Increased safety and reduction of congestion by using driver assistance technology; dream or reality?

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ABSTRACT

As accidents with trucks have a large influence on traffic flow, a large pilot on the effect of driver assistance systems was kicked off in July 2008 in the Netherlands. The primary goals of the pilot are to assess the potential for improving safety and maintaining traffic flow.
The potential contribution of driver assistance systems to these objectives will be determined with 2550 trucks from about 100 transport companies. Each truck is equipped with one assistance system and a registration unit for monitoring driving and vehicle behaviour.

Driver assistance systems used are: Lane Departure Warning, Forward Collision Warning, Directional Control, Adaptive Cruise Control, Rollover Control and Black Box with Feedback. The latter system was developed especially for this project. Based on continuous measurements, the driver receives a daily report on his "safe and congestion preventing" driving behaviour. So far, drivers and transport companies are very positive on this system.

When closing the pilot halfway 2009, it will be concluded what the effects are of these systems on traffic safety and congestion. The conclusions will be based on proving ground tests, simulations and measurements from the pilot, like:

- Average speed, speed variations, accelerations, etc.
- Time-to-Collision over a time span, headway (time)
- Warnings and actions by the systems

Effects on traffic flow will be quantified based on changes in driving behaviour and based on expected reductions of accidents. This pilot will deliver unique, statistical data on the actual effectiveness of a range of driver assistance systems.

The project is performed in a close cooperation between TNO, the Dutch Ministry of Transport, Public Works and Water Management, Connekt and Buck Consultants. Currently, the focus is on the Netherlands, but it is investigated how to interpret the results for Europe.

INTRODUCTION

During rush hour, large parts of the Netherlands are suffering from traffic jams. Especially the areas around the major cities are congested. Besides this, there are on many spots increasing congestion problems during the rest of daytime. The Dutch infrastructure is relatively vulnerable for incidents. A well know example of incidents which can paralyse large areas of motorway traffic for hours is the case of the heavy vehicle roll over accident, occurring about thirty times a year on a motorway and about one hundred times on other roads, often close to motorway areas.
Figure 1 shows the locations of rollover accidents with heavy vehicles, in 2006, on Dutch motorways.

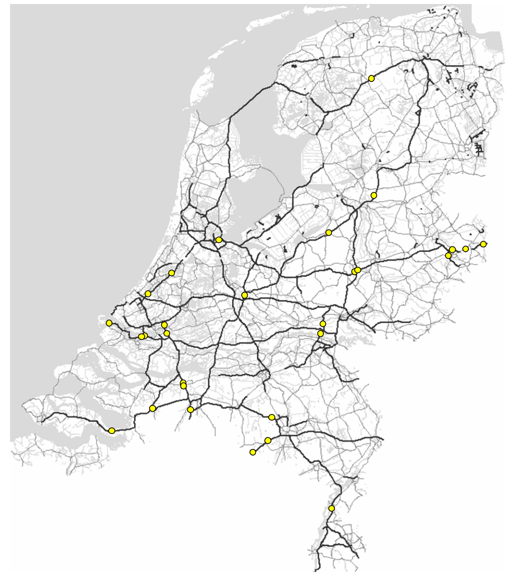

Figure 1. Locations of rollover accidents with heavy vehicles on Dutch highways, 2006

This situation is affecting of course the daily life of many commuters, but also has increasing negative economical and environmental effects. The Dutch Ministry of Transport, Public Works and Water Management has considered this situation with growing concerns and launched the so-called FileProof Programme in 2006.

At the start of FileProof, ministree employees, local governments, private citizens, business, interest groups and knowledge institutions provided a host of creative ideas on the topic. This host consisted of about 3000 ideas, which were evaluated by a group of experts, resulting in a wide programme of about forty projects. These projects all aim at short-term solutions for traffic congestion, ranging from changing driver attitude and improved road signs to implementation of Accident Prevention Systems in (heavy duty) vehicles.
It can be seen that the projects also have different objectives from increasing regular traffic flow to a more fluent level, up to the reduction of occasional traffic jams.

This paper focuses on the Accident Prevention Systems (APS) project. Determining the effects of these systems on safety and traffic flow, as well as determining the effectiveness of the systems, needs to be done in a joint effort of theoretical work and major experimental work. For this last part, a so-called Field Operational Test is an appropriate instrument which also is being applied in this APS project.

The project described here contains the most comprehensive Field Operational Test (FOT) conducted so far, on Accident Prevention Systems in heavy duty vehicles.

The objectives of this project are divided into these aspects:

1. Assess the impact of large-scale implementation of accident prevention systems on traffic circulation and traffic safety
2. Gain insight into the effectiveness of the various systems with respect to lorry traffic safety.

The APS project is conducted with full support of many Dutch transport companies and by the relevant transport interest groups.

BASICS OF THE METHODOLOGY

The Dutch Ministry of Transport, Public Works and Water Management wanted to be able to measure real-life effects of the Accident Prevention Systems, rather than purely simulation results or theoretical answers. Furthermore, a boost of the implementation of APS in the heavy vehicle fleet was considered to be highly desirable, hoping it would increase also road safety. Therefore, a FOT turned out to be a very appropriate instrument. In starting an FOT, it is best to learn from previous experiences as it is a complicated instrument. Within the EU project FESTA [1] a FOT was defined as: *A study undertaken to evaluate a function, or functions, under normal operating conditions in environments typically encountered by the host vehicle(s) using quasi-experimental methods.*

It is important to note the wording "to evaluate" in this definition. Many aspects of a system can be evaluated, ranging from technical aspects to e.g. influencing the actual driving behaviour.

In an FOT effects can be studied in real traffic conditions, rather than under pre-defined circumstances. That would be the case in laboratory testing or driving simulator testing. Though, while working in an FOT, one has to be careful with comparing measured data from several participating vehicles. Without proper reference data (measured in vehicles without APS) the benefits and effects of the in-car systems cannot be properly assessed. Furthermore, one should compare only results from similar situations. External factors like weather type, traffic condition, GPS location, time of day and road type must be taken into account.

In an early stage of the project, traffic simulations were performed to determine the number of vehicles and the period during which the measurements should be done. Statistical power analyses were conducted, using Monte Carlo simulations. This made it possible to take into account the two underlying variables; the number of vehicles in each test group (per APS) and the measurement duration. In traditional power analysis methods (e.g. Cohen [2]), this combination is not accounted for in a straightforward manner.
In the end, it was recommended that the number of vehicles in each group should be 400, while the measurements should ideally run over about 8 months. All vehicles should have a data collection unit on board, to measure basic input for later analysis. Parameters to be measured would be e.g. vehicle speed, time to collision, time to line crossing, location (GPS), time and accelerations. Furthermore, participating vehicles have at most one working APS onboard.

One group of vehicles should have only a data collection unit on board, no active APS. This group is the reference group. It is essential to have a group like this. Without it, the actual effects of the APS cannot be truly determined.

SYSTEMS

An early study in the starting phase of the project looked into the support systems to be used in the FOT. Basic issues here were the needs on the Dutch roads, availability of systems, working principle and expected benefit and effectiveness of the system. Furthermore, it was tried to pick systems with different principles of work and different types of potential accident scenarios in which the APS should be effective (head-tail accidents, side accident, single sided accidents). It was also decided to have a mixture of systems only informing the driver, and systems which actually perform actions. Also the moment in which the systems become active differs for the systems chosen (see Figure 2).

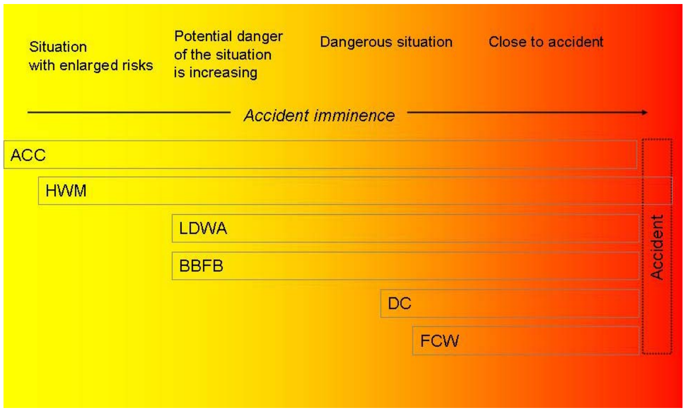

Figure 2. Accident imminence and activation of APS

There are some reference groups in the project. The trucks in the reference groups all are equipped with the same data collection unit as all other trucks.
Based on the pre-study [3, 4], the following systems were selected to be included in the FOT.

1. HWM + FCW (Headway Warning and Monitoring + Forward Collision Warning). The system used in the FOT combines the two functionalities into one module. HWM warns whenever the time headway to the preceding vehicle becomes too short. The headway is determined by using a combination of the vehicle speed and the distance to the preceding vehicle. The FCW warns the driver when the time to collision becomes smaller than a certain threshold value. Within the FOT, the driver cannot switch off the HWM/FCW system.

2. LDWA (Lane Departure Warning Assist). This assist warns the driver when he is unnoticed leaving his lane (i.e. indicator lights are not used during or close to a lane departure). This is done based on a time to line crossing criterion, determined by a camera. Also this system cannot be switched off by the driver in the FOT.

3. ACC (Adaptive Cruise Control). ACC intends to maintain the speed as programmed by the driver, but also tracks down preceding vehicles. The headway towards these vehicles is kept to a safe value. The test drivers in the FOT can switch on and off the ACC as they wish. ACC is most often used during long distance travels in uncongested traffic.

4. DC (Directional Control). DC is an autonomous system, taking action when the vehicle does not properly respond to steering actions or starts sliding. Its actions normally are performed by braking at selected wheels. DC can be combined effectively with ROC (Roll Over Control), which is an algorithm that also uses the brakes when the vehicle tends to roll over.

5. BBFB (Black Box FeedBack). This is a new system, developed especially for this FOT. This system is described in the next section.

The HWM/FCW and the LDWA can be built into (heavy duty) vehicles during the vehicle's commercial life time, as they are available as retrofit systems. This essentially speeds up the large-scale introduction of these systems. The BBFB functionality is a newly developed functionality of a kind of fleet management system which also is available as retrofit toolkit. For heavy vehicles equipped with a relatively new version of the hardware of the fleet management system, a remote software update is sufficient to equip existing vehicles with the BBFB functionality.
The ACC, DC and ROC are only available as ex factory systems. To get these systems in the FOT, also truck OEMs were involved in the project set up.

Figure 3 shows the ordering of these systems in subprojects, including the number of trucks in each group. In total, 2550 trucks are involved in the project.

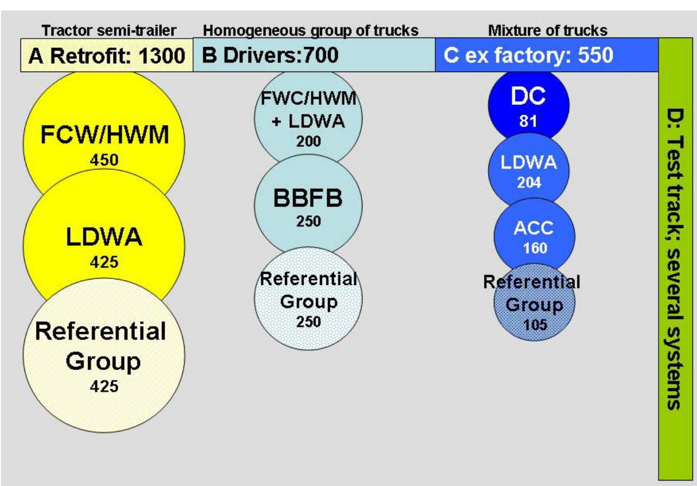

Figure 3. Groups of trucks in the FOT, including numbers

As can be seen from this figure, there are four subprojects. SP A has a focus on retrofit systems, which are being installed on the participating trucks. SP B focuses on actively influencing the driver's behaviour, including the development and use of the new Black Box FeedBack functionality. SP C works on ex factory systems, more cooperation with OEMs is taking place here. The sample groups are some smaller here as it turned out to be necessary to interfere with the actual production process which is not easily done.
SP D focuses on proving ground tests, going into issues which cannot be determined in tests on public roads. Work on SP D Track tests will be discussed in one of the later sections.

BLACK BOX FEEDBACK (BBFB)

At the moment the project was initiated, there were no systems commercially available which inform the driver on his actual driving behaviour. It is expected such system will raise driver awareness on effects of driving behaviour. This can lead to improved driving behaviour and a more effective traffic flow. Therefore, TNO developed in cooperation with the company CarrierWeb a new type of Accident Prevention System, the so-called Black Box FeedBack. This system is based on CarrierWeb's fleet management system, using its existing hardware and interface.
Figure 4 shows an example of the output the driver receives.

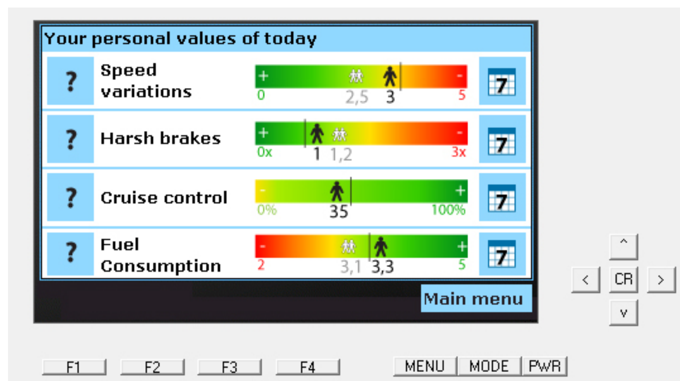

Figure 4. BBFB screen output to the driver on his daily performance

The fleet management system has a connection to the vehicle CAN. Through this connection data are transmitted to the new BBFB software. Amongst the data collected within the BBFB functionality are the vehicle speed, date, time, vehicle ID, driver ID (driver has to log on to the system, and receives personal driving information), acceleration parameters (positive and negative), fuel rate usage, distance driven, number of brakes events and GPS location.

The feedback to the driver includes amongst others:
- Speed fluctuations
- Harsh breaks
- Cruise control usage
- Fuel usage

The driver receives per variable information and explanation of his results of the last day and of the last few weeks. He can compare his results with his own long term average, but also with the long term average of his colleagues. This feature is added on specific demand by a selection of drivers in the test group.

Figure 5 shows the functional principle of the BBFB system.

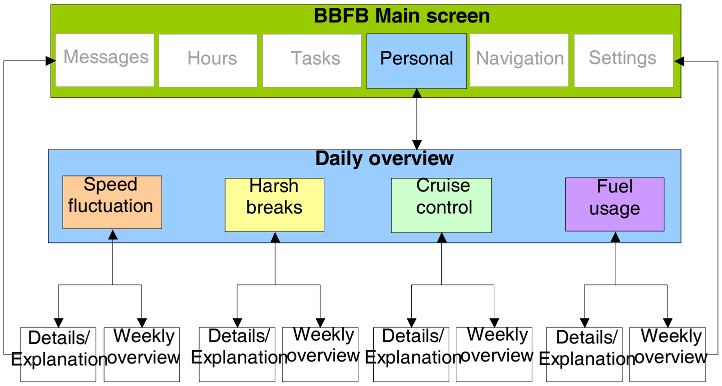

Figure 5. Functional overview of the BBFB system [5]

Feedback to the driver is presented:

- Automatically when the driver indicates that he is having a break
- Automatically when the driver logs off.
- Never while driving (where 'driving' is defined as speed > 5 km/u)
- Upon request

NOT ON THE ROAD, PLEASE

There are some items which could not be tested with large groups of vehicles e.g. due to the increased danger level or the costs.

For systems like DC and ROC, the risk towards roll over during daily transport activities had to be assessed. To do this properly, an extensive sensor system would have to be installed on the truck. This cannot be done for hundreds of trucks as in the full FOT due to high costs of sensors and long installation times. Instead, one truck was fully equipped and used extensively. There were two types of tests in which this specific truck was used: user tests and proving ground tests.

User tests

For the user test, the fully equipped truck was used by several transport companies for one or two weeks in regular transport activities. The participating companies had different types of transport activities.
An important part of the measurement equipment is the so-called RPAS module, a vehicle state estimator for trucks to assess rollover risk, developed and patented by TNO. The concept of the RPAS module is shown in Figure 6.

RPAS determines the rollover threshold value of any truck combination using data from only a few sensors that can be installed easily. The system can be used as an autonomous unit in which the sensors are incorporated and it is generally installed on the trailer. As the rollover propensity of tractor semi-trailer is mainly determined by the loading of the trailer, the internal algorithm is developed to adapt the critical roll value shortly after the load of the trailer has changed. In the user test the algorithm has been applied for post-processing of recorded data.

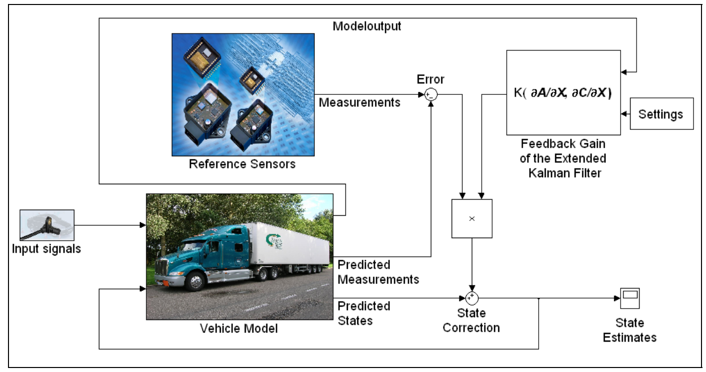

Figure 6. RPAS state estimator concept [6]

During the user test, no emergency situations occurred but nonetheless some interesting observations were made. On the proving ground it was assessed that for this particular vehicle the DC system activates at a rollover risk level of about 55% of the rollover threshold value. During three trips (more than 100 were recorded) the rollover risk marginally exceeded 55%, and during the event with the highest recorded rollover risk (61%) the DC actually was activated. As expected the rollover risk achieves significant values for the loaded truck only. For the unloaded truck the maximum rollover risk during trips never exceeded 45%.

A detailed analysis was made into the situations where rollover risk was relatively high using e.g. recorded GPS coordinates. The largest rollover risk is generally found for cloverleaf motorway junctions and on motorway entrances and exits.

Figure 7 shows the location where the DC intervention occurred during the 7400 km User test.
The rollover risk is indicated in Figure 8 together with measured vehicle speed, steering angle and lateral acceleration.

Figure 7. Cloverleaf with highest measured level of roll over risk and DC intervention.

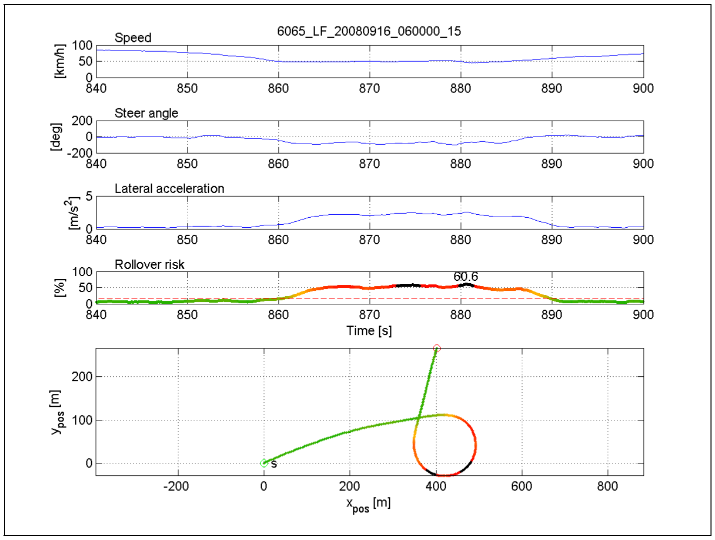

Figure 8. Measured values of speed, steer angle, lateral acceleration and rollover risk for the trip recording with DC intervention

For the occurrence of high levels of roll over risks the vehicle payload is the most influencing factor. Secondly, there is a strong relation with road infra structure, and finally the recordings have also shown that the maximum level of rollover risk is dependent on the driver. In all cases however the drivers maintained sufficient margin towards the rollover threshold so it can be concluded that in general they have a true perception of the vehicle safety levels.

Proving ground tests

On a proving ground, it is possible to go to the limits of vehicle operation. In controlled situations, one can get very close to an accident situation, while still being able to avoid it at a very late moment. Furthermore it is possible to repeat experiments with exactly the same conditions, thus testing several Accident Prevention Systems under the same circumstances.

On the proving ground, experiments were performed with roll over systems, ACC, FCW and LDWA. The test truck was a fully loaded tractor semi-trailer, which was equipped with many data acquisition systems (including the RPAS module). The truck was e.g. approaching a “target vehicle”. The FCW or ACC should in time warn the driver or undertake action, both for moving target vehicles as well as for a non-moving target. The systems were also tested on their ability to make a distinction between a vehicle and road furniture.

Furthermore other tests were performed, like:

- Driving in a constant circle, with increasing speed. Thus, near-critical levels of roll over were achieved.
- Driving in a circle with decreasing diameter, like in slip road situations.
- Braking while driving in a curve.
- Changing lanes, including extreme avoidance maneuvers.
- Line crossings including corrections.

HOW TO COME TO CONCLUSIONS

The FOT is planned to run until the end of June 2009. Only then, a full data set will be available for final analysis. The data from the 2550 test trucks will be combined with data from the track tests, the user test and results found in literature. Of course, data has to be properly collected and combined to have a solid basis for conclusions on the effects of APS on traffic flow and traffic safety.

From the overall project, some intermediate conclusions have been found:

- The preparations for a FOT like this are easily underestimated. The number of partners, the technical requirements and data acquisition are key issues for the success of a FOT.
- There is a huge enthusiasm for the project from the side of transport companies. They made large parts of their fleet available, which did cost them a considerable amount of time.
- For unloaded trucks, the measured level of roll over risk was always below 45%.
- During a majority of working days a moderate level of roll over risk are obtained with a loaded vehicle (45-55% risk level). Drivers normally assess the risk level in time and properly.
- The Black Box Feedback gives drivers information that makes them more aware of their driving habits.

Last but clearly not least: never underestimate the effect of daily life of drivers to your test…….or how lunch packaged in aluminum foil can strongly affect measurements!

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