EVALUATION OF REAL ACCIDENTS

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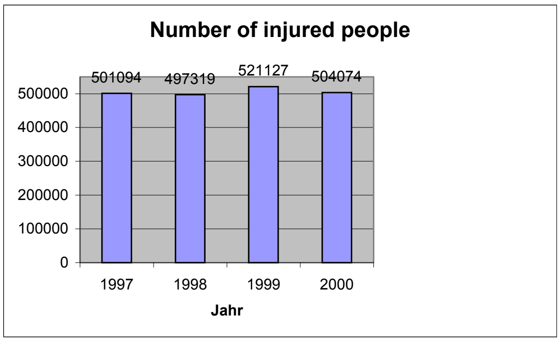
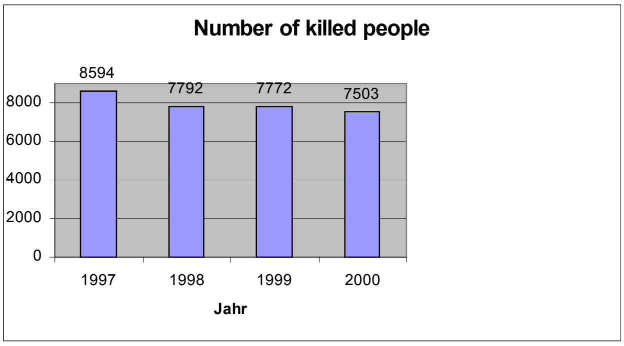
1. Introduction

– Statistics of road-accidents in Germany and Belgium

1.1 Germany
In 2000 Germany counted 382 949 road-accidents with injured people.
In 28 033 accidents of this total number, i.e. in 7,32%, trucks were involved.
In the year 2000 Germany had a number of 6827 fatal accidents. And in these accidents 7503 people were killed. In 615 of these fatal accidents or 9%, trucks were involved.

Germany keeps up very detailed accident statistics (See Statistisches Bundesambt: Verkehr Fachserie 8) . One can see from the following diagrams that the number of injured people in road accidents remains about constant, whereas the number of killed people decreases.



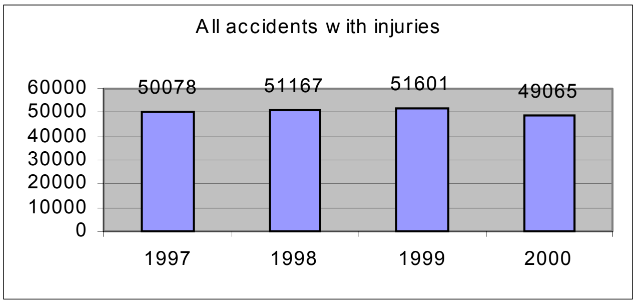


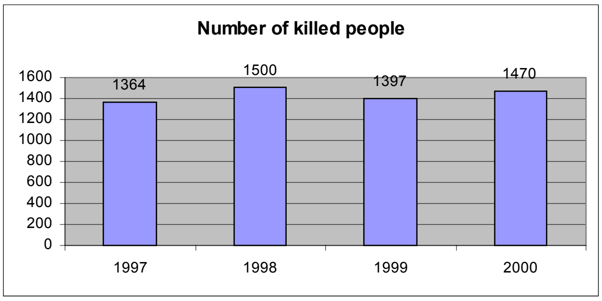
Some interesting statistic data from this publication of the "Statisches Bundesamt" with regard to the year 2000 are collected in the table below. It shows that especially on highways trucks cause serious accidents.

number of killed persons / number of fatal accidents with a truck / %			
in built-up area	outside built-up area	on motorway	total
1.759 / 193 / 10,9 %	4.289 / 239 / 5,6 %	779 / 183 / 23,5 %	6827 / 615 / 9 %

1.2 Belgium

Belgium counts approximately 50 000 accidents a year with injuries.
6 to 6,5% of this total are accidents with at least one truck involved. (> 3,5 t)
Belgium counts about 1300 fatal road-accidents a year. And in 13 to 14 % of these accidents a truck is involved.



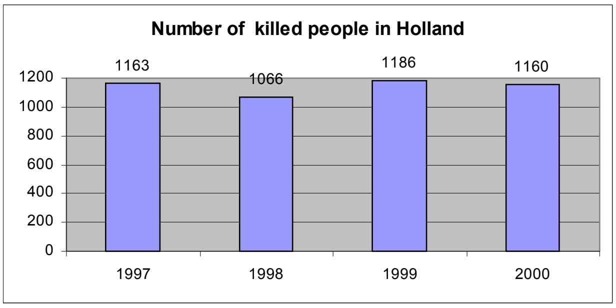


The number of accidents with injuries remains approximately constant. The number of fatal accidents on the contrary increases in Belgium.

total number of fatal accidents / fatal accidents with truck / %	
total	on motorway
1356 / 186 / 13,7%	197 / 57 / 29%

1.3 Holland

In Holland the number of killed people in traffic accidents remains about the same. However the number of fatal accidents is much lower in Holland than in Belgium.



– Methods of Analysis

Up to now only the speedometer card was the most important element to analyze a truck-accident.
Since a couple of years simulation programs such as PC-CRASH or CARAT-4 can also be used as an important aid to analyze such accidents.
These programs however are to be checked and proofed valid by means of tests.
That's why congresses of specialists such as the one here in Neumünster are of significant importance.
And which type of test is meaningful to be chosen, is in fact dictated by the every day accident-reality. That is why a survey of the different types of truck-accidents is interesting.

2. Types of truck-accidents.

The different types of truck-accidents are mentioned in this lecture. Each type has its own important parameters. Some of the weightiest parameters are partly known.
But there are still gaps in the field of our knowledge. Still a lot has to be learn about collision parameters such as restitution coefficient, EES-value, structure stiffness.
What is the influence of the load? What happens when the load starts to move? What about liquid cargo?
The following refers to the common level of knowledge. Security-aspects, typical for truck-accidents, are considered.

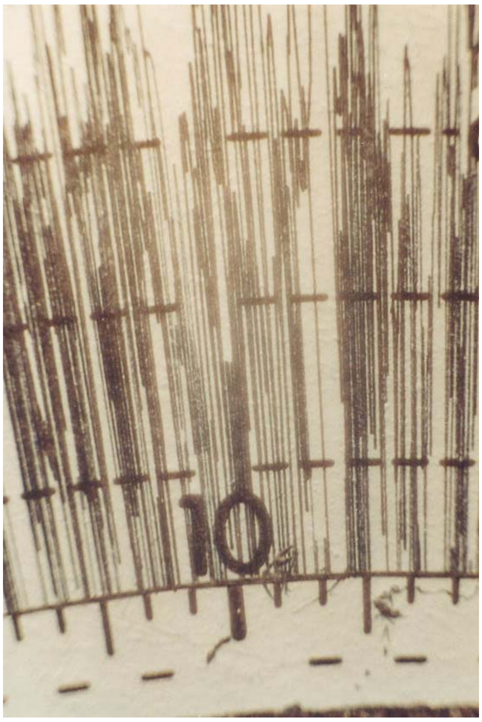
2.1. Rear -end collision

Many different combinations of vehicles can get into such a collision.
The most important part consists of the truck/truck collisions and the car/truck collisions.

2.1.1 Rear-end collision 1 : truck / truck / bus

In the pile-up collision in the fog the 29-th of January 1998 on the motorway E17 in Rekkem-Belgium near the French border approximately one hundred vehicles were involved. Seven people were killed.
The motorway E17 runs from Denmark over the German Ruhr-region and over Belgium (Antwerp) direction Paris. In all respects between Antwerp and France there is a great deal of lorry traffic.

The tractor semi-trailer with the green container stopped without any collision at the end of the traffic jam in the right lane. A smaller refrigerator truck arrived and ran into the green container. And a bus hit the refrigerator truck.
What was the order of these two collisions? Did the bus smash the smaller truck into the green container or had the driver of the refrigerator truck already crashed into the green container, before being hit by the bus?

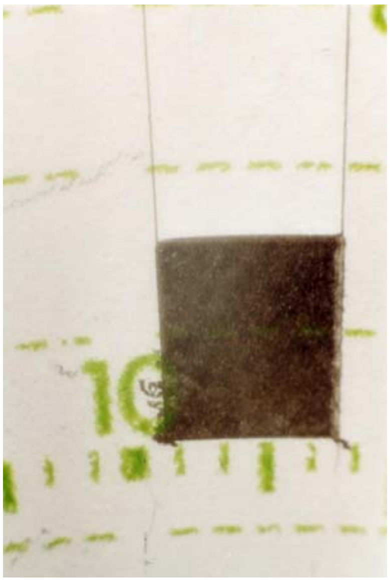


The speedometer card of the small refrigerator truck had been left several days in the speedometer and in this way had become difficult to read. Nevertheless a typical collision disturbance of the writing pen of the speedometer was visible on the zero-line of the card at the time of the accident. It meant that the refrigerator truck ran into the container with his wheels blocked by the brakes.
The cabin of the refrigerator truck was compressed in the collision on the green container.
The driver and his co-driver were both mortally wounded.
The difference between the structure stiffness of such a steel transport container and the truck-cabin appeared clearly from the damage aspect of both collision partners. This stiffness difference was fatal in this collision.

The bus hit the small refrigerator truck with an overlap of about 50%.
In this collision the bus driver's companion was killed.
The damage aspect illustrates the low stiffness of the front of such a bus.

The answer to the question whether the bus first hit the refrigerator truck and smashed it into the green steel container, or crashed into the refrigerator truck after it ran itself into the container, found his answer in the speedometer card of the tractor/semi-trailer with the green container. On this card two clearly separated acceleration peaks, caused by rear impact, appeared after the stop of the container truck. They indicated that at first the refrigerator truck collided with the green container and that only thereafter the bus arrived and hit the wreck of the refrigerator truck at the rear.

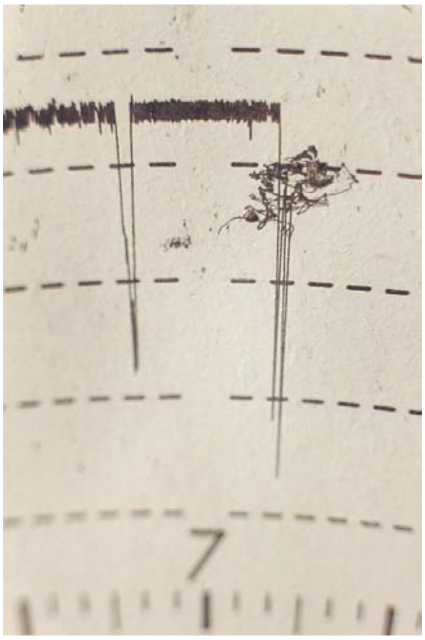
The speedometer card of the bus allowed no conclusions concerning the speed of the bus before collision and at the moment of collision.
The bus also arrived into that collision with his wheels blocked by the brakes. The vibration of the speedometer writing needle lies on the zero line of the card.
On top of that the electrical cabling to the speedometer of the bus was damaged in the collision so that the speedometer ran into his fraud alarm mode.



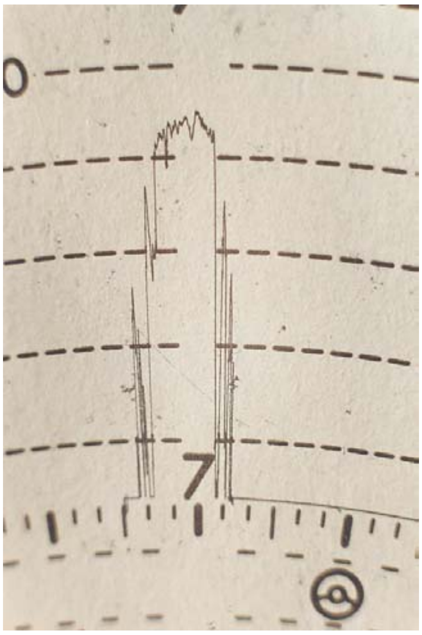
In these two collisions, i.e. refrigerator truck on the steel container and bus on the refrigerator truck, the speedometer card learned nothing about collision speeds.
They gave nevertheless crucial information about the sequence of the collisions.

2.1.2. Rear-end collision 2: truck / truck

A truck (yellow, MAN) was waiting at the traffic lights. A second truck (red, Volvo) crashed into it from behind.



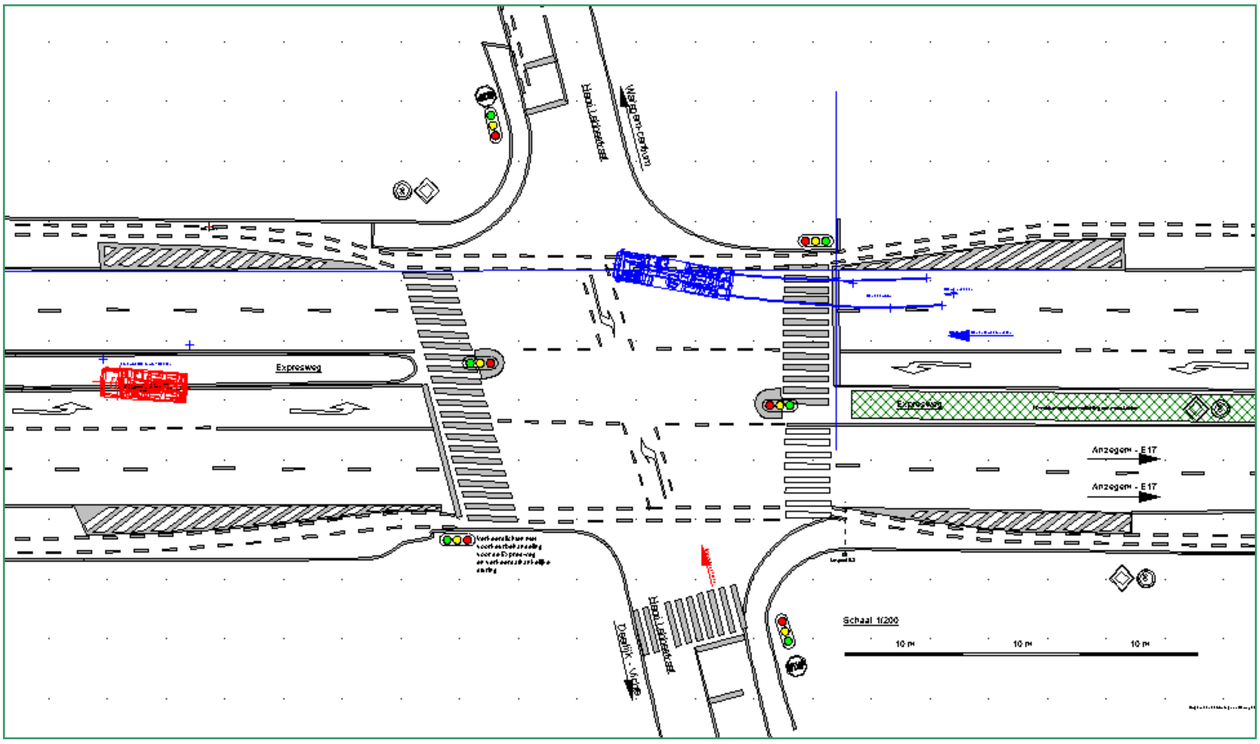
The incoming truck, i.e. the red Volvo, had a weight of 16,5 tons and, according to his speedometer card, hit the yellow MAN with a speed of about 72 km/h.



The MAN had a weight of about 11,86 tons and, according to his speedometer card, it was accelerated due to the collision from zero speed up to 35 km/h.

In the collision analysis the calculated deformation energy was divided according to the remaining deformation, about 1,2 m on the Volvo, about 0,2 m on the MAN. Doing this, an EES-value of the damage at the front of the Volvo of about 43 km/h is found. In the same way an EES-value of the damage at the rear of the MAN of about 21 km/h is found.
These values then correspond with a structure stiffness of about 1650 kN/m for the Volvo front and about 10 000 kN/m for the rear end of the MAN tipper.

Whether these values are reliable or not, is difficult to say and test results are very welcome. Moreover the data of the speedometer cards are not always sufficient.



1.3. Rear-end collision 3 & 4 : car / truck.

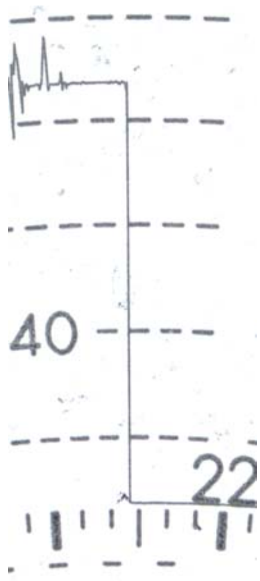
A typical security problem with respect to driver and front passenger in a car when it comes to a rear-end collision, car on truck, results from the fact that the car mostly goes under the cargo floor of the truck or semi-trailer, especially when the cargo box has a long overhang. The floor of the cargo space of the actual trucks and trailers mostly lies about 0,8 to 1,2 meter above the road surface.
Cars, when they crash from behind into a truck, go with their engine compartment under the cargo floor of the truck and in this way nearly no kinetic energy is absorbed in the crumple zones of the front and engine compartment of the car. The car hits the rear of the cargo space of the truck with the windshield and roof and the cargo space penetrates deeply into the passenger cell of the car.

Two cases are illustrated in which a car crashed into a truck from behind with rather narrow overlap. The roof of the car was torn from the body of the car. This type of accident mostly results in fatal head injuries for the front occupants of the car.
Stronger rear end construction of trucks and trailers under the level of the cargo floor could decrease the gravity of such accidents.

2.1.3.1. A Mercedes E-class driver with a passenger drove at night on a three-lane motorway and hit from behind a tractor with semi-trailer, which apparently changed lane in front of him.

EES estimated ca. 60 km/h

The collision happened in the second of the three lanes. The tractor semi-trailer, according to his speedometer card, drove at a speed of about 85 km/h at the moment of the accident.
The Mercedes spun about 90 meters further before coming to stand still. The front passenger was killed in this accident.



In such a case only an estimation of the EES-value of the damage can offer some help. In this case the Mercedes was even tilted up by the left rear wheel of the semi-trailer and the right front corner of the Mercedes, and the right front wheel remained clamped between the wheels of the semi-trailer and the cargo floor. The Daimler Chrysler Accident Research Department was contacted for help. This department estimated the EES-value of the damage of the Mercedes at about 60 km/h.

2.1.3.2. In the already mentioned pile-up collision on the 29.01.1998 on the motorway E17 in Rekkem an almost identical collision took place. A BMW-7 driver discovered too late the traffic jam in the fog, tried to pull out to the right and crashed into the rear right corner of a truck that already came to standstill. It was a collision with narrow overlap and the truck had a long overhang of its cargo floor.

The BMW driver was killed in this accident. The passenger at his right was hardly wounded. The rescue team cut off the roof from the car. This made it impossible to estimate the EES-value of the damage in a more or less narrow margin.
The deformation energy absorbed by the rear bumper of the truck and its supports is not known.
Here again one can see that too little is known to make a detailed reconstruction of the accident and that tests are welcome.

2.1.4. Rear-end collision : tractor semi-trailer / semi-trailer

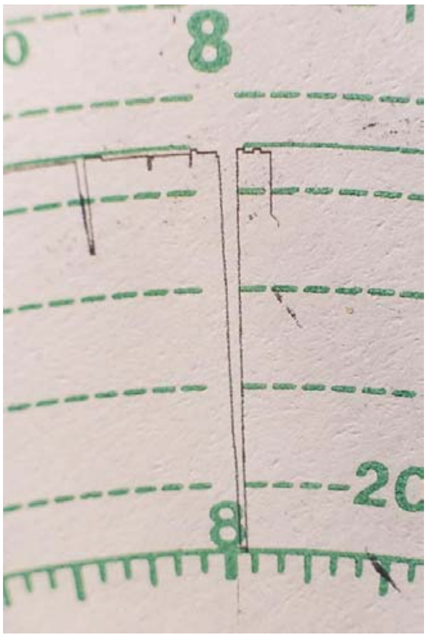
The driver of a tractor with semi-trailer, apparently inadvertent, drove on a motorway, which was partly blocked for maintenance, and crashed into a refrigerator semi-trailer, already at standstill at the end of the queue.
Also in rear-end collisions of a tractor on a semi-trailer, one frequently sees that the chassis of the incoming tractor goes underneath the cargo-floor of the semi-trailer, which was hit, whereas at the same time the cabin of the tractor is compressed between the cargo space of the trailer in front and his own cargo trailer.

First of all there is the obvious problem of security with regard to the truck-driver.
From the collision analysis point of view the question arises how to handle such a collision: what are the restitution coefficients, the EES-values, the structure stiffness?

In the shown accident the precise collision area could be located by means of a number of scratches in the road surface. These scratches were caused by the gearbox of the incoming tractor (Mercedes Actros 2540). This gearbox was torn from the motor block in the collision and touched the road surface. [The motor block tipped when the chassis of the tractor went under the cargo floor of the trailer in front.]

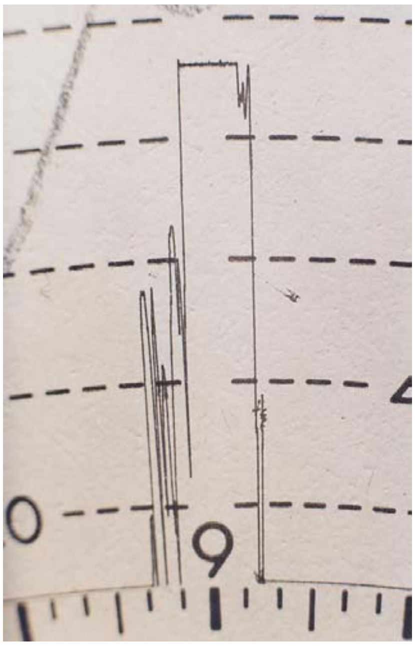
The refrigerator semi-trailer in front was pushed ca. 15 meters forward and shoved a little Ford Fiësta, which stood in front of the refrigerator truck, under a container semi-trailer ahead in the queue.

When compared to the cabin of the incoming tractor, the rear side of the refrigerator semi-trailer was hardly compressed.



From the speedometer card of the crashing tractor appears that the driver had an initial speed of 88 km/h and that he put the brake only just before the collision. He touched the refrigerator semi-trailer at the end of the queue with a speed of 75 km/h, i.e. the speed at which the speedometer registration disappeared.

From the speedometer card of the refrigerator semi-trailer appears that this refrigerator semi-trailer was accelerated by the collision up to 35 km/h.



Calculating with 1 meter deformation depth in the cabin of the incoming Mercedes tractor and a deformation depth of 0,2 meter in the rear end of the refrigerator semi-trailer, a <u>structure stiffness</u> of ca. 3000 kN/m is found for the Mercedes-cabin and a structure stiffness of ca. 15000 kN/m is found for the refrigerator semi-trailer.

The <u>EES-value</u> of the damage to the Mercedes tractor stands then at ca. 48,5 km/u, the EES-value of the damage to the Chereau refrigerator semi-trailer at ca. 21,5 km/h.

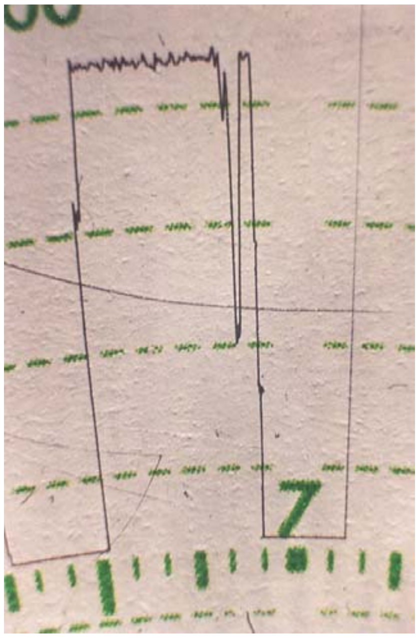
2.1.5 Rear-end collision : semi-trailer / queue of cars and lorries.

In pile-up collision in a fog bank the 15-th of March 1999 on the motorway A19 in Menen-Belgium near the French border about one hundred vehicles were involved.
Because no crash barriers were present at this place, vehicles of one section got through the central reserve into the other section resulting in a pile-up collision in both directions of the motorway.

The driver of a semi-trailer, fully loaded with stone-chippings, traveled at a speed of ca. 85 km/h, too fast to stop at the end of the jam, when he could notice it. He put the brakes and touched a first car, which had stopped partly on the hard shoulder, at a speed of about 55 km/h. This car was pushed aside. The semi-trailer then crashed into the end of the queue at a speed of about 30 km/h. A Nissan Sunny car and a Ford Transit van were compressed against the rear end of a Volvo truck that stood third from the last one in the queue. This Volvo truck, according to his speedometer card, was accelerated to a speed of ca. 12,5 km/h.

It was remarkable that the Nissan and the Ford van crashed together precisely in the same way as was already visible in the EVU crash tests in 's Hertogenbosch in Holland in 1996. The Nissan driver in this pile-up collision was as by miracle hardly injured.
The occupants of the Ford Transit had already left the vehicle when the semi-trailer swept everything together.

Another point of attention should be the rather weak vibration mark on the card of the speedometer at the moment of collision, when compared to the damage caused by the collision.



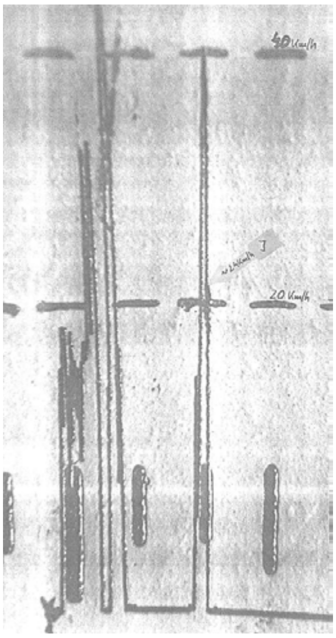
2.2. Collisions in opposing traffic.

2.2.1. Accident 1 : semi-trailer / car

The driver of an Audi left her right lane in a long right bended curve and hit a tractor semi-trailer that came from the opposite direction.
The road surface was wet and it was still dark at the time of the accident.
There was no street lighting.

The tractor was hit on the front left corner.
The Audi suffered heavy frontal damage.
The Audi-driver was badly injured.

The traces of cooling-water, the tire traces and the scratches in the road surface made clear that the Audi driver had left her right lane with half the width of her car at the moment of impact. She entered the collision apparently without any reaction to avoid it.



The speedometer card of the tractor learned that the driver of the semi-trailer approached the area at a speed of about 50 km/h - the zero line of the speedometer lies too low over about 10 km/h - and that he put the brakes before collision and in this way reduced his speed to ca. 34 km/h at the moment of collision.

The problem with this kind of collisions is to determine and establish the collision speed of the much lighter car.

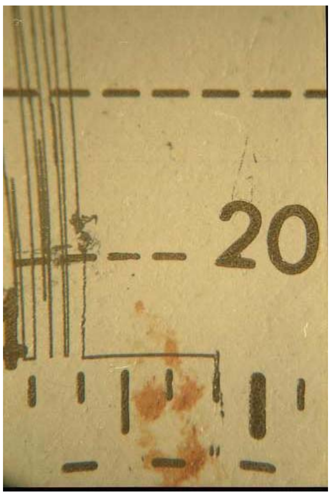
2.2.2 Accident 2 : truck / car.

The driver of a truck branched off to the left with the obvious intention to take the side road. A car, an Opel Kadett, which came from the opposite direction, hit the truck.
(The truck was a Daimler Benz 814, about 5,1 tons heavy at the moment of the accident.)

EES Opel Kadett ca. 45 km/h

The Opel was hit at the front. The Opel crashed diagonally into the trucks right front corner.

The collision speed of the truck was about 20 km/h (according to the speedometer card).



The collision speed of the car was determined with a calculation program at about 67 km/h.

The driver of the Opel put on the brakes before the collision and traveled at a speed of about 97 km/h, before he braking.

Problem here is also the estimation of the EES-value of the damage at the truck, the structure stiffness, the restitution coefficient, and in accordance with these the determination of the collision speeds.

2.3 Accidents in cross passage

The most different vehicles can of course crash into the flank of a truck. In this section only cars and trucks are considered.

Example: A semi-trailer makes a 180°-turn over the road. A car crashes into the rear wheels of the trailer.

The collision speed of the Ford can be estimated at about 40 km/h.

2.4. Tip over accidents

Simulation programs offer the possibility to assess the influence of construction parameters on the risk of tipping over of trucks and/or trailers: springs, suspension, spring track, axle construction, steered rear axles, ...
And the influence of the load can be examined just as well: type of load, liquid load, the fastening of the load,…
In addition to the speed, the road properties play a role as well: radius of the bend, the cross inclination, grooves,...

2.5. Accidents due to the driver falling asleep, so that the truck goes off the road

The expert can only establish that the truck showed no technical deficiencies in the steering, braking and suspension system or no tire problem, in cause of the accident, and that the driver went off the road without any trace of reaction. The speedometer card gives useful information.

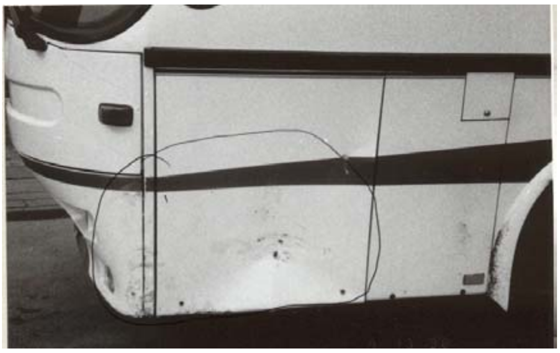
2.6. Accidents due to lane change

These accidents happen between a truck or bus and a car. A lateral sliding-contact occurs in the front flank region of the truck or bus, mostly at the right in the blind spot of the drivers view. This sliding-contact initiates a spin and skid movement of the car. The car often hits the crash barrier of the central reserve. The question arises whom of the two involved drivers carried out a lane change just before contact.

2.6.1. Lane change accident 1:

A Peugeot 309 followed the right lane of a motorway. A bus Bova drove in the middle lane. There was a sliding contact between the left rear door of the Peugeot and the right front corner of the bus. Due to this primary contact the Peugeot spun counter clockwise around the front of the bus and was smashed with its right flank into the crash barrier of the central reserve.

contact traces on the right front corner of the bus



Contact traces on the left front corner of the bus

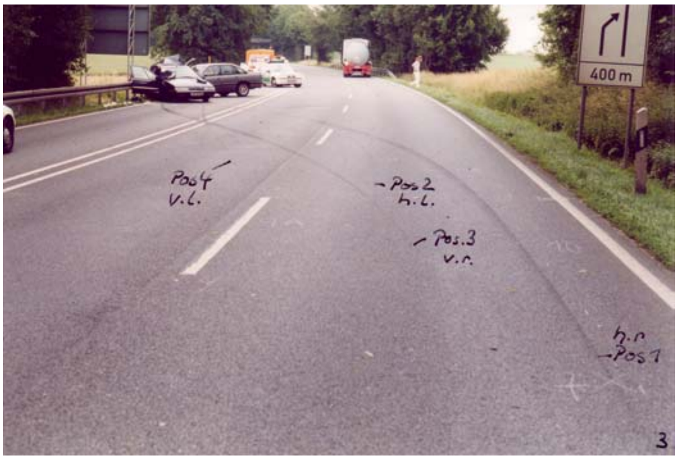
The driver of the car claimed that the bus took over and then pulled over too early to the right.

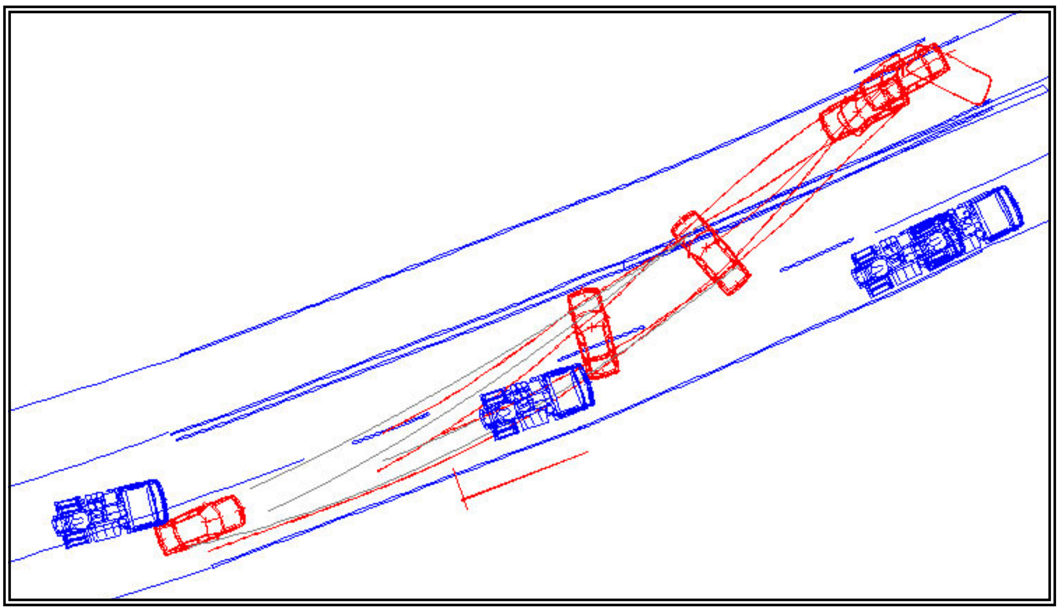
The bus driver claimed that the car driver took over in the right lane and pulled over to the left and in this way touched the bus.

The fact that the car spun to the left via the front of the bus means that the car drove slightly faster than the bus.

2.6.2. Lane change accident 2

A Citroën XM driver came via a driveway on a priority road. A tractor semi-trailer followed the priority road in the same direction. Both vehicles touched each other in a sliding collision about 250 m past the end of the driveway. The Citroën swerved to the left and was hit at the rear by an Opel Senator following the opposite lane.





In such an accident the problem of the blind spot in the view of the truck driver turns up.

Summary
Accidents with trucks involved can be split up in a number of types.
The rear-end collisions truck / truck or car / truck form an important category because of their number. With regard to security the problem of under riding of the cargo space of the truck shows up rather frequently. In addition to that the wide spread of the structure stiffness of different parts of a truck (front, rear, chassis, cabin) causes security problems when an accidents occurs. It also causes calculation problems when the accident is analyzed later on.
The speedometer card of the truck helps the accident expert and gives important information, which nevertheless is not always sufficient.
In the analysis of truck/car accidents, that happen during crossing or turning off the main road, raises the question with what speed the car hit the truck. Crash tests should learn more about the EES-value of the damage of such car/truck collisions.
Tip-over accidents can actually be analyzed with simulation programs. These programs offer the possibility to check the influence of the speed and the road parameters, as well as the influence of construction parameters such as suspension, axle construction, steered rear axles, load, etc.
Accidents in which a single truck goes off the road ask for technical examination of the steering, braking and suspension elements of the truck, so that a technical or tire problem can be excluded. The speedometer card can eventually give some answer to the question if the driver fell asleep.
The question which one of the two vehicles changed lane in a lane changing accident gets mostly an answer when skid traces of the car are available.

Epilogue
I thank everyone who helped to build up this lecture: Dipl.-Ing W. Berner, dr. Heinz Burg, Dipl.-Ing. C. Cardigno, Dipl.-Ing. J. Depuydt, P. Devieze, Dip.-Ing. T. Kaats, W. Kegelaers, dr. Köfalvi, Ingenieursbureau Sieger & Jahns, Dip.-Mat. W. Vandeweerdt, Dipl.-Ing. P.Wuylens.