regulations. In addition to these responsibilities, the National Traffic Police are tasked with control of cross-country and waterborne traffic, special security details and police driver training.

Over the past few years, traffic surveillance has constituted only a few percentage points of the total working hours of the local police. The National Traffic Police dedicate approximately one half of their total work time to traffic control. Surveillance of heavy traffic constitutes approximately 10% of all traffic control hours conducted by the National Traffic Police. In 2002-2004, the National Traffic Police's share stood for approximately 87% of heavy traffic police control.

1.17.4 The development of heavy vehicle size in Finland

In the 1960s, the vehicle combination consisting of a tractor and a full trailer became popular in Finland. The tractor would normally be 3-axled and the trailer 2-axled. In 1966 the maximum GCW of this combination was 32 tonnes and, under certain conditions, 35 tonnes. The combination's maximum length was 18 m.

The maximum axle load was 8 tonnes and the maximum twin-axle bogie load was 13 tonnes. Elsewhere in Europe axle and bogie loads and Gross Vehicle Weights were clearly higher. Hence, the need to raise axle and bogie loads arose in Finland.

In the beginning of the 1970s the first parliamentary transport committee commissioned a report on lorry axle and bogie loads and on GCWs. Based on the report, in 1975 the maximum axle load was laid down at 10 tonnes, the bogie load at 16 tonnes and the maximum GCW at 42 tonnes, respectively. The maximum length of a combination became 22 m.

In 1982, the GCW was raised to 48 tonnes.

In 1987, the vehicle's maximum width was increased from 2.5 m to 2.6 m.

In the beginning of 1990, many changes were enacted in statutes. The EU had altered regulations on axle and bogie loads and Finland followed suit on grounds of conformity. The raise in bogie weights especially increased the GCW of vehicle combinations. The maximum weight of a seven-axle road tractor and full trailer vehicle combination became 56 tonnes. During the winter when the ground is frozen, the maximum weight of 60 tonnes for such combination was allowed on roads that were expressly designated by road regions. The maximum GCW of a vehicle combination comprising a road tractor and a semi-trailer became 44 tonnes. Prior to that, no specific GCW limitations on these kinds of vehicle combinations existed.

In 1993 the GCW of a seven-axle or higher than seven-axle vehicle combination was raised to 60 tonnes, a six-axle combination to 53 tonnes, a five-axle combination to 44 tonnes and a four-axle vehicle combination to 36 tonnes.

In 1997, the maximum length of a module concept vehicle combination became 25.25 m. At the same time, the maximum GCW of a vehicle combination comprising a tractor and a semi-trailer became 48 tonnes. The maximum height grew by 20 cm to 4.20 m.

The Gross Combination Weight of heavy vehicle combinations has almost doubled during the past forty years. At present Finland and Sweden operate the heaviest vehicle combinations in all of Europe. Only in Australia and Canada are there heavier combinations in traffic but even there, they are restricted to designated roads. Holland and Belgium, too, are testing module trailers. Unlike Finland, Holland and Belgium do not allow them on all public roads.

The development and use of large and cavernous trailers is justified by lower energy consumption and emissions per unit of cargo and by lower transport costs. In 2003, road transport stood for 68% of all cargo transported in Finland. Of all EEA countries, the heavy vehicle transport ratio per inhabitant (tonne-kilometre/inhabitant) in Finland is almost twice as high compared to Sweden and Norway, the following countries on the list (Finnish Transport and Logistics *SKAL* statistic).

2 ANALYSIS

2.1 Loss of control of the vehicle combination

2.1.1 Depiction of the event leading to the collision

One of the main objectives of this investigation was to find the answer to why the driver lost control of his vehicle. The investigation commission had access to the driver's account of the event, observations of the tractor-trailer's behaviour as witnessed by the driver of a car and its passengers driving behind the vehicle combination, speed and brake application tachograph disc data and marks left on the road. This information details the event history extensively from the point in time when the vehicle combination began to fishtail. However, the data do not provide an explanation for the fishtailing. In order to establish the causes, re-enactive test runs were driven with a full trailer combination and the measured data were used to verify the accuracy of the simulated computer model.

The loss of control has been analysed as a chain of events linking several different factors. The events are shown in figure 16, mirroring the section of the road. The left side of the figure lists the driving events, speeds, times and the distance measured from the point of collision. The right side of the figure details the road itself. Figure 17 contains the vehicle combination's driving dynamics graph for the final 1 600 metres augmented with event data construed from the commission's opinion of the accident.

The tractor-trailer reached the apex of the hill (750 m from the accident site) travelling at 78 km/h. The driver steered either along the left edge of his lane or on top of the barrier line separating the opposite lanes. At this spot, all three lanes are cambered towards the inside of the turn. The camber of the two inner lanes is ca. 4% and the camber of the outermost lane, used by the vehicle combination, is ca. 2%. The camber differential formed a ridge between the tractor-trailer's lane and the overtaking lane.

The driver continued approximately 50 m past the apex of the hill with motor power on. Then he lifted his foot off the accelerator but did not yet apply the brakes - only the engine was braking. Approximately 550 m before the point of collision, the vehicle reached the speed of 85 km/h. The collision was to occur in ca. 25 seconds. The driver of the tractor-trailer probably saw the coach's headlights about 600-550 m before the point of collision and switched his headlights to low beam. The driver probably steered his vehicle over the road grooves to the centre of his lane and realized from the motion of the tractor that the trailer had begun to skid to the right. The driver tried to straighten up the vehicle combination through steering input and by applying full power. The downhill gradient was 5.9%. The speed increased to 91 km/h at 475 m before the point of impact, remaining the same for the following 200 m while the driver tried to control his speed by braking. Judging from the marks, the tractor-trailer partly occupied the overtaking lane 450-250 m before the point of collision. Once the driver realized that he was unable to straighten out the vehicle combination he applied full brakes and flashed his headlights as a warning to the oncoming coach. The distance from the point of collision was 270 m and the time to impact was ca. 15 seconds.

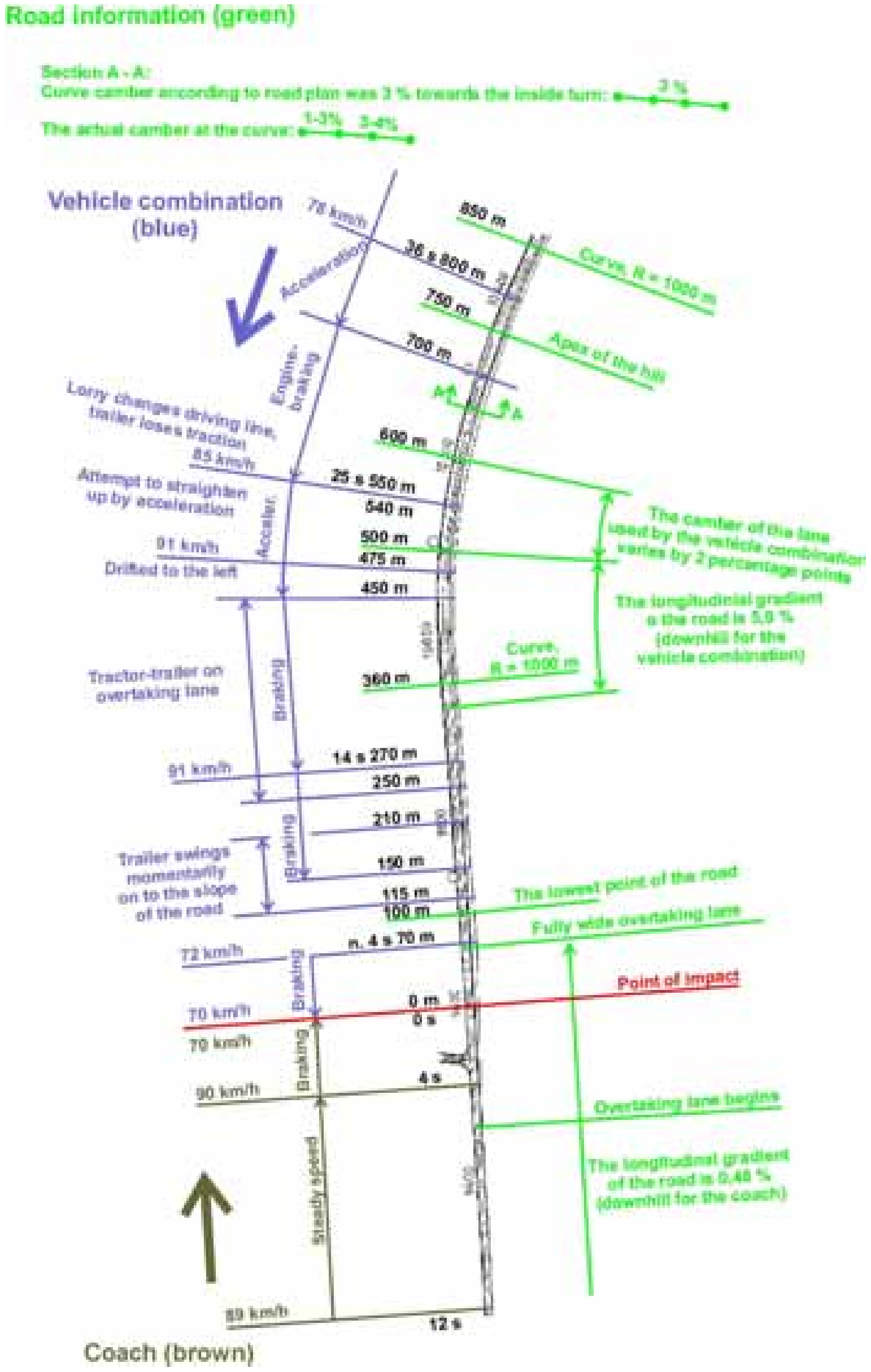
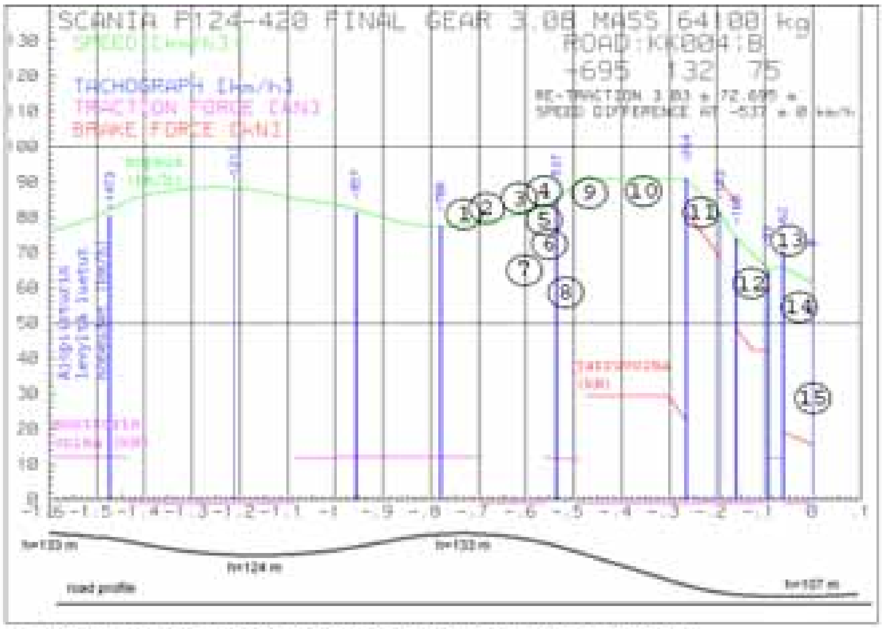


Figure 16. Drawing of the section of the road at the accident site and the investigation commission's view of events.



1. The highest point of the road (750 m from the point of impact)
2. Engine power on until this point, commencing engine braking (ca. 700 m)
3. The vehicle combination was either at the left edge of its lane or on top of the barrier line (ca. 600 m)
4. The driver saw the headlights of the oncoming vehicle and dipped his lights to low beam (600-550 m)
5. The driver steered the vehicle back from the left edge to the centre of the lane (600-550 m)
6. Variations in lane camber angle (600-550 m)
7. Point where the trailer began to skid towards the outside of the turn (ca. 550 m)
8. The driver attempted to control the skid by applying pressing the accelerator to the floor and by steering (540-450 m)
9. The driver commenced braking (ca. 445 m)
10. The vehicle combination partially travelled on the overtaking lane (450-250 m)
11. The driver managed to return the combination back to his own lane, braked hard and flashed his high beam headlights, the rear of the trailer swung to the right (250-210 m)
12. The rear of the trailer went approximately 4 m off the edge of the road at the most (210-115 m)
13. The trailer rose back onto the road and drifted to the lane used by the oncoming coach (115-0 m)
14. The driver began to brake and attempted to steer the tractor-trailer to the right (70-0 m)
15. Impact

Figure 17. Driving dynamics graph created by Vemosim software augmented with event data construed from the commission's opinion of the accident.

At approximately 210 m the rear of the trailer veered into a snow drift approximately four metres beyond the edge of the pavement on the right side of the road. At about 115 m before impact, the trailer rose back onto the road. The time to impact was ca. 5 seconds.

Once the trailer rose back onto the road the vehicle combination drifted across its own lane into the overtaking lane, used by the opposing traffic, and possibly even into the coach's lane. At this point, approximately four seconds before impact, the driver powerfully applied the brakes and attempted to steer the vehicle back into its lane. The tractor moved back to the overtaking lane but the trailer drifted into the coach's lane.

The coach approached the accident site at about 90 km/h. The driver saw the tractor-trailer's headlights about 500 m before the point of collision, lowering his own headlights. He applied full brakes approximately four seconds before impact without attempting an evasive manoeuvre.

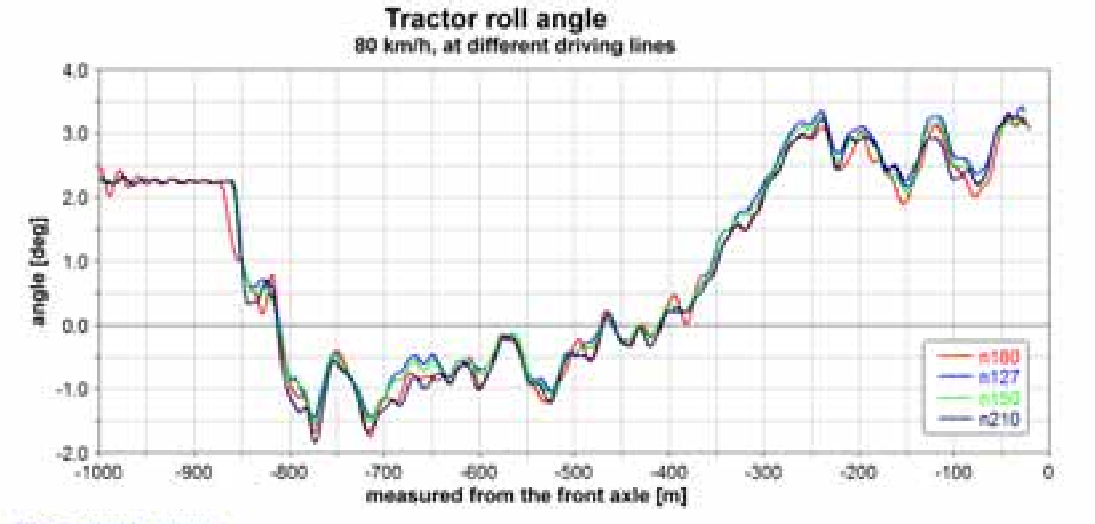
2.1.2 The effect of the road profile on the behaviour of the vehicle combination

The road profile generates some of the impulses on the vehicle. The computer simulation studied their effect on the behaviour of the full trailer combination. The accuracy of the simulated road profile significantly affects the results.

The Finnish Road Administration delivered the road profile to VTT Industrial Systems on 24.3.2005. The profile was used in Konginkangas' road section computer simulations and it was surveyed with a PTM laser measuring vehicle on 3.4.2004.

The simulation was conducted with an excessive load similar to the one in the collided vehicle combination including characteristics induced by the low tyre pressures and the trailer's shock absorbers. The selected speed was 80 km/h. The driving lines chosen were the centreline of the vehicle combination's lane (n180 = reference in figures), a driving line 0.30 m from the centreline of the lane towards the outside edge (n210) of the road as well as the driving lines of 0.30 m (n150) and 0.53 m (n127), respectively, towards the middle of the road.

The selected friction level represents good braking action so that the desired driving line can be maintained as accurately as possible and so as to be able to expose the road profile-generated effects on the different sections of the road.



VTT Tuotteet ja tuotanto

Figure 18. Positive angle = roll to the right. Coordinate 0 = point of collision.

Figure 18 graphs the roll angle of the tractor's frame. It shows that different driving lines result in different roll angles. However, large oscillations such as the ones at 750 m and

575 m are almost identical in different driving lines. The trailer frame's roll angle graph in figure 19 also demonstrates the corresponding result.

VTT Tuotteet ja tuotanto

Figure 19. The trailer frame's roll in different driving lines. Positive angle = roll to the right. Coordinate 0 = point of collision.

Results show that there are two spots in the road profile that generate road-induced impulses disturbing the vehicle's motion. The first one of these is in the curve at about 750 m at the top of the hill and the second is at around 575 m in the end of the curve. Impulses disturbing the vehicle's motion are probably generated by changes in the road profile's camber, which induce lateral vehicle oscillation. A sudden swing towards the outside turn may also contribute to the loss of control of the vehicle.

2.1.3 The effect of the excessive load on the behaviour of the vehicle combination

The simulation tested the effect of the load by comparing the Rearward Amplification (the definition of RA is in subpara 1.15.6) of a legally loaded tractor-trailer to that of one carrying an excessive load, such as the one involved in the accident. Figure 20 illustrates that a vehicle combination which is loaded similarly to the collided tractor-trailer displays higher RA, i.e. lower stability, compared to a legally loaded vehicle combination. At the steering input frequencies of 0.25 Hz and 0.6 Hz, the maximum RA grows by 6.5% and 2.0%, respectively.

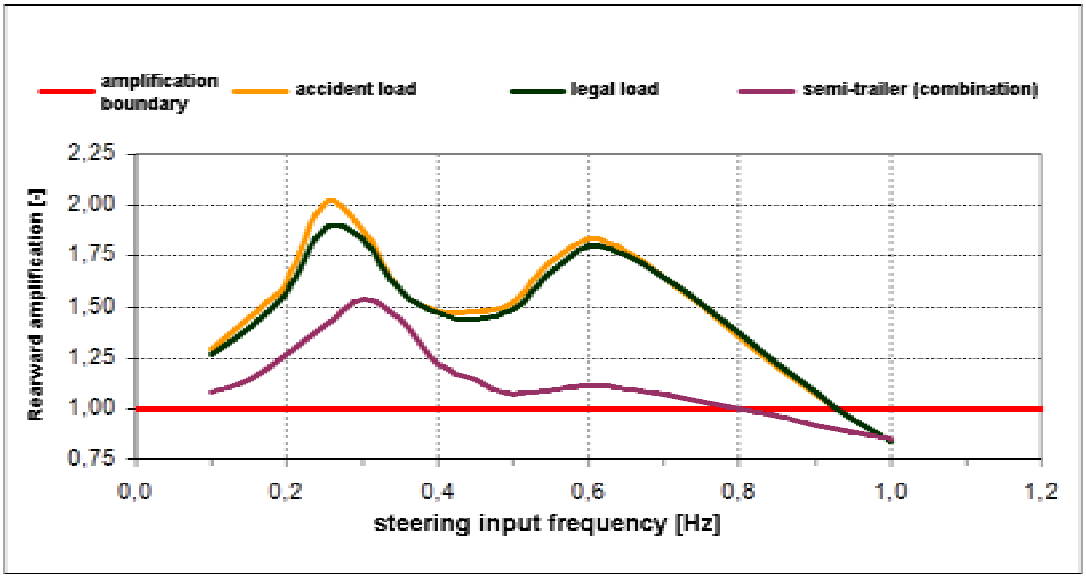


Figure 20. The effect of the load on Rearward Amplification. For the sake of comparison, the typical RA of a semi-trailer is also shown on the graph.

An increase in RA as such does not result in an accident. However, the vehicle's rearward amplification strengthens, resulting in an increase in the risk of losing control if the driver makes a steer input at a critical steering input frequency in an unfavourable driving situation.

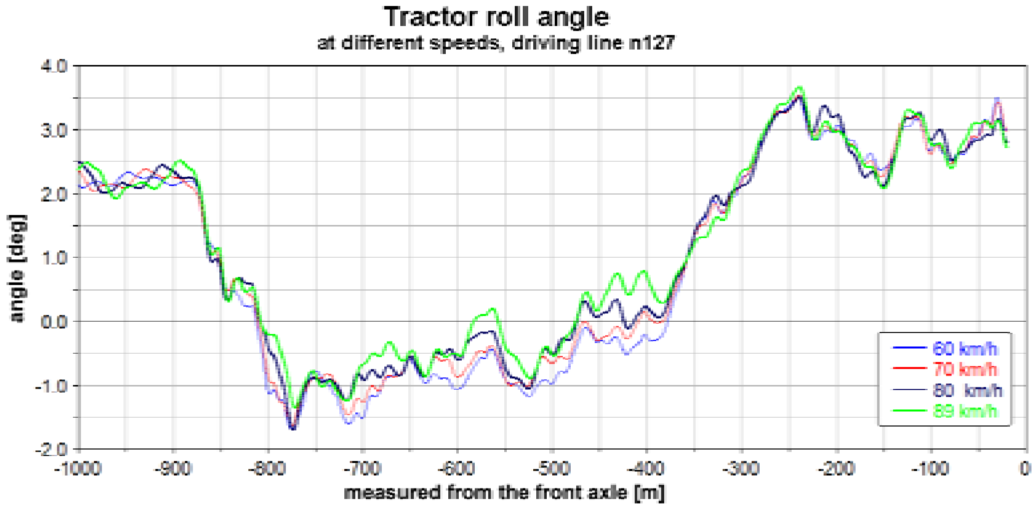
2.1.4 The effect of the driving speed on the behaviour of the vehicle combination at the Konginkangas section of the road

To measure the effect the speed had, the coefficient of 0.20 was selected for the road in the simulation. The driving line was 0.53 m from the centreline of the western lane towards the middle of the road (n127). The speeds were 60, 70, 80 and 89 km/h. The simulation used the road surface profile of the time of the accident.

The simulation showed that the trailer becomes more unstable as speed increases, figure 13. A clear change takes place as speed increases from 80 km/h to 89 km/h.

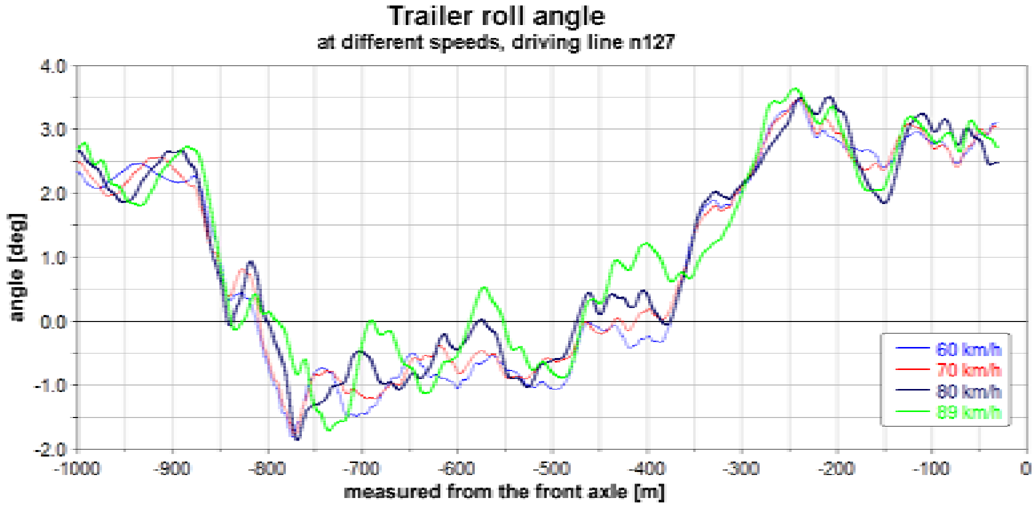
Figure 21 shows that changes occur in the tractor frame's roll as speed increases.

Figure 22 shows that the trailer's roll significantly increases as speed does.



VTT Tuotteet ja tuotanto

Figure 21. The tractor frame's roll angle at different speeds. Positive angle = roll to the right.



VTT Tuotteet ja tuotanto

Figure 22. The trailer frame's roll angle at different speeds. Positive angle = roll to the right.

2.1.5 The investigation commission's opinion of what caused the loss of control

Simulations proved that if road friction at the time of the accident was the same as was measured later in the morning, the loss of control would have required fairly extensive control errors from the driver. The investigation commission's view is that road friction at the time of the accident was lower than the values of 0.2-0.6, measured with friction measuring devices at 05:40 and 07:13. By morning, the ambient temperature had already fallen and the road surface had dried (figure 5). At the time of the accident, the road was wet and icy and, hence, road friction was 0.14 at the most (Finnish Road Administration / Winter Road Maintenance - Quality Requirements: friction of wet ice is

0.05-0.14). The assertion that the road adhesion was low is also supported by the accounts given by people who arrived at the scene of the accident.

When it comes to the vehicle combination's computer simulations the greatest risk factor lay in defining realistic tyre behaviour in very slippery conditions. Therefore, the inquiry selected an approach where the tractor-trailer's behaviour was estimated by calculating the axle-specific or bogie-specific friction demand during different simulated driving manners. Friction demand describes the theoretical minimum friction which is required on the road section for the given driving manner and speed. Each axle's friction demand was calculated by establishing the tyre's force vector sum, comprising momentary longitudinal force (acceleration, braking) and lateral force (turning) in relation to the tyre's momentary vertical load.

The simulation explored the friction demand on three different driving lines (driving in the centre of the lane, cutting to the apex of the turn with a 0.64 m and a 1 m lateral shift). Each driving line was tested by selecting two different driving manners.

The simulated driving manner number 1 adhered to the highest permissible vehiclewise speed. An economical and safe manner of driving was also observed. The vehicle combination arrived at the road section travelling 80 km/h at the dip in the road prior to climbing up the hill. As it proceeded uphill, 50% of the engine's torque was used resulting in the end speed of 65 km/h at the top of the hill. After the peak of the hill, at 725 m, the accelerator was lifted and the downhill section was coasted, using engine braking only. Once the speed reached 80 km/h, brakes were applied at 400 m, after which the speed was maintained at 82 km/h by continued braking.

The simulated driving manner number 2 was based on speed data recorded on the collided vehicle's tachograph disc as well as on corresponding control inputs. The vehicle combination arrived at the road section travelling 87 km/h at the dip in the road prior to the hill. Once proceeding uphill, the maximum torque of the engine was used resulting in the end speed of 78 km/h at the top of the hill. After the apex, at 700 m, the accelerator was lifted and the downhill section was coasted, using only engine braking. At 540 m, full power was again applied and the speed was increased to 90 km/h. Braking commenced at 445 m, after which the speed was maintained at 90 km/h by continuous braking.

Driving line in the centre of the lane

Figure 23 illustrates the friction demands on the tractor's drive axle and bogie as well as on the trailer's front and rear bogies during driving manner 1. The drive axle was observed separately so as to explore the onset of the critical drive traction zone. The bogie-specific friction demand, for its part, better depicts the friction demand required for turning, i.e. the steerability of the vehicle combination. The figure shows that for traction, the most critical phase is during the downhill braking, where the maximum friction demand is 0.08. On the uphill section, the tractor's drive axle is the most critical, demanding the maximum friction of 0.07. Friction required to complete the turn between 700 m and 500 m is fairly low, approximately 0.03.

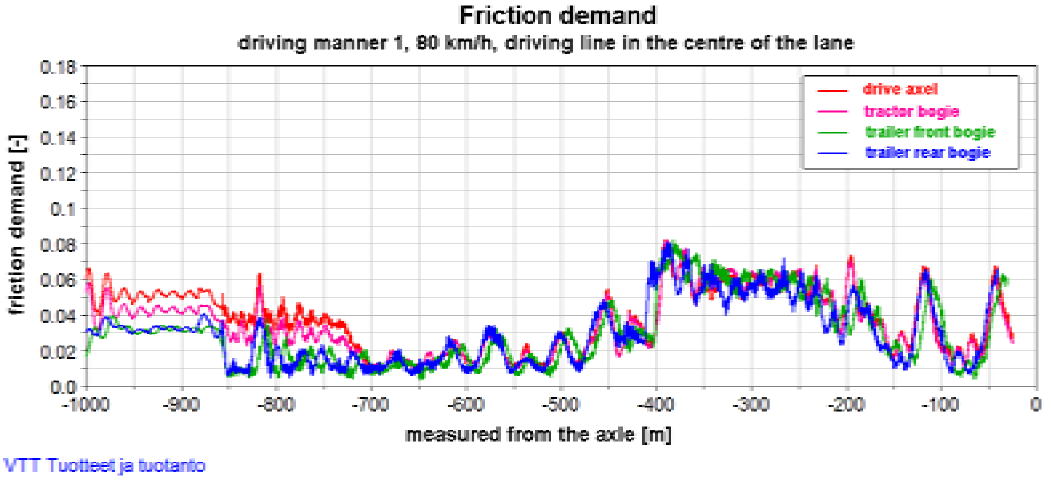


Figure 23. Friction demand during driving manner 1 in the centre of the lane.

Correspondingly, figure 24 illustrates the friction demand during driving manner 2. It shows that when one attempts to maintain a higher speed the drive axle is most traction-critical on the uphill section. The friction demand at maximum is approximately 0.11. The same friction demand is experienced at the beginning phase of the braking. Based on this, had the friction been below 0.1, the driver should already have noticed the slipperiness when climbing the hill.

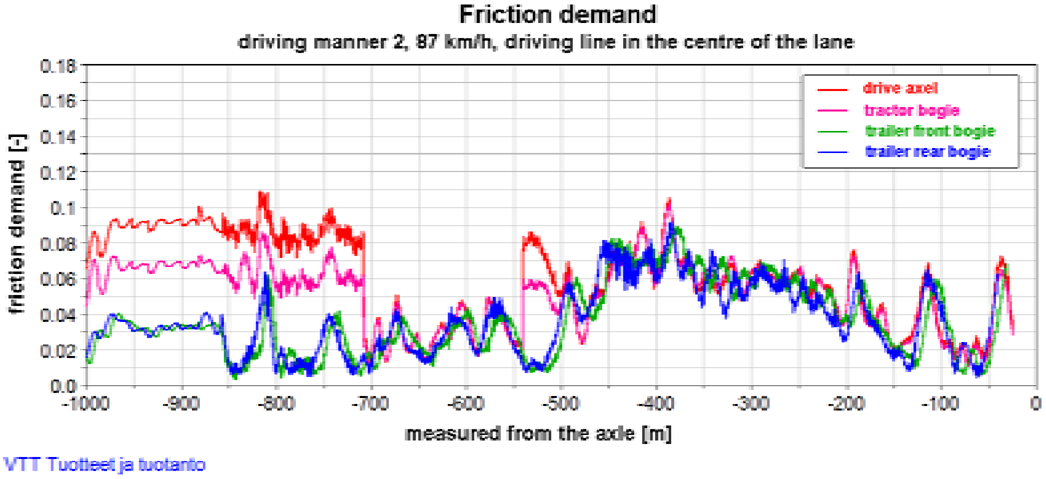


Figure 24. Friction demand during driving manner 2 in the centre of the lane.

Figure 25 sums up the friction demand maxima on the four sections of the road:

1) uphill straight section, using engine power
2) curve section, using engine power
3) curve section, engine braking (driving manner 1) and using engine power (driving manner 2)
4) downhill curve and straight section, braking.

The summation shows the effect of speed on friction demand. Apart from the downhill braking section, friction demand clearly increases with driving manner 2. Friction demand specifically increases on the drive axle and, in the uphill curve, also on the trailer's bogies.

Based on simulation it can be stated that had the driver driven in the centre of the lane, no loss of control would have resulted at higher than 0.11 friction.

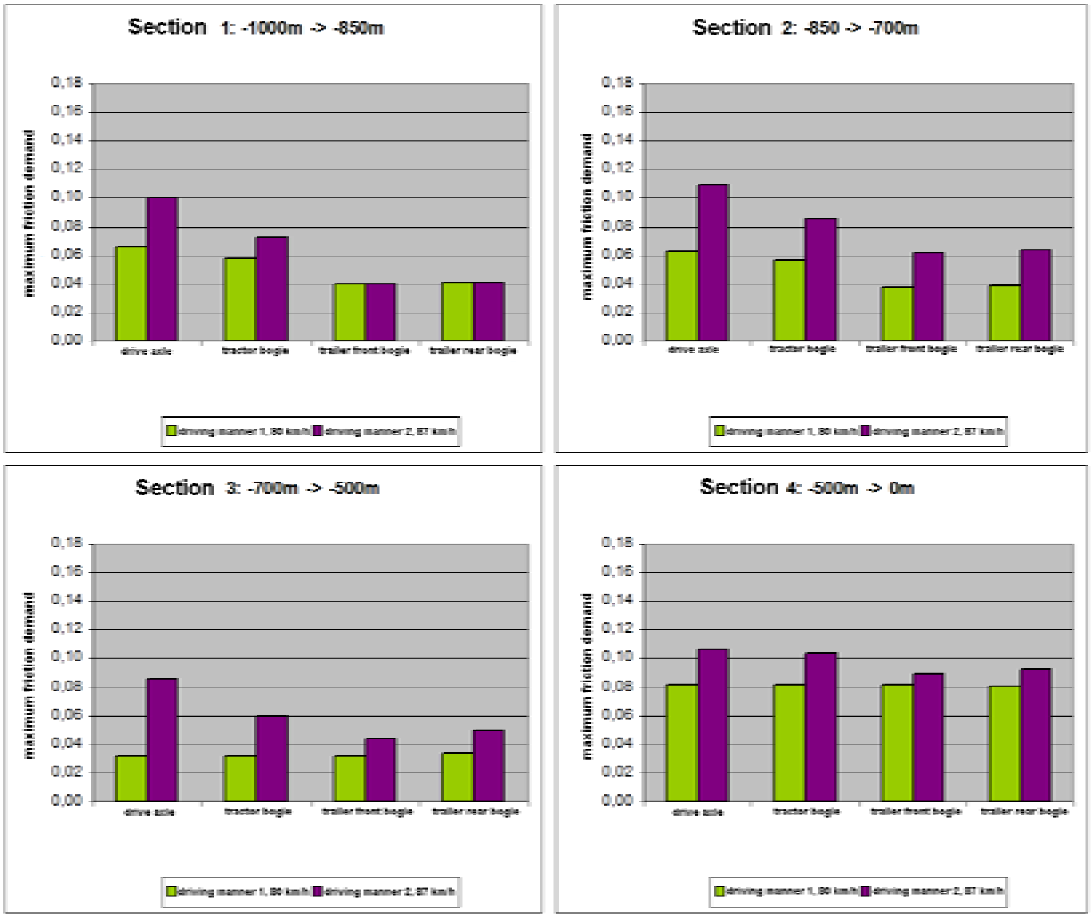


Figure 25. Summation of friction demand maxima in the centre of the lane on different road sections.

Cutting to the apex of the turn with a 0.64 lateral shift

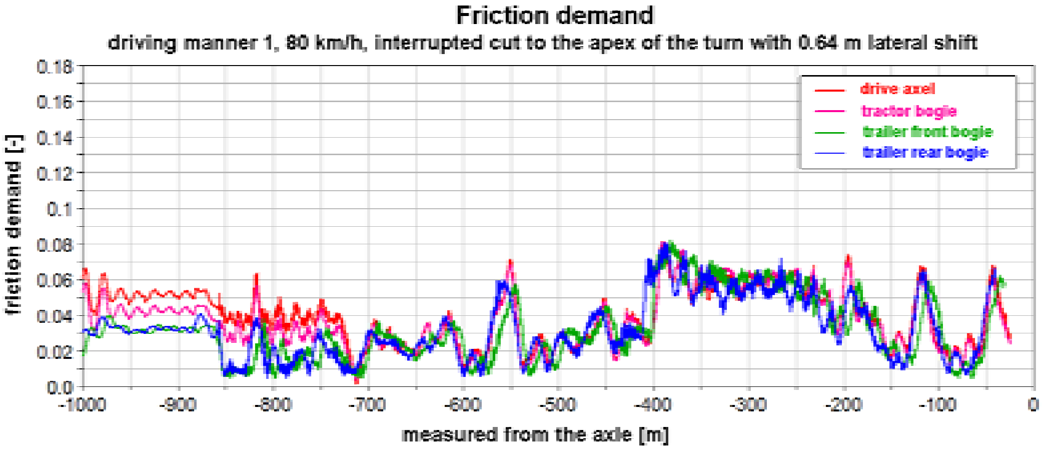
The driver said that he drove on the left side of his lane on top of the hill, from where he returned to the centre of the lane. It is estimated that he returned to the centre of the lane at 500-600 m before the point of collision. From there it was possible to see the oncoming coach's headlights.

The simulation followed the driver's account so that upon entering the curve the vehicle combination cut to the apex of the turn with a 0.64 m leftward shift from the centre of the lane, from where the combination later returned to the centre of the lane. The return was simulated in two ways: the first manner involved a gradual return within 100 m using moderate steering inputs and the second one a more abrupt return within 50 m by using more determined steering at the 600-550 m spot.

By performing the return by means of gradual steering friction demand was similar to driving within the centre of the lane. In other words, in a curve as gradual as the one in question, the effect of cutting to the apex of the turn is marginal.

The more determined steering input simulated a situation in which the cut to the apex was interrupted and the return to the centreline of one's lane was done faster than originally intended due to, for instance, oncoming traffic. The results of the tighter return lines are presented in figures 26, 27 and 28. Driving manners 1 and 2 correspond to the driving manners that are described in the section "Driving line in the centre of the lane".

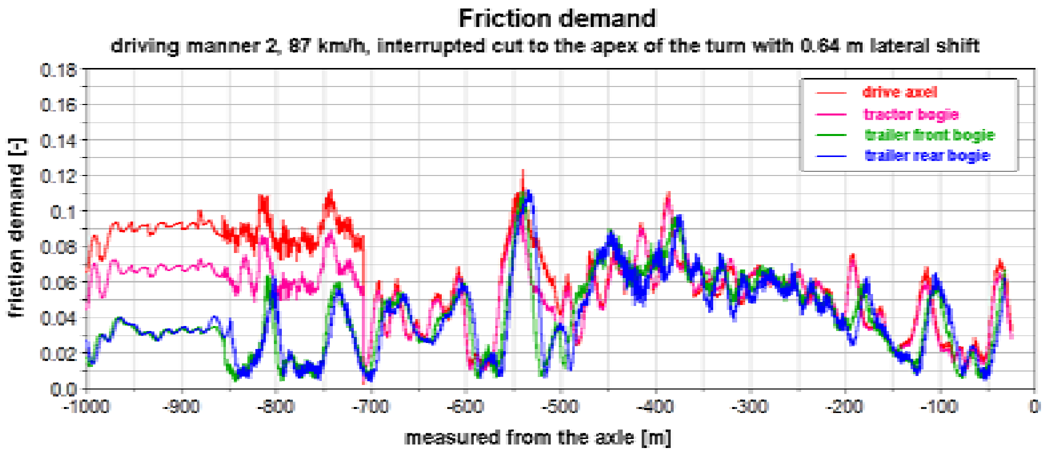
Via driving manner 1, friction demand decreases from 600 m onwards as one steers towards the centreline of the lane, i.e. as the driving line is made more gradual; figure 26. When the vehicle reaches the centreline of the lane one must countersteer in order to complete the turn. At this point friction demand shows a spike at 550 m.



VTT Tuotteet ja tuotanto

Figure 26. Friction demand during driving manner 1 by interrupting a cut to the apex of the turn.

Figure 27 shows that due to the speed during driving manner 2 the spike at 550 m is clearly higher compared to driving manner 1. However, friction demand at this point is approximately the same as friction required for uphill drive traction.



VTT Tuotteet ja tuotanto

Figure 27. Friction demand during driving manner 2 by interrupting a cut to the apex of the turn.

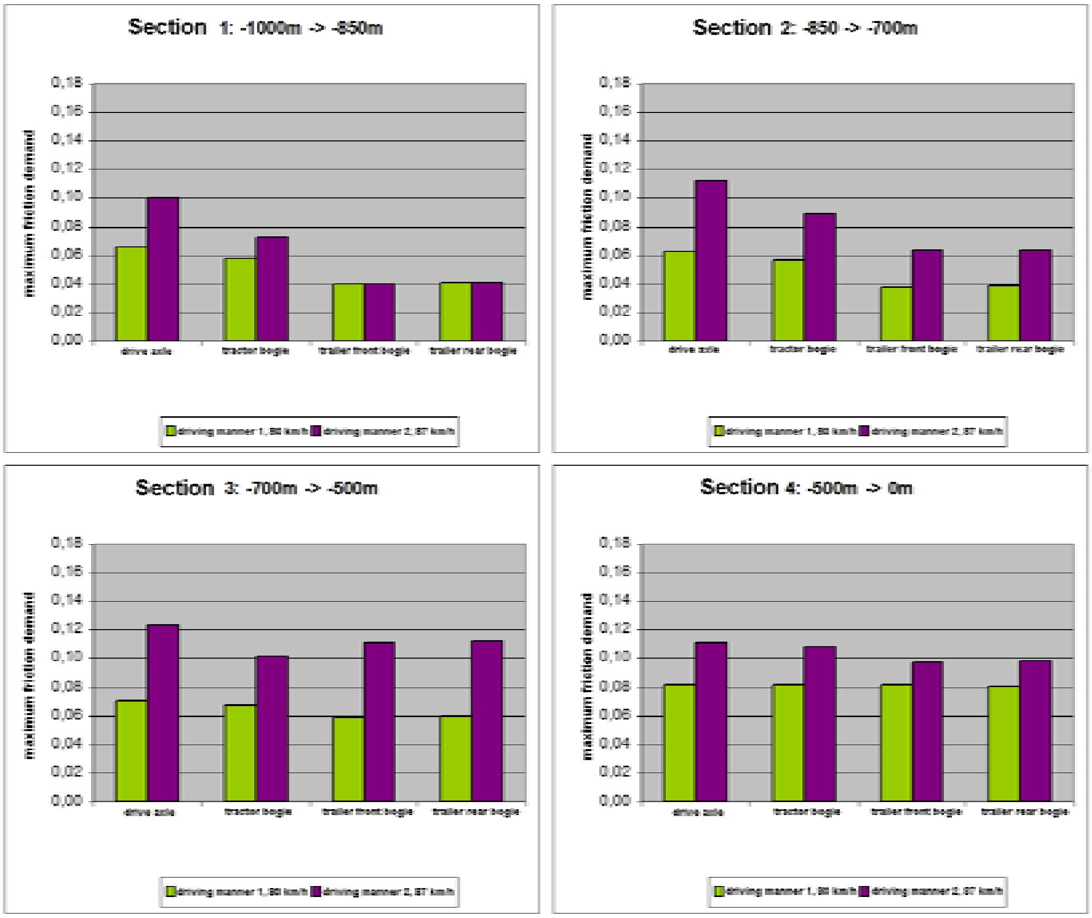


Figure 28. Summation of friction demand maxima on the different sections of the road when the cut to the apex of the turn is interrupted.

As one studies the friction demand maxima in figure 28 from the point of view of the vehicle combination’s steerability, i.e. from the bogies’ friction demand, the following is noticed: the highest friction demand 0.11 is placed on the trailer’s bogies on section 3 during driving manner number 2. The figure also shows that a change in the driving line in mid-turn at a lower speed on section 3 (driving manner 1, 80 km/h) does not cause any higher friction demand compared to the other sections.

Cutting to the apex of the turn with a 1 m lateral shift

The investigation commission also considers it possible that the cut to the apex was more pronounced than previously described. Therefore, simulation also explored a driving line in which the vehicle combination entered the curve by shifting one metre to the left from the centreline of its lane and returned to the centre of its lane within 50 m at 600-550 m.

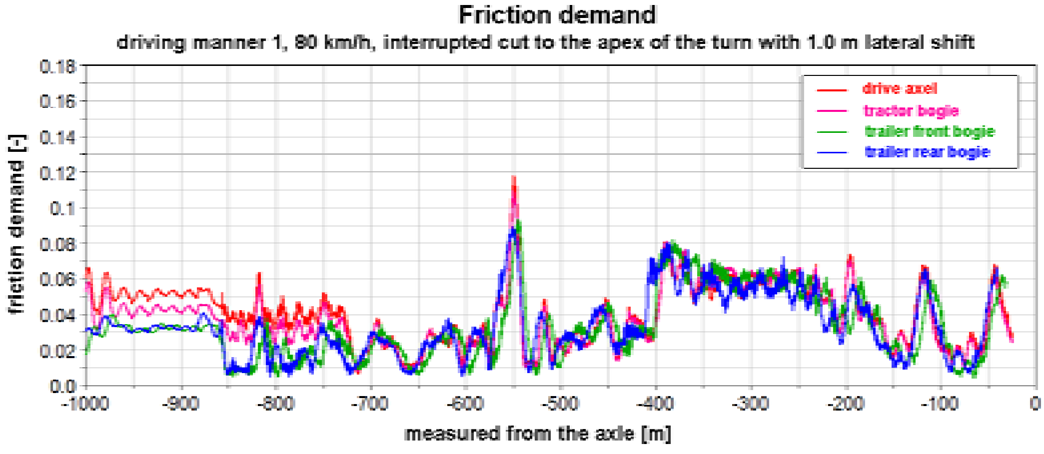


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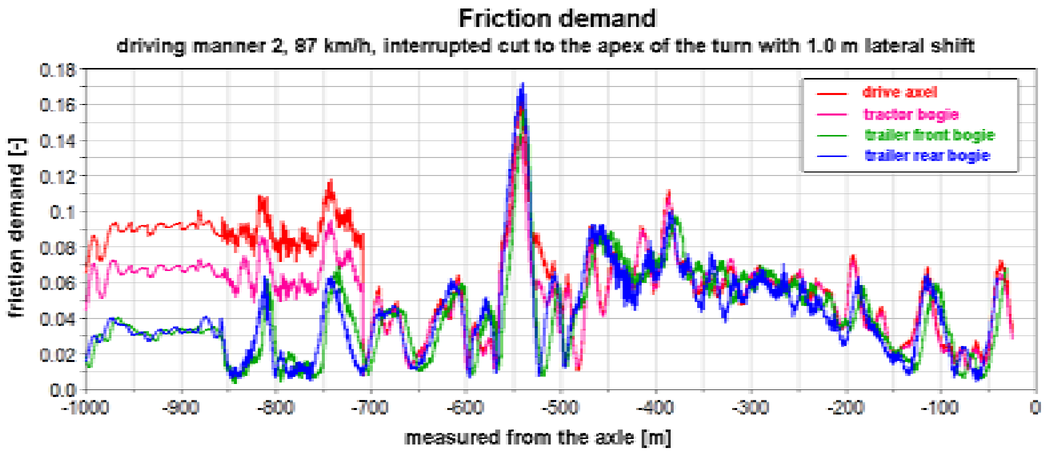
Figure 29. Friction demand during driving manner 1 by interrupting a one metre lateral shift cut to the apex of the turn.

Due to the more pronounced lateral shift, friction demand peaks at 0.12 at the distance of 550 m; figure 29. The bogies' friction demand at this point, too, exceeds the demand required by uphill drive traction.

The effect of speed on friction demand is markedly accentuated on a driving line such as this one. Figure 30 shows that the maximum friction demand on trailer bogies is greater than the maximum friction demand on the tractor bogie.



VTT Tuotteet ja tuotanto

Figure 30. Friction demand during driving manner 2 by interrupting a one metre lateral shift cut to the apex of the turn.

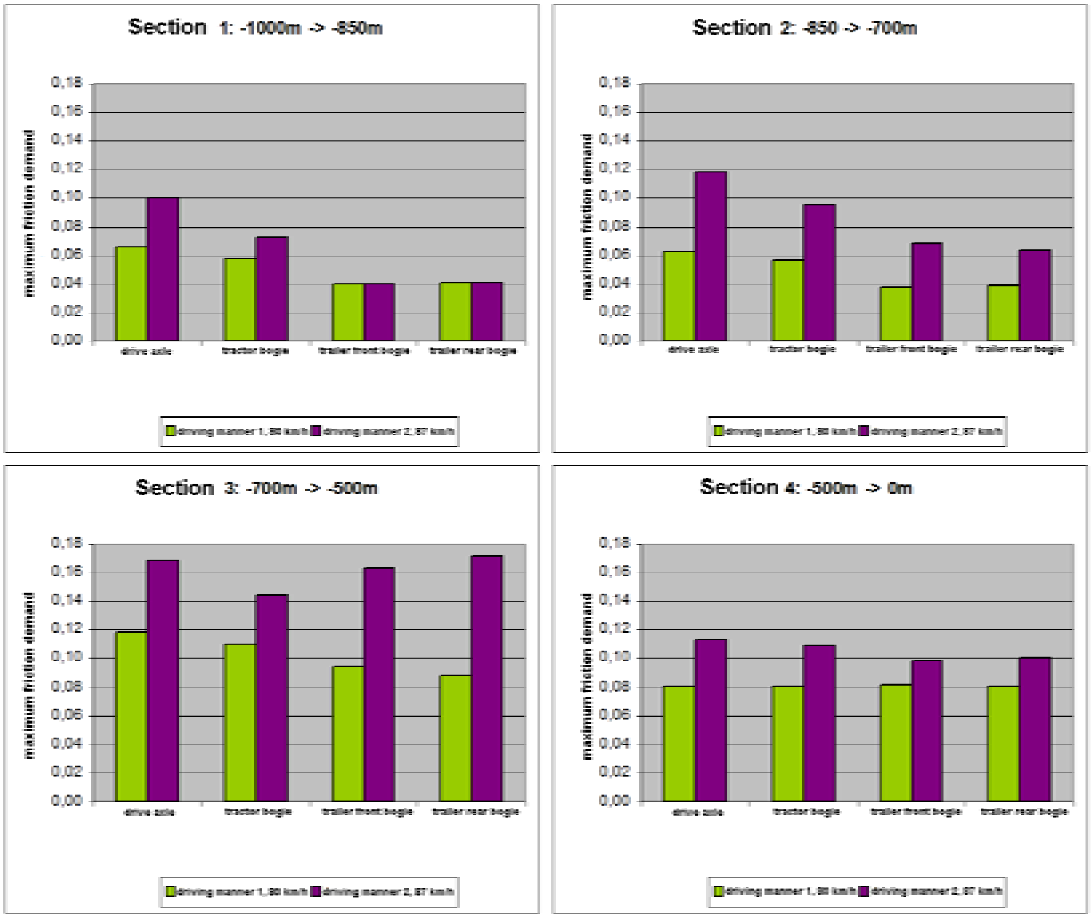


Figure 31. Summation of friction demand maxima on the different sections of the road when a one metre lateral shift cut to the apex of the turn is interrupted.

Figure 31 shows that the highest friction demand is placed on the trailer's rear bogie on section 3 during driving manner 2. Friction demand at the end of the cut to the apex clearly exceeds the demand of uphill drive traction. The trailer bogie friction demand (0.16-0.17) matches the friction of dry ice.

Synopsis of the simulation results

Although simulations were modelled to correspond accurately to the collided vehicle's characteristics and road geometry, some of the questions did not receive precise answers. The most significant risk factors were the lack of exact friction data at the time of the accident as well as the uncertainty over what kind of steering input the driver made right before the trailer began to fishtail.

When the results were analysed, the highest friction level of wet ice 0.14 was used as the default value. Based on the simulations, the following conclusions could be made:

- The most significant factor on handling was the smoothness of steering inputs and the second most significant factor was speed
- Both the curve and the downhill could be successfully completed without loss of control with driving manner 2 (87 km/h), provided that one drove along the centre of the lane
- The downhill section could also be successfully completed with driving manner 2 (87 km/h) with a 0.64 m lateral shift
- A one metre lateral shift during driving manner 2 (87 km/h) clearly raises the friction demand above the friction of wet ice
- A one metre lateral shift during driving manner 1 (80 km/h) caused no control problems.

The simulations did not explore what the highest possible lateral shift on wet ice using driving manner 2 (87 km/h) would be without resulting in loss of control. Based on the results presented above, however, it can be stated that a lateral shift between 0.64 and 1 m results in friction demand exceeding the friction of wet ice, i.e. 0.14.

In addition, simulation showed that:

- The effects of wear grooves, longitudinal road heaves and camber variations on the loss of control at the time of the accident could not be accurately proven. However, simulation does demonstrate vehicle roll in the curve on the hill
- Engine braking did not result in loss of traction on the drive wheels
- The excessive load increased the risk for losing control
- The effect of tyre pressure imbalance on the handling of the vehicle could not be confirmed.

The re-enactive test run with an actual vehicle combination showed that the force on the drawbar and the drawbar angle during engine braking were so small that they did not generate any significant jackknifing effect. The trailer brake lag did not produce a sizable force pushing the drawbar.

2.2 Situational speeds of both vehicles

2.2.1 The vehicle combination

The tachograph disc shows that the driver used cruise control on the Helsinki-Heinola leg, selecting approximately 85 km/h as his speed. On the Heinola–Viitasaari and Viitasaari–Konginkangas legs, the driver probably pushed the speed limiter because the speed was for the most part somewhat higher compared to the motorway section. However, due to the hilly terrain speed varied greatly, especially with regards to lower speeds. The disc showed that on the return leg from Viitasaari to Konginkangas the speed varied towards lower speeds even more than on the outward leg, evidently because of the heavy load. Approximately four minutes before the accident the speed of the tractor-trailer peaked at 94 km/h and for the final minutes preceding the collision the speed mostly remained at 80-90 km/h. Speed increased on downhill sections only to decrease on uphill sections. Due to hard braking and the fact that the trailer had swept the side of the road, the speed at impact was around 70 km/h.

When the driver of the full trailer combination drove to Viitasaari approximately one hour before the time of the accident the road was clear and dry. According to his account, the slipperiness of the road caught him by surprise on the downhill section preceding the site of the accident. The tractor-trailer was fitted with a wheelspin warning system but, according to the driver, the alarm did not go off at any stage. The slipperiness of the road also surprised the driver of a car trailing the vehicle combination as he was planning to overtake the tractor-trailer approximately one kilometre before the site of the accident. He detected the slipperiness when the back end of his rear-wheel-drive car briefly skidded.

It is customary in heavy traffic to push the speed limiter to approximately 90 km/h even in winter conditions. An automatic traffic monitoring unit, some 14 km south of the accident site, recorded that vehicle combinations maintained an average speed of 85 km/h during the night of the accident and coaches drove at 90 km/h. The winter speed limit on that section of road is 80 km/h.

Experiences from previous investigations of fatal heavy traffic accidents show that many losses of control are caused by excessive situational speeds. In winter, the situational speed refers to a speed appropriate for the road weather conditions. Often the reasons for high speed are driver judgement error when it comes to the level of slipperiness, negligence, haste created by the transport chain or tight schedules. This accident was not caused by tight schedules because the cargo would only have been taken from the terminal to the harbour later on that morning. The investigation commission’s opinion is that, in this case as well, the reason for speeding was the generally accepted and widely used practice among heavy traffic drivers to exceed the vehiclewise speed of 80 km/h.

The safe flow of highway traffic largely depends on weather conditions, including road adhesion. Unexpected or local slipperiness or exceptionally heavy snowfalls repeatedly generate the kind of driving conditions in various parts of Finland in which, from the viewpoint of traffic safety, it would be necessary to at least reduce speed or even stop driving altogether until the roads are cleared or de-iced. However, the Finnish heavy traffic culture does generally not embrace such caution.

2.2.2 The coach

According to the tachograph disc, the driver drove the Helsinki-Tampere motorway section by pushing the speed limiter to around 104 km/h. On the Orivesi-Konginkangas section, the vehicle was mostly driven at around 90 km/h, varying on the uphills and downhills. During the trip the speed exceeded 100 km/h several times.

In the driving direction of the coach, the road had been slippery for at least 20-30 kilometres prior to the site of the accident. Therefore, it can be presumed that the driver was aware of the low adhesion. However, slipperiness can not be inferred from the speeds recorded on the tachograph disc. The disc showed that during the final minutes preceding the accident the coach was for the most part travelling at 90-100 km/h. Approximately 4.5 minutes before the collision the speed momentarily peaked at 113 km/h. The roadwise winter speed limit was 80 km/h and there was an elk warning sign in effect for the area of the accident.

From the speed of 90 km/h braking began at approximately four seconds before impact. According to the tachograph disc, speed at impact was ca. 60 km/h. However, taking into account the ABS brake system’s inherent speed display error, the speed at impact was ca. 70 km/h. A reduction of 20 km/h in speed within four seconds would have required 0.14 friction.

At the time of collision, the coach was travelling in its own lane and nothing points to loss of control. Evidently, no evasive manoeuvres were attempted. The coach was fitted with ABS brakes and, thus, it would have been steerable even under full braking. From this it can be concluded that the driver was never aware of the fact that he was about to collide with a destructive object in his lane. Apart from braking, he did not have the time to make the decision of swerving around the obstacle. The front wall of the trailer was white, embossed with the company name. There were white low-intensity outer edge lights in the corners of the front wall. The technical inspection showed that at least the upper lights were on at the time of the collision. A lower speed might possibly have given the driver enough time to make the detection and decision to execute an evasive manoeuvre. Furthermore, a lower speed would have made it easier for the driver to make the difficult decision to drive deliberately off the road. The consequences of driving off the road would have been significantly less serious than the collision’s were.

The investigation commission considers it likely that a collision would not have taken place in daylight or on a lighted section of the road. In such conditions, the coach driver would have detected the tractor-trailer’s control problems from afar; he would have followed the development of the situation, reduced his own speed, made the decision to complete an evasive manoeuvre and subsequently would have swerved around the trailer by driving off the road. Darkness was a significant condition factor, which required lower speeds than daytime driving.

2.3 Drivers' working hours, driving and rest periods

General

The purpose of regulating drivers' driving and working hours and rest periods is, among other things, to maintain their state of alertness. Studies show that when a driver is tired, his attentiveness and functioning deteriorate and his reaction speed decreases.

Drivers can not be held as the only ones generating traffic risks. Risks are also inherent in the hauliers' operating culture and clearly show deficiencies in their quality systems. In addition to drivers and hauliers, the other links in the transportation chain can also be regarded as traffic safety factors. Their assignments and demands can generate overly tight schedules and haste, spawning risks.

2.3.1 Driver of the vehicle combination

The driver of the full trailer combination had only partially taken the prescribed brakes during the shifts preceding the one of the accident. He usually began taking his first long break at 02:30-04:00, i.e. some 7-8.5 hours from the beginning of his shift.

The tachograph disc used on the night of the accident revealed that the driver had not adhered to prescribed driving hours and rest periods during this shift either. In addition, the maximum uninterrupted working time was exceeded.

The investigation commission also examined the tachograph discs of some of the other drivers working for the same company on the approx. 750 km long Helsinki–Viitasaari–Helsinki leg. The investigation exposed that it was only possible to remain on schedule by pushing the speed limiter (ca. 90 km/h) and by allowing the speed to increase to 95-105 km/h on downhill sections. Furthermore, drivers took fewer breaks than required.

The investigation commission also examined the tachograph disc of another driver working for the same company driven on the very same Helsinki–Viitasaari–Helsinki leg on 22-23.3.2004 after the accident. At that time, the vehiclewise and roadwise speed limits were adhered to. The average speed was 73 km/h and the driving time was 10 h 48 min (the maximum driving time is limited to 10 hours twice per week at most). Breaks had been taken almost as per regulations. The combined break time was 1 h 9 min (the required minimum is 1 h 30 min). The maximum working time was 14 h 14 min (the maximum permissible working time is 15 hours three times per week at most). The distance covered was 791 km.

The driver on the northern leg (Rovaniemi–Viitasaari–Rovaniemi) of the transport chain repeatedly exceeded the 10 hour daily driving limit. Once he logged over 11 hours (11 h 19 min). Even though the driver pushed the speed limiter and went even faster on downhill sections, he exceeded the maximum driving time limit. The distance covered was approximately 925 km. Furthermore, on at least one of the days he had done other work during the times designated as breaks on the disc.

2.3.2 Driver of the coach

The coach driver had not used the tachograph's mode switch during his previous driving shifts and, therefore, the disc displayed no breaks. However, they were recorded in his work schedule report. No aberrations from prescribed break times could be noticed in the report.

The coach driver's route plan

The driver of the coach involved in the collision was assigned the Vantaa–Helsinki–Tampere–Jyväskylä–Oulu–Kuusamo–Ruka route, altogether a distance of about 910 km. The driver had almost fully complied with the prescribed driving hours and break times.

The driver pushed the speed limiter during the first leg, to Tampere, driving to around 106 km/h. The average speed from the beginning of the trip to the accident site was ca. 87 km/h.

In the opinion of the investigation commission, it is impossible to complete the Helsinki–Tampere–Jyväskylä–Oulu–Ruka trip within the maximum daily driving time of 10 hours adhering to speed limits. It is difficult to complete chartered trips from Helsinki to the ski resorts in the north using only one driver because the maximum daily driving time would then be exceeded.

2.3.3 The state of alertness of the driver of the vehicle combination

This investigation examined the vehicle combination driver's tachograph discs for every driving day of the week of the accident and the last driving day of the week that preceded the accident. The data revealed that driving and working hours as well as break time regulations were not completely followed.

The work shift on the night of the accident was the driver's fourth consecutive night shift. According to the driver's account, he had slept for approximately five hours during the day prior to his shift and had had a regular meal at home at around 17:00. During the trip he had taken an eight minute break at 22:45. He had not taken the required 45 minute break after having driven for 4.5 hours. By the time of the accident, he had logged 5 h 10 min of driving time. The driver had started working at the terminal at around 19:30 and, hence, had accumulated 6 h 38 min of working time by the time of the accident. This exceeded the maximum uninterrupted working time of 5.5 hours, as stipulated in the collective agreement.

Studies show that getting less than six hours of sleep the night before a drive increases the risk of an accident. The latest studies (in the USA) show, among other things, that the fourth consecutive night shift is clearly more accident-prone than the third night shift. This is due to accumulated fatigue. Many studies show that daytime sleep is qualitatively inferior to night time sleep and does not provide equivalent rejuvenation.

According to earlier studies, the risk of a traffic accident peaks between the hours of 01.00-05.00. The risk of a fatigue-induced accident is increased by lack of sleep due to previous night shifts, sleep deprivation caused by inadequate sleep and the small hours of the morning.

The driving fatigue of professional drivers has been extensively studied in many countries. Results show that long-distance lorry drivers do not sleep enough in order to be sufficiently alert on the road. The greatest danger of falling asleep at the wheel occurs in the small hours. According to studies, fatigue reduces one’s reaction speed, impairs one’s attentiveness and one’s capacity to anticipate future events as well as easily leads to making bad decisions. Unintentional vehicle speed deviations and steering overcorrections are routinely uncovered in fatigue-induced accidents.

Sleep deprivation from the preceding days and driving at night probably resulted in a less-than-optimal state of alertness for the tractor-trailer driver.

The fact that the driver did not react to the change in road weather conditions can be considered a symptom and consequence of fatigue in this investigation. In addition, the choice of driving line and the unnecessarily hasty return to the driver’s own lane, in view of the conditions, can also be seen as consequences of fatigue.

2.4 Route planning and supervision

(Abridged from the original Finnish text)

From looking at Transpoint Oy Ab’s material on work schedules and duty rosters, it can be inferred that there were shortcomings in the planning of transports and in the supervision of the drivers’ working hours and rest periods.

The company had not planned the routes in a way that complied with driving and working hour and rest period regulations. Because of this, the 10 hour maximum daily driving time was exceeded on long legs, breaks were not always taken and speeding took place. A good example is the Helsinki-Rovaniemi trunk route, which was driven in two segments at the time of the accident. At that time it was impossible to complete the route by adhering to driving hour and rest period regulations. Soon after the accident, the company changed the route to be driven in three segments.

The company’s monitoring of tachograph use was inadequate. In many cases the mode switch had not been used as per instructions. For example, the driver had designated the loading of paper reels as a rest period, even though he was ratcheting the reels during this time.

Transpoint Oy Ab had partly violated its own operations manual and business manual. Immediately after a shift, the driver gives a copy of the tachograph disc to the employer. Violations that were discernible on the disc were not dealt with. Supervisors are instructed to monitor that transport activities are completed in accordance with the law. Based on the analysis of this transport route it can be concluded that supervisors had neither reacted to driving hour and rest period violations nor to speeding, all of which were conspicuous on the tachograph discs.

Based on Sunny Buses Ltd working schedule material it can be construed that the Helsinki-Ruka route was improperly planned. Had the driver adhered to winter speed limits and to rest period regulations, the trip could not have been completed within the maximum 10 hour daily driving time limit. In many cases the tachograph mode switch was not used as per instructions. Tachograph monitoring was not routine in this company either.

2.5 Examination of responsibilities between the parties: the customer, the haulier and the driver

2.5.1 Driving hours and rest periods

When traffic control exposes violations in driving hours or rest periods, it is usually only the driver who receives a warning or a penal order from the police. Even if the violation was caused by the haulier's driving assignment it is a complicated process to make the company answer for the violation. If necessary, the relevant district administration for occupational safety and health audits the haulier. If significant driving hour or rest period violations are discovered, the district administration notifies the police or the prosecutor. The police conduct a pre-trial investigation to establish whether to issue fines or to forward the material to the prosecutor. The prosecutor deems whether the case warrants prosecution.

A haulier's customer can only monitor driving hours or rest periods or maximum speeds by introducing germane clauses in transport contracts. Issues furthering traffic safety can be included in contracts and the customer can be given the right to inspect tachograph discs from transports containing their cargo.

The investigation commission maintains that it should be possible to also hold the customer responsible for driving hour and rest period violations in instances where the customer has exercised, for example, the right to direct the work of the driver. This was not the question, however, in this case.

The coach's trip schedule was planned at Sunny Buses Ltd charter sales. Since comparable trips had been completed before, Sunny Buses' driving arrangements staff decided to go ahead with the trip the way it was eventually implemented without consulting the driver.

2.5.2 The excessive load

(Abridged from the original Finnish text)

Transpoint Oy Ab and the plant supplying the paper reels planned the transport together. Transpoint had available transport capacity on its route from the north to Helsinki and the plant had freight to be delivered from Kemi to Helsinki harbour. The plant and Transpoint agreed on the transportation of approximately 37-38 tonnes of paper reels.

Transpoint's transport planning assigned a full trailer combination which was capable of hauling ca. 34 000 kg of cargo. The driver participated in the loading by designating and defining the total weight taken on as cargo. It was at this point that the Gross Combination Weight was exceeded by 4 005 kg. The investigation commission's impression is that both the haulier and the driver on the northern leg were aware of the excessive load. The haulier reaped the benefit from the excessive load because it was remunerated based on transported weight.

In Viitasaari the driver who had departed from Helsinki received the swap body and the trailer, both of which had been loaded in Kemi. Since the Net Vehicle Weight of the tractor coming from Helsinki was greater than that of the NVW of the tractor on the northern leg, the GCW was then exceeded by some 4 100 kg. It was not possible to reduce the load in Viitasaari.

2.6 The effect of the transport system on the occurrence of accidents and its possibilities to prevent accidents

(Abridged from the original Finnish text)

Road traffic legislation primarily places the onus for traffic safety on the driver. Legislation does not take into account the effect of the transport chain on the transport itself. Instead, the underlying idea is that the driver has unlimited decision-making powers over his own actions. Even though the driver's role on traffic safety is paramount, he has only limited influence on transport planning, schedules and route selection. In other words, it is not the driver who makes the ultimate decision on the aforementioned issues.

The decentralization of supervision and decision-making powers, common in the professional transport business, may generate risks coming from within the system. As an example, among others, one can mention such route and schedule planning which ignores the risks inherent to the season and those arising from potentially adverse road conditions. Tight schedules and transports planned in a manner making it is impossible for the driver to complete the transport without breaking driving hour and rest period regulations or daily working hour limits, are also system-generated risks.

The case under scrutiny reveals several system-generated risk factors. The work shifts of both drivers involved in the accident were planned to last too long. The fact that both of them had been speeding could have been their attempt to complete the trip without exceeding the maximum daily driving time.

Based on this investigation, previous accident investigations and heavy traffic safety studies, it can be stated that there are system-generated risks in the heavy traffic sector. In order to raise the safety level these risks should be confronted in the planning of both cargo and passenger transports, in transport legislation as well as in transport control and accident investigation.

2.7 Control of licensed transport of goods and passengers

The local state provincial office issues transport licences to transport businesses that are subject to licence. A transport licence is issued to an applicant who is reputable, professional, financially sound and also otherwise suited to carry out transports. The licence can completely or temporarily be revoked, should the licence holder fail to comply with the conditions of the licence. If the detected violations are minor, the licence holder can be issued a warning in lieu of revoking the licence. The licence holder’s local state provincial office makes the decision either on revoking the licence or on issuing a warning.

It is mentioned in the Decree that the licence holder’s local police must notify the licensing authority of issues, which could be presumed to result in the revoking of a licence or in a warning. Transport licences have never been temporarily or completely revoked in Finland even in the case of recurring violations.

2.8 Managing of road maintenance

During wintertime the road weather centres, operated by road maintenance contractors, monitor weather developments and the need for road maintenance. The centres estimate the near future weather by comparing information gathered by weather satellites, doppler weather radars, road weather stations and weather cameras. When necessary, the centres initiate road maintenance activities. The Finnish Road Enterprise’s Helsinki road weather centre, which also covers the Central Finland region, monitors a total of approximately one hundred road weather stations and weather cameras.

Based on information at hand the road weather centre supervisor estimates the next few hours’ development in weather. The supervisor monitors the doppler weather radar picture in order to establish the track of rain fronts. He or she also checks whether a rain cloud has passed over road weather stations in such a manner that the amount of precipitation is discernible. By combining the information gathered from road weather stations (surface moisture, cooling, conductivity), from weather cameras and from prevailing weather forecasts, the road weather centre supervisor estimates how road weather will develop. Based on the collected information, he or she then makes a decision on what maintenance activities the future weather warrants, if any.

According to the road weather centre supervisor the prevailing forecasts on highway 4 at Konginkangas did not contain such information, which would have required anti-icing that night.

Local scattered showers formed in the Bothnia region moving east-southeast during the evening before the accident. The Finnish Meteorological Institute’s doppler weather radar picture showed that the showers passed Kyyjärvi municipality at around 22:00. It rained at Konginkangas at around 23:00 but at that time the road surface temperature was above freezing. It is probable that the pavement dried due to traffic because the driver of the tractor-trailer held that, as he was on his way towards Viitasaari at around 01:00, the road was dry.

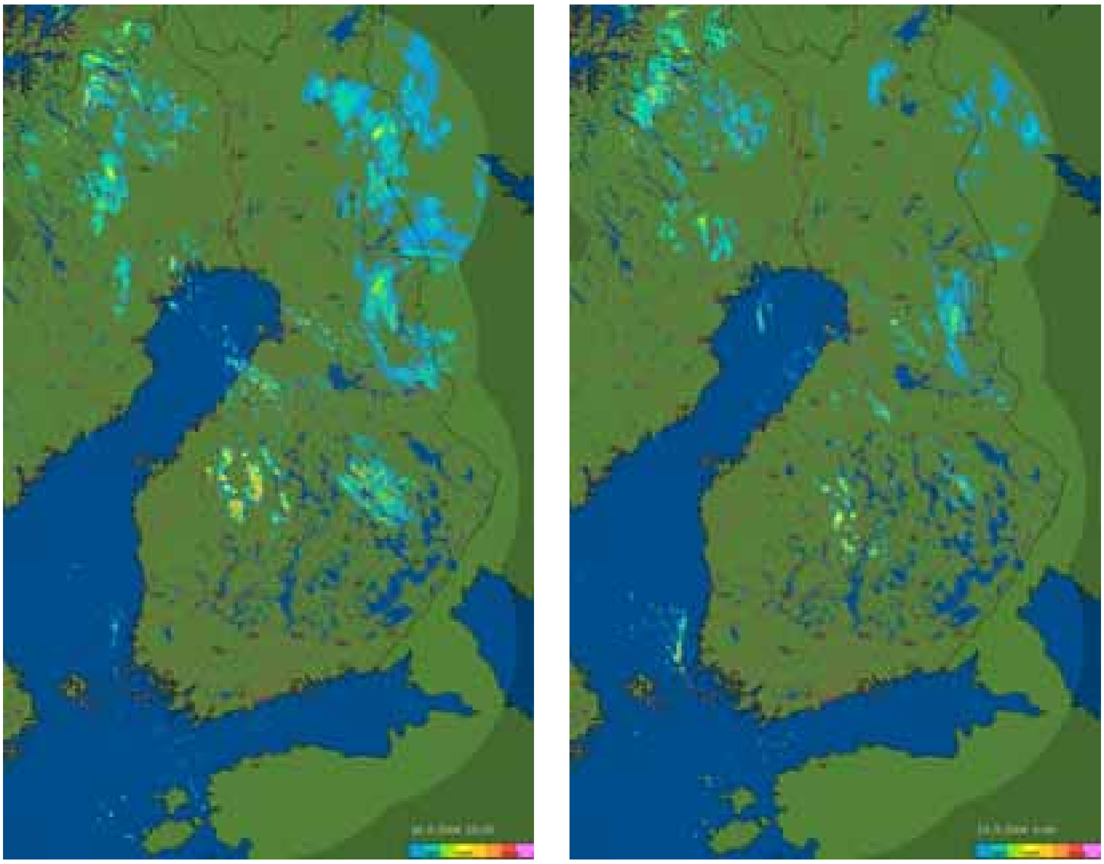


Figure 32. Doppler weather radar pictures at 22:00 and at midnight. Due to a technical malfunction the doppler weather radar picture was not updated after midnight.

The last updated doppler picture at midnight showed the next rain shower front close to Kannonkoski, some 30 km west-northwest from Konginkangas, moving towards the accident site. At that time the Konginkangas and Äänekoski road weather stations indicated that road surface temperatures were about one degree below freezing. The rain, extending about 10 km both north and south from the accident site, fell on highway 4 at around 01:30.

The doppler weather radar picture is one of 14 monitored computer displays at the road weather centre. Due to a malfunction the picture was not updated on the Helsinki road weather centre displays between midnight and 04:00. The supervisor did not notice the update malfunction because the system continued to repeat an animation of the situation that had prevailed until midnight.

In the case in question, the decision on anti-icing measures on highway 4 at Konginkangas should have been taken around midnight so that they could have been implemented in time before the accident took place. At that time the road weather centre supervisor still had access to all available information for weather analysis. The Konginkangas and Äänekoski road weather stations indicated a drop in pavement temperatures to below freezing and warned about impending frost. However, the road weather centre supervisor did not feel that the weather development warranted anticipatory anti-icing. The post-midnight malfunction in radar picture updates did not have any effect on the road weather centre supervisor’s decision on the need for anti-icing.

In hindsight, the first indication of rain in the accident area was noticeable in the Petomäki weather camera image taken at 01:36. This camera is located ca. ten kilometres south of the accident site. Konginkangas road weather station data warned of rain at 02:18. Owing to sensor technology and the data transmission network the communication is neither completely reliable nor real-time. Even if the road weather centre supervisor had detected the rain in the weather camera image and concluded that the pavement was freezing and then alerted the maintenance contractor, there would not have been enough time to de-ice the road before the accident.

2.9 Meteorological and road weather conditions

Weather constitutes an unalterable element in the traffic environment. Hence, one must take weather conditions into account in all activities and adapt to them. Different weather phenomena cause road slipperiness but this can not be considered as the direct cause of the accident, albeit on several occasions it has been a significant indirect cause in accidents involving loss of control. In this particular case the system, established for road maintenance and anti-icing, did not receive the information on fairly localized slipperiness and, thus, did not properly function. Pertaining to road condition issues, drivers or authorities can alert Finnra’s Traffic Management Centre by calling the Road User's Phone Service number 0200-2100. Prior to the collision on the night of the accident, nobody had called this number from the Äänekoski-Viitasaari section of the road.

Several times each winter rapid and significant weather phenomena occur in Finland which worsen local road conditions and to which the road maintainer can not immediately react. In these instances it is up to the road users themselves to maintain traffic safety. The quickest and the best way to maintain traffic safety is to reduce speed to match the road conditions. The appropriate speed for the road conditions can not be determined in advance. Instead, the driver must be able to select the proper speed by using his judgement and by taking the characteristics of his vehicle into account. Nevertheless, the speed in slippery winter conditions should never be identical to the one used in summer conditions.

2.10 Alerting of exceptional road weather and road conditions

(Abridged from the original Finnish text)

Nowadays, heavy vehicle drivers keep each other informed of road hazards by CB radio or by mobile phones. This communication is based on driver initiative. The receiving of information on, for example, road conditions is sporadic at best, because not all vehicles are even fitted with CB radios.

After this accident the Finnish Meteorological Institute, the Finnish Road Enterprise and TeliaSonera started to develop a commercial route weather forecast and warning service for professional drivers in the heavy transport business. The pilot phase of the so-called VARO service began in the autumn of 2005 and the target date for taking the service into operational use was 1.1.2006. The service provides route weather forecasts and real-time warnings.

The route forecast service provides a road weather forecast for the following 2-6 hours on the selected route. The forecast can also include information on other known problems along the route.

The real-time warning service alerts drivers of suddenly altered road weather conditions or other traffic hazards, for example. The first warning is issued to drivers within 22 km of the location of the hazard. In addition, vehicles within a 160 km radius from the hazard are tracked. If necessary, they are also warned of the situation. Warnings are broadcast by voice mail messages on mobile phones. Road weather traffic warnings are short-time forecasts, valid for 0-2 hours.

2.11 The effect of tyres on the behaviour of both vehicles on a slippery surface

(Abridged from the original Finnish text)

General

Vehicle control is based on the friction between the tyres and the road surface. Friction is affected by the tyre’s normal force as well as the friction coefficient between the pavement and the tyre. The tyre’s tread pattern, tread depth, quality and hardness of the rubber compound, tyre pressure as well as the condition and roughness of the road surface have an effect on the friction coefficient. The friction coefficient of a non-studded tyre on dry asphalt is 0.5-0.8. Impurities, such as water, snow or ice, reduce the friction coefficient. The friction coefficient of a non-studded tyre is 0.2-0.4 on dry snow, 0.15-0.20 on dry ice and 0.05-0.14 on wet ice, respectively.

The traction of heavy vehicle tyres on an icy road is inferior to that of car tyres. The reason for this is the large surface pressure and that tyres heated during the drive melt ice from under the tread, forming a film of water at the contact area. Especially when the ambient temperature is close to 0 °C, the friction coefficient between the tyre and the icy pavement can be as low as 0.05-0.14. In practice, this means that diminutive external impulses or changes in the driving situation can result in loss of traction and vehicle control.

2.11.1 The tyres of the vehicle combination

The average tread depth was 11 mm, translating into approximately 60% of the tread still remaining. Almost all tyres carried the M+S designator, which means that the tyres were suitable for winter driving. Three retreaded tyres did not have the M+S marking but their tread patterns matched that of an M+S pattern.

The two right hand tyres on the first axle of the trailer’s front bogie were clearly more worn than the other tyres. Their tread depths were lower and the tyres were older than the trailer's other tyres. The lowest measured tread depth on the outermost tyre's outer edge was approximately 1 mm. Tread depth on the inside edge of the tyre was approximately 8 mm. The rubber compound used on this tread was harder than on the other tyres. Because of the aforementioned reasons the winter traction of these two tyres was poorer than of the others. The other six tyres on the trailer's front bogie axles were in good shape. The required minimum tread depth on heavy vehicle tyres, in wintertime too, is 1.6 mm, whereas the corresponding requirement for car tyres is 3 mm.

Almost all of the tyres on the trailer were slightly underinflated. According to a tyre expert this fact had little bearing on tyre traction on a slippery surface. Simulation proved that underinflation affected road stability less than expected. A twin wheel setup increases stability and evens out the differences between the wheels.

2.12 The structural integrity of the body of the vehicle combination and load anchoring

2.12.1 The structural integrity of the trailer's body

(Abridged from the original Finnish text)

Finnish legislation does not provide structural requirements as regards the body of a full trailer. In practice, manufacturers of enclosed bodies construct the front wall of the load space in the same way they manufacture the front wall of the tractor's swap body. Structural integrity requirements exist for the front walls of swap bodies so as to protect the tractor's cabin. In the decision of the Ministry of Transport and Communications regarding vehicle load spaces, loading and cargo securing (14.12.1982/940 section 6 subsection 3), it is required that "the structure of the front wall withstands at least one third of the maximum load which the manufacturer permits for the body, however, not more than 60 kN".

The weight of the cargo in the trailer was 24 985 kg and its average deceleration during the collision was ca. 50 m/s^2. The precise value of the force on the front wall can not be calculated because the exact deceleration and friction at the time of the impact remain unknown. According to a rough estimate, the cargo was projected onto the front wall with a force of more than 1 000 kN. This force exceeds the structural integrity requirement for the tractor's swap body front wall by almost 20 times.

No ordinary body structure could have survived the impact because the coach crushed the structure from the outside and the paper reels tore into it from the inside. Had the trailer's body been a steel sea container, for instance, it might have mostly retained its original shape and the paper reels would have remained inside it. In such case, the impact mechanics would have been different but, due to the considerable deceleration, the collision would have resulted in a large number of casualties anyway.

2.12.2 Load anchoring in the trailer

The paper reels on the floor were inadequately anchored. One of the reels in front was approximately 10 cm off the front wall of the load space and during the collision it generated lateral forces on the side wall and door of the body. The reel could have been buttressed against the front wall with, for example, a wood strut. No anchoring existed to resist forward forces.

The anchoring of the top row of paper reels was also inadequate. Two reels at the front of the trailer were positioned side-by-side on top of the front paper reels. One of them was approximately 10 cm off the front wall. This reel should have been buttressed against the front wall as well. No anchoring existed to block forward forces.

Friction between the reels was measured at 0.4 and the friction between the reels and the longitudinally grooved aluminium floor, measured at the grooves, was approximately 0.7. Taking into account these friction coefficients, the load in the trailer and the 10 m/s^2 (1 g) force of acceleration, the forward force generated by the cargo was ca. 110 kN. Since there is no strength requirement for the front wall of the body, it can not be calculated into the anchoring of the load. In this case the cargo should have been secured with tie-down straps to the anchoring points on the floor to resist any forward force. The straps selected should have been able to withstand the force of 110 kN (11 000 kp). In this case the load anchoring manual allowed the use of three tie-down straps with the rated strength of 2 000 daN (2 000 kp) and the tensile strength of 4 000 daN (4 000 kp) each.

Perpendicular beams resting on top of the two pairs of reels in the rear prevented their vertical movement. The rearmost pair was also secured to load anchoring hooks on the floor with a tie-down strap traversing the reels at a 45 degree angle in relation to the trailer's longitudinal axle. This was done with the intention of preventing the reels from sliding backwards.

The anchoring solution prescribed by law would not have survived the impact because the force was almost 10-fold compared to the required load anchoring. The inadequate load anchoring in the trailer had no causal effect on the occurring of the accident. However, it possibly exacerbated the consequences.

Many other heavy materials are also transported by road. In a possible accident they create a similar, if not even greater, risk of destruction compared to the paper reels in this accident. Among other things, only the cabins of vehicle combinations used in lumber transport are protected. Trailers have no protective structures whatsoever to block forward forces.

2.12.3 Load anchoring in the road tractor

The paper reels were not secured to the floor because there are no anchoring points on swap body (the so-called State Railways container) floors. The tie-down straps were fastened to wall anchoring rails and doors. The structural integrity of the wall rails renders them suitable for securing only tall and light loads to keep them from falling down. The row of three paper reels on top of the ones on the floor shifted forward in the collision and the front reels partly went through the swap body's front wall, damaging the rear wall of the tractor cabin. In this case, however, the inadequate anchoring had no bearing on the occurrence neither of the accident nor to the severe damage on the coach. A cargo space without floor anchoring points is unsuitable for transporting paper reels.

2.13 Index of the gross weights in the vehicle combination

(Abridged from the original Finnish text)

Pursuant to road traffic legislation it was permissible to hitch a full trailer to the tractor involved in the accident, since the towed weight did not exceed the 2.5 times GVW of the tractor, as per registration. The towed weight of the collided vehicle combination's trailer was 1.38 times the tractor's GVW, i.e. clearly below the legal maximum.

The weight index between the tractor and the full trailer affects the handling of the vehicle, especially when braking and during evasive manoeuvres.

2.14 Loosening of the passenger seats in the coach and the use of seat belts

2.14.1 Loosening of the passenger seats

After the rescue operation the only seats still in place in the back of the coach were the back row seats, three pairs of seats farthest back on the right side and the back pair of seats on the left side of the aisle. According to rescue personnel many other seats had also remained in place, albeit partially tilted forward. The aisle side seat legs had detached but the window side fastenings remained intact. Passengers were pinned under the seats and sandwiched between them. Many of the seats, both in the back of the cabin as well as those extricated or still in place, showed major structural bending caused by passengers having been thrown against the seat backs.

The chassis manufacturer puts the seats through a structural test during which the seat belt brackets under the seat cushions are simultaneously subjected to a tractive force of 21 700 N (ca. 2 000 kp). The seat belt brackets as well as the seat leg anchoring to the floor held. At the time of impact the passengers were subjected to an average deceleration of ca. 20 g (200 m/s^2). From this figure it can be calculated that, for instance, two persons weighing 70 kg each smash into the seat back with the force of approximately 28 000 N. The impact affects the entire seat back but for the most part targets the top part of the seat back. This creates a moment arm focusing a force which is 2-3 times greater than the tested tractive load on the seat.

2.14.2 Use of seat belts

(Abridged from the original Finnish text)

All seats in the coach were equipped with seat belts. The requirement of putting seat belts on every seat of a new coach entered into force on 1.10.1999. Seats, which had seat backs in front of them, had two-point seat belts. Those seats that did not have seat backs in front of them were fitted with three-point seat belts. Up until today the use of seat belts in coaches is voluntary and few people wear them. Judging from seat and seat belt inspection none of the passengers were wearing seat belts. During the investigation it became apparent that at least some of the passengers were even unaware of the existence of seat belts. Seat belts would not have saved the passengers up front but had the passengers in the back used them, some of their injuries would probably have been less severe and a couple of the passengers could possibly have even escaped alive.

The driver of the tractor-trailer did not sustain injuries in the collision. He wore his seat belt, which prevented him from being thrown around inside the cabin.

The large size of a coach and its relatively strong chassis protect passengers well in ordinary traffic accidents. Injuries are mostly sustained when passengers are flung from their seats. During driving-off-the-road accidents when the coach may roll over, seat belts are of paramount importance from the point of view of passenger survival. In such cases the seat belt prevents the passenger from flying off his seat and landing on other passengers. Furthermore, it keeps the passenger from falling through a broken window and protects against being crushed between the vehicle and the ground.

2.15 Driving stability of the tailored module trailer

When Finland joined the European Union, the so-called tailored module trailer was developed in Finland. It is of similar size to the full module trailer and is assembled by coupling a semi-trailer with a dolly and then hitching this combination to a tractor. Figures 33-35. The maximum permissible combined length of a tractor and module trailer is 25.25 m and its permissible GCW is 60 tonnes. Differing from the abovementioned two-part module trailer, the tailored module trailer’s front bogie is fixed.

It is already previously known that the road stability of a module trailer or a tailored module trailer is inferior to that of a semi-trailer. The road stability measurements conducted during this accident investigation yielded similar results. During test runs and simulations the trailer’s road stability clearly deteriorated as speed increased. Other negative factors affecting the trailer’s road stability are increased axle suspension play caused by wear, weak shock absorbers and a worn out fifth wheel.

Figure 33. Semi-trailer

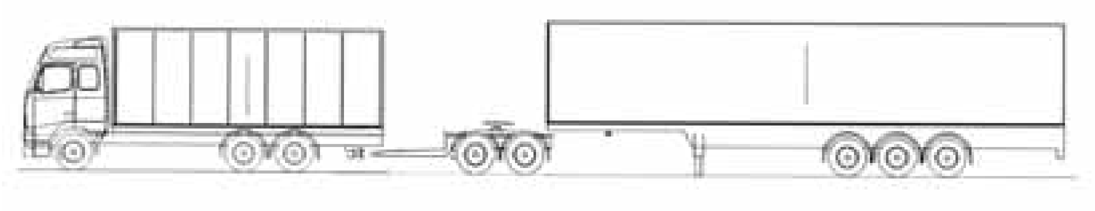


Figure 34. Module trailer assembled from a separate dolly and a semi-trailer.

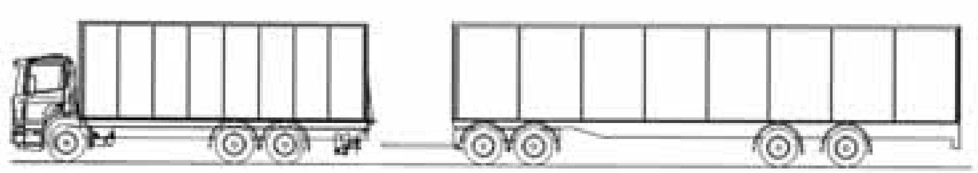


Figure 35. Tailored module trailer with a fixed front bogie. (This was the type of the vehicle in the accident.)

These days an ESP (Electronic Stability Program) road stability system is available for most lorries and trailers. Soon a road stability system will also be available for full trailers. This system is intended to react to danger in real-time and to commence braking as required. The system is capable of independently braking individual wheels and, thus, improves the vehicle combination’s road stability.

2.16 Compatibility between different types of brake systems

The tractor was fitted with electronic pneumatic disc brakes (EBS) and the trailer with pneumatic drum brakes (ABS). Both brake systems were anti-lock brakes. The investigation commission attempted to establish the effect of the compatibility and of the dissimilarity of these different “generation” brake systems on the accident. Test runs showed that the brake lag of this combination could exceed the maximum permissible lag by two and a half times. During brake lag, the trailer pushes the tractor. The forward force measured on the drawbar during the test run was fairly small but then again, no hard braking took place during the runs. In slippery conditions the forward force may play a part in the loss of control.

Provisions that apply allow the coupling of vehicle units fitted with dissimilar brake systems. For example, an EBS-brake tractor an EBS-brake trailer can be coupled even if an ABS-brake dolly is hitched between them. It is also permissible to hitch an EBS-brake or an ABS-brake tractor to a trailer fitted with neither of these brake systems.

The investigation commission attempted to establish how the coupling of electronic brakes with pneumatic brakes affects traffic safety. The commission found that experts and vehicle operators disagree on how different types of brake systems function in vehicle combinations. Furthermore, the rapid development in EBS brakes and the fact that several system versions are already in use add to the uncertainty as regards the functioning of the systems. The investigation commission notes that due to the prevailing uncertainty, no reliable or explicit conclusions regarding the compatibility of dissimilar brake systems can be made.

The investigation commission considers it important that a thorough separate study be made on the coupling of vehicles fitted with dissimilar brake systems. The Finnish Vehicle Administration has launched a research project related to the topic called: “Standardizing the dynamometer testing of heavy vehicle brakes”. The project explores, among other things, the behaviour of different types of vehicle combinations during braking. Should the results prove that mixed brake system couplings generate questionable combinations from the point of view of traffic safety, permissible combinations should be then indicated in vehicle registrations.

2.17 Communicating by flashing headlights

The driver of the tractor-trailer said that he flashed his high beam headlights to warn the coach of his vehicle handling problems. The tractor had extra high beam headlights mounted above the windscreen. The investigation commission reconstructed the headlight flashing situation during a test run at Konginkangas on 11.12.2004. The commission watched the flashing of the tractor’s headlights from where the coach was estimated to have been at the time. It was noted that short flashes did not cause glaring.

Flashing one’s headlights is a common manner for drawing an oncoming vehicle’s attention to some unexpected traffic situation. However, no explicit interpretation exists for communication by headlights. Therefore, the driver who is being flashed at must always interpret the reason for the signal. Still, the investigation commission regards it possible that the headlight flashing alerted the driver of the coach and possibly caused him to initiate braking earlier.

2.18 Developing the heavy traffic accident investigation process

(Abridged from the original Finnish text)

Apart from major accidents, all fatal road and cross-country traffic accident are investigated by regional accident investigation teams organized by the Finnish Motor Insurers’ Centre. The investigation method is standardized to apply to all accidents and it does not specifically take into account the peculiarities of heavy traffic.

Almost every working day a heavy vehicle combination drives off the road in Finland. When it comes to other than fatal heavy traffic accidents, no dedicated accident investigation system exists. Usually the police only conduct a pre-trial investigation in order to establish any possible criminal liability. Hence, all direct and indirect factors contributing to heavy traffic accidents are not established in enough detail. These factors include, for instance, working hours and rest periods, route planning, cargo and loading, driving speeds as well as the types and condition of vehicles. However, to develop heavy traffic safety, it is imperative to establish these factors.

The Road Accident Investigation Delegation, responsible for road and cross-country traffic accident investigations, should study all heavy vehicle combination accidents that are reported to police. This could be done, for example, in some given region and at least for a fixed period. Investigations should cover all accidents irrespective of their consequences. Every single loss of control of a heavy vehicle constitutes a potential major accident. It is only happenstance when the prospective major accident converts into an actual one.

2.19 Developing the lorry simulator

(Abridged from the original Finnish text)

Simulators have already been in use for a long time in aviation and navigation. When it comes to basic training and particularly to training for emergency situations, they are indispensable. Simulators can also emulate hazardous conditions and they offer opportunities for practicing correct control inputs in emergency situations, which would otherwise be impossible to replicate for safety reasons.

There are many European lorry simulator manufacturers. The investigation commission thinks that lorry simulators could benefit both basic and advanced lorry driver training. By simulating different vehicle combinations as well as difficult road and road weather conditions, one can safely practice “driving” even while pushing the envelope of vehicle control.

2.20 Operation of the emergency response centre

2.20.1 Response plans corresponding to emergency codes

(Abridged from the original Finnish text)

The authorities direct Emergency Response Centres (ERC) by establishing alarm procedures, on the basis of which response plans are created. Response plans list the units that the emergency response centre must immediately dispatch. Furthermore, the ERC must carry out the tasks given by the authorities within their powers at the scene of an accident. This could entail, for example, the dispatching of more units to the site than required by the response plan. The rescue authorities have the overall responsibility for directing rescue operations.

There was no specific major traffic accident emergency code in the emergency code list of the ERC of Central Finland. Traffic accidents were categorized in four groups: A traffic accident of unclear nature and traffic accidents involving minor, moderate or large kinetic energies, respectively. The large kinetic energy category refers to an accident involving, for example, an aircraft, train, lorry or coach.

Neither the health authorities in Äänekoski and in the Central Finland health care district nor the rescue authorities in Äänekoski and in the Central Finland rescue department had created a response plan for a major traffic accident, i.e. listed the rescue and ambulance units to be automatically dispatched in a major accident.

Based on the initial situation the appropriate rescue response would have been a so-called company alarm[4] (previously known as “area alarm”). At no stage was a company alarm sounded even though the rescue director should have ordered one after having been informed of the extent of the accident.

2.20.2 Alarm procedures for medical establishments and for their medical and response teams

(Abridged from the original Finnish text)

The ERC did not have instructions for alerting medical establishments. There were no existing instructions for alerting hospital medical and response teams either. According to Central Finland central hospital’s own operations manual a medical team is dispatched to an accident site if requested by police or rescue authorities. The Äänekoski Health Centre manual requires a response team to be dispatched to the scene of an accident by taxi whenever the health centre receives a major accident alarm.

2.20.3 Dispatching

(Abridged from the original Finnish text)

In evaluating the operation of KEHÄ (the ERC of Central Finland) as part of the rescue effort, the starting point must be the information that KEHÄ asked for and received from those calling in and reporting the emergency. The driver of the collided tractor-trailer made the first emergency call at 02:08:06. Within 37 seconds of the beginning of the call it became evident that the accident involved a tractor-trailer and a coach. Within 55 seconds of the beginning of the call it became known that paper reels had penetrated the coach. The location of the accident was established after one minute and nine seconds of the beginning of the call. KEHÄ received the next emergency call approximately three and a half minutes after the collision, establishing that there were some 40 passengers on the coach.

The ERC should have regarded the emergency as a major accident. In a major accident all available help must be dispatched as soon as possible. Had the proportion of fatalities to the injured been inverse in this accident, the number of rescue and ambulance units dispatched would have been woefully inadequate.

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[4] The “company alarm” tops the three-tier alarm scale used in Finland, dispatching at least nine rescue units.

The regional fire chief had drawn up a high kinetic energy accident alarm procedure for the Konginkangas area. As per this plan, a squad alarm was sounded at 02:10:50, i.e. about 2 minutes from the time of the first emergency call. The squad response comprised two fire units, one rescue unit, one personnel transport vehicle and four ambulance units. The number of units and rescue personnel dispatched was insufficient for a major accident of this nature. In practice, one seriously injured patient requires one ambulance and at least three fire fighters to extricate him. Due to the shortage of ambulances dispatched to this accident, the transportation of patients had to be prioritised in order of urgency, which was detrimental to the patients.

The Central Finland rescue department's Jyväskylä units should have been immediately dispatched. However, in this case they received the alarm only after some 30 minutes from the time of the collision.

Within about three minutes of the beginning of the first emergency call the ERC had unambiguous information about a tractor-trailer and a coach with some 40 passengers onboard being involved in an accident. At this phase the ERC should have reasoned from the nature of the accident that there could be large numbers of casualties. After having dispatched the rescue units prescribed in the response plan, further units were dispatched to the site one at a time, even though the Äänekoski fire chief, while enroute to the scene of the accident, had ordered several ambulance units to be dispatched. Nevertheless, the last ambulance was not dispatched until some 40 minutes after the first emergency call. In spite of the direct order, two available ambulance units in Jyväskylä as well as the units available at Laukaa and Pihtiputaa were not dispatched.

2.20.4 Dispatching air ambulance[5] and rescue helicopters

(Abridged from the original Finnish text)

The ambulance helicopter ILMARI (in Varkaus) was not available for air ambulance missions because the organization behind it had run out of the funds to employ a doctor.

Due to adverse flying weather the air ambulance SEPE (in Oulu) could not take off.

The air ambulance and rescue helicopters ILMARI and SEPE are not fitted with an alarm responder system by which a dispatched helicopter could acknowledge an alarm to the ERC and inform them of its possibilities of taking off to the accident site.

Emergency response centres should be aware of all possible alertable rescue helicopter and doctor units. This information should also be included in the area's alarm procedure with a major accident in view. When an accident takes place, the location and availability of air ambulances should be established from either the Air Navigation Services Centre for South Finland (EFES) or from the Northern Finland Air Navigation Centre (EFPS).

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[5] The air ambulances in question include a doctor as a crew member

2.20.5 Instructions to patients from the emergency response centre

(Abridged from the original Finnish text)

At 02:18:59 KEHÄ received a call from a female passenger. She said that she had been in an accident and that she wanted to proceed to the hospital immediately by a private car, which had arrived at the scene. The ERC operator attempted to persuade the caller to remain at the accident site by explaining that help was on the way. When the caller still insisted on leaving for treatment without delay, the operator gave her permission to go to a hospital.

The ERC operator should not have given the caller the impression that one can leave an accident site on one's own initiative. The operator did not ascertain her possible injuries, i.e. did not make a risk analysis. The patient’s condition could have rapidly deteriorated during the drive to the hospital.

2.21 Accident site clearance and casualty extrication

(Abridged from the original Finnish text)

This was an exceptional major accident in the sense that most of the passengers perished. Normally in a major accident some people die, more are severely injured, even more are lightly injured and most escape uninjured.

The rescue units at the site did everything humanly possible to extricate the casualties rapidly. The rescue effort was slowed down by the total destruction of the front of the coach as well as by the complete or partial loosening of almost all of the passenger seats. For these reasons the extrication had to be performed by continually clearing the vehicle structures before the casualties could be freed. The clearance was started at the rear of the coach.

2.22 Command of rescue activities

(Abridged from the original Finnish text)

The chain of rescue command at the accident site was somewhat blurred because three different firefighting supervisors, who arrived at the scene during the rescue operation, gave orders to the rescue personnel. The rescue personnel were uncertain as to who was actually in command and who had the overall responsibility for the situation at any given time. However, these command issues did not really impede the actual rescue activities.

The unclear chain of command also led to a lack of sequencing the work during the rescue operation. Being the first to arrive, the voluntary fire brigade of Konginkangas had to remain at the site for 17 continuous hours. Thus, some of the rescue crews had a very strenuous and extra long shift. Overwork and fatigue easily weaken attentiveness and jeopardize occupational safety. If an operation is exceptionally long-lasting and demanding, a unit's supervisor must monitor the behaviour and activities of his crew in the extreme conditions and rotate them in good time.

2.23 Use of the VIRVE network

(Abridged from the original Finnish text)

The public authority network VIRVE enables designating communications into call groups, thus preventing radio traffic from jamming during rescue operations. To benefit from VIRVE it is essential to be well trained in the use of the equipment and the system itself. Even though all rescue crews had VIRVE data terminals, some parties were unable to communicate with each other. All users, apart from the police, used the ÄÄNEKOSKI call group at the site and no other call groups were designated. Considering the communications at the accident site and even elsewhere, it would have been prudent to designate at least two distinct call groups: the medical group and the rescue group. KEHÄ recorded all VIRVE traffic, which transpired between the ERC and the units.

There was no ÄÄNEKOSKI call group on the VIRVE data terminal of the Jyväskylä rescue department unit transporting the central hospital's medical team to the site. Hence, the EMS doctor could not communicate with the on-scene rescue authorities. There were no VIRVE data terminals at the Central Finland central hospital. Therefore, the hospital could not communicate by VIRVE with the accident site and, correspondingly, the site could not get in touch with the hospital. There was no VIRVE terminal at the Äänekoski health centre, either. When a major accident occurs, it is imperative that the regional hospital's medical director, the response directors at alerted health centres, the medical and response teams as well as the on-scene medical commander can constantly communicate with each other.

2.24 How the medical rescue activities succeeded

2.24.1 Medical rescue activity

(Abridged from the original Finnish text)

The medical chain of command at the accident site was established before the first units arrived. The on-scene medical commander had already directed ambulance units while they were enroute to the site. The very same person remained in command during the entire operation. Early on, the on-scene medical commander designated the accident site call group for ambulance units arriving from a wide area.

Due to the fact that the casualties were difficult to reach and because of the nature of the accident itself it took a relatively long time to establish the number of patients. There was no communication link between the hospital's medical director and the on-scene medical commander. The on-scene medical commander said that he had tried to call the central hospital, however, in vain. There were no previously drawn up and clear-cut directives on who should contact whom at different locations. This is why, for example, the hospital tried to contact the rescue commander even though the operations manual states that the hospital should cooperate with the on-scene medical commander.

2.24.2 Ambulance transport and emergency medical services

(Abridged from the original Finnish text)

The first ambulance arrived at the scene of the accident at 02:29:07 and the last one at 03:25:07.

Because of the lack of ambulances the Äänekoski rescue department fire chief, who had assumed the on-scene medical command, had to resort to solutions not required in normal accidents. According to universal triage procedures very severely injured patients are left at the site to wait for transport so that priority can be given to those severely injured patients who are deemed to have a clear chance of survival. When ambulance resources are scarce, this can result in an exceedingly long wait for the very severely injured patient for transportation to hospital.

The initial assessment protocols were very incomplete. Several serious injuries had been undetected in the EMS phase. Patient monitoring during ambulance transport was insufficiently documented.

Basic level ambulance personnel administered medical care without consulting a doctor. Considering the long distance to the hospital the medical care was insufficient. Basic level ambulance units had to monitor severely injured patients during the transport to the hospital. Their skills were not up to par with this task; resulting in compromised patient safety.

2.25 Operation of the Central Finland central hospital

(Abridged from the original Finnish text)

KEHÄ alerted the Central Finland central hospital at 02:20:20, i.e. approximately 12 minutes after the first emergency call. Relying on vague casualty information the hospital's medical director decided to sound the full alarm because he estimated that there would be more than 25 injured patients. Large numbers of hospital staff were summoned to report to work.

The first casualty estimate was given to the hospital at 03:03:03. At that time the estimate included five deceased and 10 seriously injured but no additional information on any other possible casualties. The central hospital received the final casualty estimate at 03:10:27.

The hospital was well prepared when the first patients arrived. A complete medical team was assigned for each patient. Routine patients were treated elsewhere in the hospital. A sufficient number of security personnel guaranteed the patients' and their families' privacy both in and around the hospital.

A bulletin on the hospital website significantly reduced the number of phone calls to the hospital's switchboard. The media and the general public were informed by periodic press conferences, announced on the hospital's Internet page.

As per the operations manual, a hospital medical team is to depart to the accident site when requested by police or rescue authorities. In this case no such request was made. Instead, the hospital decided to dispatch a team on its own. KEHÄ sent a suitable emergency vehicle from the Jyväskylä rescue department to transport the medical team to the accident site. The medical team stopped enroute to treat two patients who were being transported to the hospital. The team arrived at the accident site at 04:04 but there were no patients left at the scene by then.

2.26 Äänekoski health centre

(Abridged from the original Finnish text)

Äänekoski health centre had recently updated its preparedness plan. According to it they implemented their activities. The plan included an attachment containing triage and emergency care instructions for the accident site response team. Äänekoski health centre raised its preparedness promptly and properly, even though there was no on-call night time staff at the centre.

One patient came to the health centre on her own. She was examined and treated. Later in the morning she was sent to the central hospital by taxi.

The local Voluntary Fire Brigade transported the health centre response team to the site. The team arrived approximately one hour after the collision. At that time there were only two patients remaining at the scene.

2.27 Dispatching and operating instructions of the medical rescue service

KEHÄ did not have the regional major traffic accident response plan prepared by local rescue and health authorities. The highest possible response corresponded to a high kinetic energy traffic accident. This response plan was prepared by rescue authorities and did not sufficiently take into account the possibly large number of casualties. Considering the magnitude of the accident, too few ambulance units were dispatched in this case. Furthermore, direct orders given by on-scene authorities to dispatch more units were not immediately followed and not to the extent required.

The health authorities must update the alarm procedures and see to it that the alarm procedures are also available to health centre and hospital medical teams. The health authorities must also issue directives on how to carry out each medical establishment's daily routines if a major accident ties up an exceptionally large number of care units.

Medical rescue instructions for administering treatment outside the medical establishment were lacking. The Handbook on Preparedness Planning for Health Care 2002:5 obliges medical establishments and hospital districts to prepare risk analyses based on their regional rescue branches' danger scenarios. They must prepare contingency plans and resource analyses for any possible accidents and exceptional situations. An accident involving heavy traffic on a busy road can be considered a very likely hazard. The contingency plan must describe the functions of the different authorities, medical rescue activities, ambulance capacity, available equipment and number of units.

Medical establishments are to issue alarm procedures to the ERC on how to employ and dispatch their medical response teams. As per the Handbook on Preparedness Planning for Health Care, it is of great importance to pre-plan the transportation of a doctor to the accident site.

2.28 Police activities

(Abridged from the original Finnish text)

Police duties are categorized as normal, demanding and special tasks. As a rule, normal tasks are handled by one patrol. Several patrols are required for demanding and special tasks. In order to handle duties in such cases an operational organization to police is formed in which functions and responsibilities are clearly designated.

The operational organization to police is led by a superintendent who is usually a police officer in a position of high command. A staff assists him. Prior to transferring overall command to the superintendent, his duties are dispatched by the field supervisor. Depending on the task at hand, special teams, functional teams or other such teams can be set up, each led by its own supervisor. The chief of investigation and the investigative team as well as communications comprise parts of an operational organization to police.

No clear and sufficiently extensive operational organization was formed for the accident. The task was handled as any other normal police task. The provincial on-call police supervisor mainly agreed with the district police field supervisor on who would send the required reports. For a long period the field supervisor was left completely in charge of organizing on-scene police activities as well as partly in charge of the activities at the Äänekoski police department. The field supervisor was also in charge of initiating the investigation as well as on-scene public information.

An operational organization to police should have been established for such a serious traffic accident, led by a chief superintendent. In the initial situation the functional responsibilities should have been delegated in a more appropriate manner by dispatching readily available patrols from the Jyväskylä police district in addition to the off-duty police officers who were summoned to work and the ones dispatched from the Saarijärvi police district.

2.29 Road signs to hospitals

(Abridged from the original Finnish text)

Pursuant to a decision of the Ministry of Transport and Communications, the road sign number 715 “First Aid” can be used to give directions to a general hospital or to a health centre hospital where physician’s services are available at all times. Medical establishments have rapidly cut their night time staff during the past few years and the previously erected road signs do not always correspond to the present regulations. An erroneously used road sign can even direct a seriously ill patient to a medical establishment where doctor services are not available.

3 CONCLUSIONS

3.1 Findings

1. Both transport companies had valid licences entitling them to conduct transport business.

2. The drivers of both vehicles had valid driver's licences.

3. Neither alcohol nor other intoxicants played any part in the event.

4. The regular motor vehicle inspections of the tractor and the trailer were valid.

5. The regular motor vehicle inspection of the coach was valid, albeit lacking the vehicle alteration inspection after the addition of two passenger seats.

6. All vehicle units were fitted with anti-lock pneumatic brakes (ABS). The tractor's brakes were electronically controlled (EBS).

7. The tractor was fitted with a traction control and skid warning system.

8. The tractor did not have an ambient temperature indicator. The coach was fitted with one.

9. The investigation revealed no such technical faults that factored into the occurring of the accident.

10. Both vehicles exceeded the 80 km/h roadwise winter speed limit and both of them used situational speeds that were too high for the low adhesion of the road surface.

11. The road was extremely slippery at the accident site after rain had frozen on the pavement.

12. Friction between wet ice and a tyre is 0.14 at best.

13. According to simulations, friction between the road and the tyre on the uphill section was at least 0.11.

14. During simulations, an unfavourable change in the driving line resulted in loss of control.

15. Simulations showed that the road stability of a vehicle combination clearly decreases as speed increases.

16. Simulations showed that the most significant factors affecting the handling of a vehicle were the gentleness of steer inputs and the driving speed.

17. The weather forecasts made for the Keski-Suomi (Central Finland) Road Region differed from each other. However, neither forecast required alerting the road maintenance contractors.

18. The road weather centre supervisor estimated that the weather development did not warrant preventive anti-icing.

19. The road contractor did not receive information from the road weather centre regarding the approaching rain nor the need for preventive salt spreading.

20. Due to a malfunction the Finnish Meteorological Institute's weather radar picture was not updated on the road weather centre supervisor's displays for the four hours following midnight.

21. The update malfunction did not make a difference as regards to not commencing preventive anti-icing.

22. The monitor displays no warning when the doppler weather radar picture update malfunctions.

23. The driver of the vehicle combination wore his seat belt and that prevented him from sustaining injuries.

24. All seats of the coach were fitted with seat belts.

25. At the moment of the accident nobody in the coach was wearing seat belts.

26. Some of the passengers did not even realize that the seat belts existed.

27. Some of the paper reels transported in the trailer penetrated the coach.

28. Anchoring of the paper reels in the tractor and in the trailer was partly inadequate.

29. There were no anchoring points on the floor of the tractor's swap body, hence making it unsuitable for transporting paper reels stacked on top of each other.

30. The tractor's steering rear wheels had no effect on the loss of control of the vehicle combination.

31. The full trailer combination's route was planned in such a way that it was impossible to complete it in accordance with speed limits or driving hour and rest period regulations. After the accident the company changed the two-leg route to be driven in three legs.

32. The tractor-trailer's driver had exceeded the maximum permissible 4.5 hour uninterrupted driving time as well as the maximum uninterrupted 5.5 hour working time.

33. The coach's route planning was done in such fashion that it was impossible to complete it in accordance with speed limits or driving hour and rest period regulations.

34. The vehicle combination transported too much cargo and, therefore, the permissible Gross Combination Weight was exceeded by ca. 4 100 kg.

35. The Emergency Response Centre (ERC) did not have the emergency code "major accident" and a corresponding alarm procedure. This resulted in dispatching too few ambulances in the beginning. Furthermore, the on-scene authorities' direct orders to dispatch more units were neither immediately followed nor to the extent required.

36. Shortcomings were noted in emergency medical services and in patient transports. The medical director's direct orders were broken resulting in, for example, too many seriously injured patients being placed in one ambulance and transported then in a seated position.

37. The ERC did not have the health authorities' directive on how to administer medical care to routine patients during a multiple-casualty event.

38. There was no clearly designated rescue commander in charge at the accident site.

39. The Konginkangas Voluntary Fire Brigade staff had to work continuously for more than 17 hours, i.e. from the first alarm until the site clearance was over.

40. The Äänekoski regular fire brigade unit left the accident site at the end of their shift at 07:35 and the following shift never came to the site.

41. The public authority network VIRVE radio traffic at the accident site is not recorded anywhere and, therefore, it was impossible to study the activities retroactively in detail.

42. Because the central hospital and the health centre had no VIRVE data terminals, they were unable to communicate with the accident site during the rescue effort. Hence, all of the needed information did not reach everybody.

3 The clocks on KEHÄ's different equipment were not synchronized.

3.2 Causes of the accident

This cause analysis, based on the method used by the road and cross-country traffic accident investigation commissions, examines the accident as an event in which the point in time of the collision is the beginning of a continuum. After the starting point the study focuses on the event, which immediately preceded the collision and made it possible. This is called the key event. The key event, for its part, is preceded by those direct, active causal factors that contributed to the arising of the key event.

Indirect causal factors are the factors and causes that contributed to the arising of the key event and the direct causal factors or enabled them or at least did not prevent the arising of these direct causal factors. One must especially take note that a factor, which contributed to the chain of events by its absence, can also be an indirect causal factor. Accident analysis, therefore, is all about disassembling the chain of events into smaller parts.

3.2.1 The collision

In the middle of a curve to the left on the apex of a knoll the vehicle combination's trailer began to fishtail and on the downhill section the rear part of the trailer skidded off the road down the slope of the shoulder. From the slope the trailer rose back onto the road and the vehicle combination drifted to the left. The driver tried to steer the tractor-trailer back to the right but the trailer continued to travel in the lane occupied by oncoming traffic. The collision took place in that lane. At the time of impact both vehicles were travelling at around 70 km/h. Due to the force of impact and the weight of the paper reels the coach's front part was badly crushed and paper reels penetrated the coach's cabin.

3.2.2 Key events

The vehicle combination's trailer drifted into the lane used by oncoming traffic and in front of the oncoming vehicle in a situation where the coach came into close range.

The driver of the coach could not prevent a collision after having noticed the oncoming vehicle's trailer in front of him.

3.2.3 Direct causal factors

Driver error:

Vehicle combination: Loss of control. The trailer began to fishtail.

Coach: The coach driver's detection error. The driver did not notice the fishtailing of the oncoming vehicle combination. He noticed the trailer's presence in his lane too late.

3.2.4 Indirect causal factors: the vehicle combination

The driver: The following driver-related factors contributed to the loss of control of the vehicle combination:

An unfavourable driving line selection. While changing the driving line on the top of the hill and as the vehicle was returning to the centre of its lane, the friction demand of the trailer wheels exceeded the existing friction and the trailer began to fishtail.

The vehicle combination's high situational speed. The tractor-trailer exceeded its vehiclewise speed limit as well as the roadwise winter speed limit. In addition to the practice adopted by heavy transport drivers of trying to drive as fast as possible, also the driver's route (see: system factors) that was planned in a fashion which necessitated either speeding or breaking the maximum permissible daily driving hours, contributed to the high speed.

Studies show that a trailer becomes more unstable and more difficult to control as speed increases. A significant unfavourable change occurs as speed is increased from 80 km/h to 90 km/h

State of alertness. The driver's state of alertness was possibly reduced. This can be explained by the late hour of the accident and the driver's previous driving history of having worked four consecutive night shifts. No irregularities were found on the driver's daily and weekly rest periods. By the time of the accident the driver had driven 5 h 10 min and he had not taken the 45 min break prescribed by law for every 4.5 hours of driving time.

The driver's possibly reduced state of alertness may have delayed the detection of the slippery conditions, which he only noticed once the trailer began to fishtail. The reduced state of alertness may also have affected the steer inputs that resulted in fishtailing.

The vehicle: The following vehicle combination characteristics affected the loss of control:

The excessive load. The tractor-trailer transported an excessive load of ca. 4 100 kg, which resulted in decreased controllability in simulations.

The lack of a road stability system. The fact that the vehicle was not fitted with a road stability system made the handling of the vehicle more difficult.

The road and the environment: The following road surface and road weather conditions at the accident site factored into the loss of control of the vehicle combination:

The slipperiness of the road. The road was extremely slippery at the time of the event. The slipperiness was local and unforecasted as well as difficult to detect visually.

The curve and the variation in the camber of the lane. Looking at the site of the collision from the tractor-trailer's driving direction, the place was preceded by a curve to the left immediately followed by a straight section. The curve was cambered toward the inside of the turn. The camber of the southbound lane varied between 1-3 percentage points in places. The camber variation generated side-to-side rolling motions on the vehicle combination. It is probable that while on the top of the hill the full trailer combination was travelling on the left side of its lane and upon returning to the centre of its lane it steered into the wear grooves. The wear grooves may have impaired the control of the trailer.

The lack of physical barriers between opposing lanes. The fact that a vehicle could end up on the opposing lane made the collision possible. There were no centre guard rails or other physical dividers separating opposing lanes.

Darkness and the lack of road lights. Darkness prevailed at the time of the event and that section of the road was not illuminated. Darkness and the lack of road lights made it more difficult for the lorry driver to notice the movement of his trailer once it began to fishtail.

Shortcomings in anti-icing. The road at the accident site was extremely slippery and the slipperiness facilitated the trailer's fishtailing and the loss of control. A brine solution had been spread in the evening on a 500 m downhill section of the road in the tractor-trailer's driving direction. However, by the time of the event the road salt had already lost its effect. The weather forecast did not require the road weather centre to issue a road weather warning to the road maintenance contractors. The rain during the night froze on the pavement. The contractor responsible for the maintenance of that section never received word of the black ice, which had formed.

Lack of speed control. At the time of the event there was no automatic speed control in the traffic environment. When the situation leading to the accident was developing, the full trailer combination was breaking roadwise and vehiclewise speed limits.

High tolerance for speeding. Traffic control allows the method of driving by pushing the speed limiter, i.e. speeding. Furthermore, the fact that the speed limiter is set at 90 km/h proves that the vehiclewise speed limit is not considered the highest permissible speed.

System factors: Factors related to the traffic and transport system explain the driving hours and rest periods that were used, the speed and, consequently, the loss of control of the vehicle combination:

Errors in route planning. The haulier had planned the route, schedules and size of cargo. The driver of the northern leg supervised the loading and anchored the load. The driver of the collided vehicle had no practical possibilities to influence the aforementioned issues. The route was planned in such a fashion that it was impossible to complete it by adhering to speed limits or driving hour and rest period regulations. The company's in-house control had not reacted to shortcomings or unsound practices. After the accident the haulier changed the two-leg route to be driven in three legs.

Inertia in the anti-icing organization. The existing anti-icing systems could not react swiftly enough to unforeseen local road weather changes.

The lack of a system warning of low road adhesion. There was no automatic information system warning drivers of slippery roads and, hence, the driver was never warned of the onset of slipperiness.

3.2.5 Indirect causal factors: the coach

The driver: The following factors explain the coach driver's detection error and his subsequent failure to notice the probability of collision:

High speed in slippery conditions. The driver exceeded the local winter speed limit (80km/h) and failed to adjust his speed to the slippery road weather conditions. The driver did not have the time to form a clear picture of the risk caused by the oncoming vehicle. The high speed hindered the early detection of the oncoming trailer's fishtailing and caused problems for successfully executing an evasive manoeuvre. The driver applied the brakes approximately four seconds prior to impact. There were no marks on the road indicating an evasive manoeuvre.

The vehicle: The coach was fitted with anti-locking brakes, which enable evasive manoeuvres during braking. Apart from applying the brakes, nothing suggested that the driver would have tried to dodge the approaching vehicle combination's trailer.

The road and the environment: The coach driver's detection error and the overly late braking can be explained by the following road and environmental conditions:

Darkness and the lack of road lights. Darkness prevailed at the time of the event and the section of the road was not illuminated. Darkness and the lack of road lights made it more difficult for the coach driver to notice the movements of the oncoming vehicle combination's trailer as it began to fishtail.

Lack of speed control on the section of the road at the time of the event. As the accident was about to occur, the coach was breaking the roadwise speed limit. By employing automatic speed surveillance cameras, control can also be executed on less trafficked road sections and during times of less traffic.

The slipperiness of the road and the speed of the coach. The road at the accident site was extremely slippery and the low adhesion increased the coach's braking distance. The slipperiness resulted from a local rain shower, which froze on the cold road surface. However, the coach was approaching from the south where slipperiness had already been detectable for the previous twenty kilometres. Judging from the tachograph, it can not be concluded that the driver had adjusted his speed upon arriving at the slippery road section.

The non-separation of opposing lanes. The road was constructed without erecting a centre guard rail or any other divider separating the opposing lanes. The fact that the vehicle combination's trailer could enter the opposing lane made the collision possible.

Systems: The following road and traffic system related factors explained the driver's speed and the consequent late detection of the obstruction formed by the oncoming vehicle:

Errors in route planning and scheduling. The coach's route was planned in such a way that it was impossible to complete it by adhering to existing speed limits and simultaneously complying with driving hour and rest period regulations

Inertia in the anti-icing organization. The existing anti-icing systems could not react swiftly enough to unforeseen local road weather changes to maintain the friction demand required by the road section's winter maintenance classification.

The lack of a system warning of low road adhesion. There was no automatic information system warning drivers of slippery roads.

3.2.6 Causal factors for injuries

The following factors explained the occurrence of fatal and serious injuries:

<u>In the vehicle combination:</u>

The excessive load. The excessive load increased the vehicle combination's kinetic energy by ca. 7%, which in turn amplified the effect of collision-generated damage.

The high speed of the vehicle combination. The high speed of the vehicle combination first contributed to the occurrence of the collision and, additionally, amplified the destructive outcome of the impact.

Use of seat belts. The coach driver wore his seat belt and that prevented him from sustaining injuries.

<u>In the coach:</u>

The great dissimilarity between the vehicles' gross weights. The great respective difference between the vehicles' GVWs generated a deceleration of over 20 g on the coach and the passengers.

The high speed of the coach. The high speed of the coach first contributed to the occurrence of the collision and, additionally, amplified the destructive outcome of the impact.

The shifting of the paper reels in the vehicle combination's trailer. The force of impact was so high that the paper reels, weighing 800 kg each, did not remain in place. Instead, they penetrated the coach causing massive destruction. The fact that the trailer and coach floors were roughly at the same height contributed to the shifting of the paper reels.

The low crashworthiness of the coach's front section. The front structure of the coach collapsed as the result of colliding with a high opposing mass.

The non-use of seat belts. Every seat on the coach was fitted with a seat belt but no one used them. Had people used seat belts at the back of the coach, a couple of passengers could probably have escaped alive and the injuries of others would have been less severe.

4 SAFETY RECOMMENDATIONS

A generally adopted practice in heavy traffic is driving as fast as the speed limiter allows. This means that lorries are driven at around 90 km/h even though their vehiclewise speed limit is 80 km/h. The fact that vehicles break the speed limit by more than 12% is generally tolerated in practice even in traffic surveillance. It is only rarely that action is taken on speeding of this scale. The increase in speed from 80 km/h to 90 km/h significantly reduces the controllability of a heavy vehicle. Simultaneously brakeing distances and impact energies increase by more than 26%. If all vehicles were travelling at the same speed, for instance at the 80 km/h winter speed, traffic tempo would be calmer. Moreover, on roads where the speed limit is 100 km/h it is difficult to overtake heavy vehicles that are driving at 90 km/h because the small difference in speed means that a long stretch of road is required to complete the overtaking manoeuvre. Furthermore, by reducing speed from 90 km/h to the legal limit, fuel consumption is also reduced by 5-10%.

> *1. The investigation commission recommends that the Ministry of Transport and Communications implement measures to change legislation in such a manner that the speed limiters of lorries be set to the maximum vehiclewise speed of 80 km/h.*

In some EU Member States the driver can be issued a fine for breaking the vehiclewise speed limit also by virtue of inspecting tachometer data during routine traffic surveillance or in conjunction of an accident investigation. In Finland this is not possible.

> *2. The investigation commission recommends that the Ministry of Transport and Communications implement measures to change legislation in such a way that by virtue of inspecting recorded tachometer speed data during routine traffic surveillance or in conjunction of an accident investigation it would be possible to issue a penalty to the driver for having broken the vehiclewise speed limit.*

The training of a coach driver and of a vehicle combination driver includes a mandatory anticipatory driving segment. Drivers that enter the branch through work experience are exempt from this mandatory segment.

> *3. The investigation commission recommends that the Ministry of Transport and Communications introduce a legislative proposal for making a successfully completed anticipatory driving course for heavy traffic a prerequisite for the examination of a coach or a vehicle combination transport licence.*

Heavy vehicle drivers often work under line managers who have the right to direct the work of the driver. The driver’s role in traffic safety is significant but his influence on transport planning, schedules and route selection is limited. Someone other than the driver makes the decisions on these issues. By virtue of a transport contract the one commissioning the transport, i.e. the customer, can also participate in providing guidance for the transport. Even in spite of this, the responsibility and the surveillance mainly focus on the driver.

> *4. The investigation commission recommends that the Ministry of Transport and Communications introduce a legislative proposal for making the party using the right to direct work on the driver liable for its part for any possible infraction or consequence.*

Clear shortcomings in compliance with driving hours and rest periods, among other things, are discovered in heavy traffic surveillance. Excessive loads are also quite typical, especially in night time transports. Based on information received, compared to Finland the other EU countries impose significantly tougher penalties for these violations. Transport licences have never been temporarily or completely revoked in Finland even in the case of repeated violations.

> *5. The investigation commission recommends that the Ministry of Transport and Communications take action to increase the penalties imposed for violating driving time and rest period directives, the working time legislation as well as for exceeding vehiclewise axle and bogie loads and gross vehicle weights. Penalties and consequences should bear real significance to the driver and to the haulier as well as to those in the transport chain who with their own actions, by giving inadequate or incorrect information, by using the right to direct work or by applying other such direct control, have influenced the arising of an unlawful situation.*

On almost every working day in Finland one heavy vehicle combination drives off the road (approximately 200 annual driving-off-the-road accidents). Investigations of non-fatal accidents are not concentrated under a single authority and, hence, no uniform statistics exist on them. Every single loss of control of a heavy vehicle constitutes a potential major accident.

> *6. The investigation commission recommends that the Ministry of Transport and Communications develop an investigation system in Finland responsible for investigating all heavy traffic accidents, including driving-off-the-road incidents. This investigation could be temporary, yet long-term enough to expose driver errors and transport system related flaws as well as any possible traffic safety decreasing vehicle characteristics.*

Serious shortcomings in placing, anchoring and buttressing the load are often discovered during traffic surveillance. Finnish Transport and Logistics SKAL and the National Traffic Police have jointly produced a manual for load anchoring. An expert group has also been set up in the EU to develop “best practice guidelines for cargo securing”, to be applied in the load anchoring of transnational transports.

> *7. The investigation commission recommends that the Ministry of Transport and Communications actively participate in the work of the EU’s expert group developing the best practice guidelines for transnational transport cargo securing. Moreover, the Ministry of Transport and Communications should support the production of national instructional material on load anchoring as well as to mandate specific load placing, buttressing and anchoring training for drivers and loading personnel, certifying the trainees for loading operations.*

According to several international and domestic studies, police traffic control is an effective and economical method to fight illegal traffic behaviour on the part of the drivers and, thus, to focus on the key issues related to traffic safety. Automatic surveillance constitutes an important part of the work but it can not replace, for instance, breathalyser tests and heavy traffic control personally conducted by the police.

> *8. The investigation commission recommends that the Ministry of the Interior channel police funding towards more traffic surveillance so that the police could satisfy the heavy traffic surveillance requirements established by the Government and the EU.*

Road stability systems are available for some vehicle combinations. The system reacts to an incipient loss of control and stabilizes the vehicle’s abnormal motion by braking individual wheels.

> *9. The investigation commission recommends that the Ministry of Transport and Communications contribute to making road stability systems standard equipment in heavy vehicles as soon as possible.*

There was no centre guard rail on the section around the accident site which, according to the opinion of the investigation commission, would probably have prevented the accident. According to a Swedish study, a centre guard rail reduces accidents by 80% on semi-motorways and by 60% on wide-lane roads at best. A study commissioned by the Keski-Suomi Road Region shows that it would cost approximately 7.6 M€ to convert the some 20 old overtaking lanes on highways 4 and 9 in Central Finland by erecting centre guard rails. The new evaluated accident rate would correspond to some 1.2 fewer annual accidents resulting in personal injury and ca. 0.3 fewer annual traffic fatalities. The traffic fatality cost-benefit ratio is 2.35, meaning that when it comes to erecting centre guard rails on overtaking lanes it is possible to recuperate the investment already in the savings from accident expenses.

> *10. The investigation commission recommends that the Ministry of Transport and Communications take action to accelerate the rate of constructing road sections with centre guard rails.*

There was no road lighting at the site of the accident which, according to the opinion of the investigation commission, would probably have prevented the accident. Studies show that the danger of an accident resulting in personal injury is 1.5 times higher in the dark compared to the daylight. Research indicates that lighting is estimated to reduce 45-55% of personal-injury accidents and 30-40% of all accidents. According to a requirement study, new road lighting in Central Finland is needed on the total distance of approximately 214 kilometres. Approximately 50 km of the roads require improved lighting or conversion to improve collision safety. The cost estimate of the aforementioned lighting and conversion measures totals at ca. 6.6 M€ and the evaluated reduction in annual fatal accidents is 3.8.

> *11. The investigation commission recommends that the Ministry of Transport and Communications take action to increase road lighting on such road sections where traffic volumes and intersection densities are high or where heavy traffic volumes are high or where a reduction in accident expenses warrants increased lighting.*

During the wintertime there are not enough rest stops available that are suitable for heavy traffic. These stops could also double as heavy traffic control stations for the police.

> *12. The investigation commission recommends that the Finnish Road Administration build and appropriately maintain a sufficient number of all-season rest stops along the main roads that experience high volumes of heavy traffic.*

The accident investigation revealed that neither the Central Finland health care district nor Äänekoski health centre had approved major accident contingency plans for operations outside their premises. A medical rescue manual existed for the health centre response team and instructions for the hospital's medical team were included in the hospital's own major accident plan. However, there were no directives for ambulance units. The Central Finland rescue department had instructions only for large chemical accidents. The proper authorities' alarm procedures for a major accident were not provided to the Central Finland ERC. Neither were there instructions on how to implement practical measures during a major accident. These activities comprise, for instance, ERC operations, public authority network systems, communications systems and basic principles in patient care.

> *13. The investigation commission recommends that state provincial offices ascertain for themselves on the existence and updating of contingency planning for major accidents and of appropriate activities, in accordance with the guidelines of the Ministry of Social Affairs and Health. Notwithstanding health care district or regional rescue service boundaries, all key actors must agree on*

uniform modes of operation and common contingency plans for a major accident.

The accident investigation revealed that at least three different time stamps existed on the very same event in ERC reports. These times differed up to several minutes from each other. Some of the times were probably recorded afterwards. The time differences made it more difficult to follow the event timeline. Imprecisely recorded times may weaken patients' and actors' protection under the law.

14. The investigation commission recommends that the Emergency Response Centre Administration implement measures to synchronize all Emergency Response Centres' information system clocks to the official time.

A similar recommendation was issued to the Central Finland ERC in the inquiry report A 2/1996, which was compiled after the accident that happened at the Jyväskylä 1000 Lakes Rally in 1996.

Providing emergency medical services in an accident requires special skills from the doctor. It can not be expected that any on-call physician would be capable of dispatching these duties. Medical care in a major accident should build on daily routines. The EMS doctor should be an integral team member in every EMS system. The police and the rescue service already employ an operational organization of this kind.

15. The investigation commission recommends that health care districts and health centres develop their operations to include an emergency medical services physician in their regional emergency services system, capable of supporting the ambulance units and capable of being immediately dispatched to an accident site.

All seats of the coach were fitted with seat belts. At the time of the accident nobody in the coach was wearing seat belts. The investigation revealed that some of the passengers did not even realize that the seat belts existed. In ordinary bus accidents it is particularly beneficial from the viewpoint of passenger survival for everyone to wear their seat belts. The use of seat belts in buses will become mandatory in 2006 but even before this, the bus transport business should adopt a new seat belt culture. A good example of such a culture exists in aviation.

16. The investigation commission recommends that the Finnish Bus and Coach Association launch a public awareness campaign to increase the use of seat belts and that bus transport companies instruct their drivers to inform passengers of the existence and use of seat belts. All seats fitted with seat belts should have signs exhorting the passenger to wear the seat belt.

A bus simulator has been developed in Finland and it has been used in driver training since 2004. Practical experiences have already been gathered from the simulator and it has been noted to be suitable for driver training. By simulating different environmental conditions, one can create a virtual world in which even difficult road and road weather conditions can be safely and effectively trained. Furthermore, simulator training is more environmentally friendly than real-life driving in traffic.

> *17. The investigation commission recommends that the Ministry of Trade and Industry launch a project to acquire lorry simulators and versatile software applications in Finland. These simulators could be used to train drivers to control different vehicle combinations in difficult road weather conditions in basic and advanced training. This project could be included in, for example, the research and development programmes of the Finnish Funding Agency for Technology and Innovation Tekes.*

Jyväskylä, 18.10.2005

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