ABSTRACT

The euroFOT project is the first large-scale Field Operational Test (FOT) of multiple Advanced Driver Assistance Systems (ADAS) in Europe. It will evaluate the impact of ADAS on safety, traffic efficiency, environment, driver behavior and user-acceptance in real life situations with normal drivers by means of collected data from instrumented vehicles. By offering valuable information for the short- and long-term impact of ADAS the euroFOT project aims to encourage the deployment of ADAS. Altogether, about 1000 vehicles equipped with different ADAS technologies take part in the field operational test. The FOT is coordinated by five Vehicle Management Centers (VMC) and carried out at various operation sites across six European countries (France, Germany, Italy, Netherlands, Sweden and United Kingdom). Within this paper the approach for conducting a field operational test for assessing the impact of ADAS at the German1-VMC and selected first results are presented.

1 INTRODUCTION

Today road transport in Europe faces enormous challenges caused by economical and social changes in the last years. These lead to new demands for each individual as well as for the entire economy. The individual demand for personal mobility and flexibility is increasing in Europe as it has already been over the last ten years. Studies show that the number of vehicles has grown from around 400 vehicles per 1000 inhabitants in 1995 to 480 in 2005 within the EU25, which caused a higher traffic density [1].

This growing number of vehicles is accompanied by an increased driver workload, due to increased traffic complexity and driving tasks, which results in a higher accident risk. In order to support drivers and to make driving safer, more comfortable and efficient with respect to environment and traffic flow advanced driver assistance systems have been developed. Their potential to provide a positive impact on traffic safety and efficiency is partly recognized [2].

Over the past years Anti-lock Braking Systems (ABS) and the Electronic Stability Program (ESP) as well as passive safety systems, e.g. safety belt or airbag, caused a significant reduction of accidents with injuries and especially of traffic fatalities. However, there are still 35000 fatalities on European roads every year. Hence the European Commission (EC) has announced in the 2001 White Paper on transport the objective of halving the number of fatalities on European roads until 2010 [3].
Started within the seventh framework programme of the EC, the euroFOT project establishes a comprehensive, technical and socio/economic assessment programme for evaluating the impact of ADAS on safety, traffic efficiency, environment and user-acceptance in real life situations. By means of instrumented vehicles data is collected and evaluated within the field operational test, in order to answer the pre-defined research questions.

1.1 German1-VMC

The fleet of the euroFOT project is coordinated by five vehicle management centers (French, German1, German2, Italian and Swedish) across several European countries. The following map presents the geographical location of the VMCs in the euroFOT project.

Figure 1. Vehicle management centers in the euroFOT project

This paper focuses on the approach defined for the German1-VMC. Here a fleet of 200 vehicles is managed, which consists of 60 trucks from MAN, 100 passenger cars from Ford and 40 passenger cars from VW. The data acquisition and processing as well as data storage processes for collected data from these 200 instrumented FOT vehicles are defined and implemented by the Institut für Kraftfahrzeuge of the RWTH Aachen University (ika). The field operational test is conducted for a period of 12 months. The tested ADAS functions cover Adaptive Cruise Control (ACC), Lane Departure Warning (LDW), Forward Collision Warning (FCW) and Curve Speed Warning (CSW).

All 200 vehicles are equipped with Data Acquisition Systems (DAS), which allow recording and temporary storage of all relevant measured values as well as the transfer of previously recorded data to a central storage server. The estimated amount of data at the German1-VMC adds up to approximately 6 TB, considering a duration of one year for the field test. The following figure provides an overview of the German1-VMC.
As a result of this huge amount of data a detailed analysis of the complete data within the planned period of time is not feasible. Hence a limitation of the evaluation to relevant driving events is necessary, in which the particular tested functions have an influence (e.g. car following, lane change manoeuvres, critical distance situations (incidents) etc.). These events are extracted from the collected data by an automated process which has been developed at ika. The event recognition algorithm automatically detects certain patterns (combinations of different measures) in the CAN- and GPS-data. Although this approach demands high computational performance, it enables saving considerable amounts of time compared to manual processing of the large amount of data. In the following the methodology, the data processing chain as well as the automated event recognition processes are presented.

2 METHODOLOGY

The relevant data to be collected within the field test has been derived from the research questions of the project. Based on these research questions (assessment of the impact of ADAS on traffic safety, traffic efficiency, environment as well as driver behavior and acceptance) hypotheses to be tested (e.g. „ACC decreases the number of incidents“) have been defined. By means of the hypotheses the required signals and data sources have been identified. The definition process applied for the euroFOT project is presented in Figure 3.

Depending on the vehicles used, the available signals can vary between the different vehicle types and the VMCs. Moreover the vehicle types and instrumentations are not the same at all VMCs. Some of the VMCs collect only CAN-data, while others additionally collect video data, eye glance information etc..
For each operation site an adapted experimental design has been defined, in order to consider the specific basic conditions. In general the experimental design consists of a baseline (system-off period) as well as a treatment period (system-on period). At the German1-VMC the first three months of the field operational test will serve as a baseline period during which the ADAS functions will be deactivated, while data on driving performance (e.g. vehicle speed, acceleration) is collected. During the following treatment period, the functions to be tested will be activated and the recording of the same driving data will be continued. Comparisons between recorded driving behaviour and performance data for the same participant in the baseline and treatment periods will be made, in order to assess the impact of the functions. As an example the figure below presents the experimental design for 60 trucks at the German1-VMC.

![Experimental design for 60 trucks at German1-VMC](image)

The trucks are equipped with ACC and LDW and are divided into two fleets. After the three month baseline period \((A_1)\) the functions will be tested separately at first. 30 trucks will have only ACC available while for the other 30 trucks only LDW is available. In the second treatment period \((B_2)\) both functions will be activated and available for the drivers. By means of comparisons between relevant data sets for the same participants in the first treatment \((B_1)\) and second period \((B_2)\) the impact of the combination of functions (ACC and LDW) will be assessed. Both tested functions will be deactivated within the second baseline period \((A_2)\), in order to assess potential learning effects by comparison with baseline period \((A_1)\), due to seven month treatment period \([4]\).

During the whole experimental phase data is collected from the instrumented vehicles. For the German1-VMC it has been decided to continuously record the required signals with defined sampling rates instead of collecting data only after detection of a relevant situation.
Thereby some remarkable disadvantages can be avoided. One of the main disadvantages of a discontinuous recording of the data is a loss of possibly relevant data because of a not well-suited event recognition (e.g. wrong thresholds). The detection cannot be adapted at a later stage, if relevant raw data has not been collected. At the German1-VMC the signals are recorded permanently and event recognition is applied afterwards “offline” within a server-side process. The availability of the complete raw data allows reprocessing of information after implementing any desired adaptations. However, the high amount of data that is generated compared to the situation-based approach results in higher demands on the data management.

3 DATA MANAGEMENT

For data collection in the field, the German1-VMC has equipped in total 200 vehicles with data acquisition systems (DAS). These DAS will collect data from up to four CAN-buses of the vehicles and additionally GPS-information. Other signal sources on vehicles side are not used at the German1-VMC, in order to ease the integration of the DAS into the vehicles compared to other scenarios such as integration of additional sensor equipment (e.g. video sensors).

The data measured on the connected CAN-channels will be stored in a first stage on a FLASH storage device installed on the DAS. The DAS at the German1-VMC offers the possibility to communicate with the device during operational time of the field test using an integrated GPRS module. This allows wireless uploading of recorded information to a centralized server system, while the DAS is collecting data simultaneously. Therefore the data is compressed and encrypted. By means of a GPRS connection the DAS status and operation on board of the vehicle can also be checked and monitored during the entire operation time. Figure 5 presents an overview of the process stages of the German1-VMC approach.
These stages are data acquisition, pre- and post-processing of data, storage and analysis of data. After the data has been uploaded to the server, further processing steps are conducted. Within these processing steps the data will be enriched with additional attributes from a digital map (e.g. road type, speed limit), which are derived by means of GPS-information. Afterwards all necessary signals for the detection of relevant events and situational variables are available. Finally the processed data as well as the initially recorded data is stored on a server. Here the raw data is stored in files on a per-trip basis (i.e. for each trip one data file is recorded) as a backup for the case that a re-processing of certain data sets will be necessary. The processed data is filled in tables of an SQL-server. Data on the SQL-server will serve as basis for the evaluation.

The upload procedures are designed and implemented to work fully autonomously. Autonomous operation means that no user interaction – neither on the driver side nor on the operator side – is required. Hence the drivers are totally kept out of the data retrieval loop. No training of the drivers participating in the field test is needed and the loss of data due to maloperation is excluded. Besides the event recognition and data retrieval steps the entire process chain for data management has been automated. Figure 6 presents the structure of the software architecture that has been developed at ika for this purpose.

The architecture for data management on the server side consists of several different software components. The coordination of the interaction between the software components is performed by the Central Management System (CMS). After data has been successfully uploaded on the server, the CMS is responsible for passing the data to the Data Manager, which subsequently manages the data processing. Data is passed between these software elements each time one process step is accomplished. The processing contains the conversion of the data to a standardized file format, the quality check and plausibility analysis as well as the enrichment and classification processes. The processed data is stored on an SQL based server at the end, in order to make the data available for the analysis. For configuration management and diagnostic purposes as well as operator access, additional
software components (e.g. diagnostic processor etc.) complete the infrastructure for the automation of the whole process chain.

3.1 Data processing

All data files collected by the DAS are on a per trip-basis. This means that the recording is started as soon as the vehicle’s engine is started and is completed at the latest one hour after the vehicle’s engine has been switched off. The follow-up time is applied, in order to provide additional time for data upload, which might have been not possible during the trip. If all collected data has been uploaded to the server during the trip, the DAS will be deactivated directly after the engine has been switched off.

The data files are directly passed to the processing chain by the CMS as soon as an entire recording file is available on the server side. The pre-processing is designed to work on a per-trip basis, while the post-processing (on SQL-database) will build a more complete overview.

The pre-processing of data can be subdivided into two main process steps:

- Generation of processed and derived data (needed for hypotheses testing).
- Quality analysis, in order to ensure reliance of the analysis.

These two processing steps are split into two software components with a similar processing structure.

The Plausibility and Check Manager is responsible for analyzing the usability of signals. Thereby the main functionality is realized by several extensions, each responsible for a specific aspect of data quality analysis. Checks for missing data and check for signal ranges are considered together with wrong dynamic behaviour and incoherent behaviour of signals. The data quality checks are performed directly after the upload and after each modification of the data.

In the next processing step the available signals are used to detect relevant events as well as situational variables, in order to classify the data for focusing the analysis on relevant data sets. Furthermore the performance indicators (PI) needed for testing of hypotheses (e.g. time headway, time to collision etc.) are calculated. For the whole process additional information is needed, which is derived from the existing signals (GPS and vehicle dynamics) by using attributes from digital maps (e.g. road type, number of lanes etc.). These processes are conducted by the Event, Enrichment and PI Manager [6]. Each function (event recognition, PI calculation etc.) is realized as a separate extension of this software element.

After the data has been processed it will be uploaded onto a database. The processed data stored on the database will be used for data analysis purposes. This data includes objective data from the vehicle CAN-busses as well as subjective information collected by means of time based questionnaires. In the following first results based on the initial analysis of the questionnaires received for 97 Ford drivers are presented. The final results of the objective as well as subjective data will be available by Spring 2012.
4 First results

The FOT at the German1-VMC started for Ford and VW in June 2010. For MAN the FOT started some months later. Since then approximately 2.6 million kilometres have been driven and more than 200,000 trips have been conducted.

In the following the kilometres driven by the Ford drivers divided into baseline and treatment phase are presented in the figure below. The ramp-up phase started in May 2010 for the first vehicles. In August 2010 the baseline (3 months) has been accomplished and the following treatment phase started. Altogether 1.6 million kilometres have been driven by the 100 Ford vehicles in the period May 2010 till May 2011. The FOT will be accomplished for all Ford vehicles in September 2011.

Within this time period approximately 2 TB of vehicle data has been collected (only Ford drivers). Furthermore several time based questionnaires [7] have been collected. The first questionnaire (T1) is filled out at the beginning of the FOT. The second questionnaire (T2) is provided at the end of the baseline phase. Within the treatment period a questionnaire (T3) is provided after 3 months driving with the systems and a second questionnaire (T4) at the end of the system-on phase.

In the following first results of the questionnaire analysis are presented. Altogether 97 T1-questionnaires for the Ford drivers have been received and evaluated. The T1-questionnaires contain questions on driving patterns and experience with the tested functions.

The figure below presents the estimated percentage of their road type usage by the participants. On average the drivers estimate to drive 23% on motorways, 19% on rural roads and 20% on urban areas. Furthermore the estimated percentage for driving on familiar
roads adds up to 23% (unfamiliar roads 20%). The high percentage of motorway and rural road usage is very positive, because these road types represent the areas where the tested functions are designed to be used (e.g. ACC).

Figure 8: Estimated distribution of road type usage (T1; n=97)

For the analysis it is of importance to have an indication to what extent the participants are experienced with the tested functions. Thus the drivers have been asked in the T1-questionnaire on their experience with the tested functions as well as with other automotive technologies. A comparison between the experience with navigation systems, ACC, FCW and LDW is presented in Figure 9.

Figure 9: Experience with navigation systems, ACC, FCW and LDW (T1; n=97)
A high percentage indicated extended experience for navigation systems (81%), ACC (68%) and FCW (37%). In contrast only 3% of the drivers indicate to have extended experience with the LDW. The low experience with LDW can be explained by the fact that the LDW was not available in Ford vehicles at the time the FOT started.

In the T3-questionnaire (after 3 months driving with systems) questions on workload as well as acceptance [8] are asked. In the following the feedback with respect to acceptance is presented. At the moment 48 T3-questionnaires have been received and evaluated.

Acceptance is evaluated in euroFOT by means of several indicators. As indicators usefulness, pleasantness, goodness etc. are asked. The scale for these indicators ranges from “-2” (very negative) to “+2” (very positive) [9]. The average for the different acceptance indicators is presented in the figures below. On average no negative feedback for any of the indicators has been indicated by the Ford drivers for ACC as well as FCW. In general the acceptance for ACC is rated higher than for FCW. High acceptance values (>1.5) are indicated for usefulness, pleasantness, assistance and desirableness. Only for the indicator necessity the drivers indicate a higher acceptance for the FCW.

![Figure 10: Acceptance indicators for acceptance evaluation (T3, n=48)](image)

Figure 11 presents the feedback for further acceptance indicators. For these indicators the response of the driver is positive. High positive acceptance values (>1.0) are indicated for effectiveness, satisfaction and simpleness. The FCW is rated to be more intuitive and alertness raising than ACC. It is also noticeable that for ACC and FCW the indicator “raising alertness – sleep-inducing” is rated significantly lower compared with the other indicators.
Figure 11: Acceptance indicators for acceptance evaluation (T3, n=48)

The evaluation of the acceptance indicators shows that the participants find ACC and FCW “attractive to buy”. Both functions are also rated to be reliable, whereas the ACC is rated significantly higher than FCW.

Figure 12: Acceptance indicators for acceptance evaluation (T3, n=48)

Altogether the first evaluation of the questionnaires shows a positive response feedback and in particular a positive acceptance rate for the ACC and the FCW.
Moreover the first evaluation of the objective data indicates a positive effect of the tested functions as well. The evaluation shows that the number of critical situations while driving with FCW is reduced by approximately 30%, which indicates a lower accident risk (accidents in longitudinal traffic – same direction) when driving with the FCW. Within the next months the analysis of the objective as well as subjective data will be intensified, in order to have the needed information available to assess the benefit of the tested functions.

5 SUMMARY & OUTLOOK

In this paper the approach for conducting a field operational test at the German1-VMC within the euroFOT project has been presented. Especially the methodology as well as the developed data management processes for data upload, processing and storage have been introduced. Furthermore the challenges faced during the implementation phase for data processing (e.g. event recognition, harmonization of different signal outputs etc.) are exemplified. Moreover first results of the questionnaire analysis for 97 Ford drivers have been presented. The results show that the acceptance for the ACC and FCW is rated very positive. In total no acceptance indicator is rated negative. The analysis of the available objective data shows that the accident risk while driving with FCW is reduced by approximately 30%.

Currently the final data processing activities are conducted and first data uploaded onto the databases for analysis. Within the next months the hypothesis testing as well as the impact assessment on safety, traffic efficiency and environment will be started. The final results of the project will be available by Spring 2012.

6 REFERENCES