European Large-Scale Field Operational Tests on In-Vehicle Systems
7th Framework programme
INFORMATION AND COMMUNICATION TECHNOLOGIES
ICT-2-6.2 ICT for Cooperative Systems
Large-scale integrating project
Grant agreement no.: 223945

Deliverable 6.3

Final results: User acceptance and user-related aspects

Version number	Version 1.1
Dissemination level	PU
Lead contractor	CTAG
Due date	30.06.2012
Date of preparation	19.11.2012

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Revision and history chart

Version	Date	Reason
0.1	2012-01-20	First structure (IFSTTAR)
0.2	2012-02-08	Structure Review (CTAG)
0.3	2012-02-29	Templates for data, function consolidation (CTAG)
0.4	2012-04-14	Content update (CTAG)
0.5	2012-04-17	New reorganization of chapter 3 (CTAG)
0.6	2012-04-22	First introduction of VMC data (IFFSTAR, ika, IZVW, BAST, VW, MAN, FORD, CRF, POLI, CTAG)
0.7	2012-04-27	Chapter 3 (Analysis) and Annex updated with data (IFFSTAR, ika, IZVW, BAST, VW, MAN, FORD, CRF, POLI, CTAG)
0.8	2012-04-30	Harmonization, Chapters 1 and 4 available (CTAG)
0.9	2012-04-30	Format review (CTAG)
0.91	2012-04-30	Final Review (CTAG, ika)
0.92	2012-05-19	Peer reviews comments and amendments included (all)
0.93	2012-05-28	Annex review (ika)
0.94	2012-06-15	Final integration of deliverable and J. Irion review (CTAG)
1.0	2012-06-19	Final review (EICT)
1.01	2012-06-21	Small formatting changes
1.02	2012-11-12	EC review changes Eva Garcia (CTAG), Mohamed Benmimoun (ika)
1.1	2012-11-19	Final check (EICT)

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Executive Summary

The euroFOT project is a large-scale Field Operational Test (FOT) undertaken in Europe in order to evaluate different Advanced Driver Assistance Systems (ADAS) with regard to user related aspects, traffic safety, efficiency and environment. Test vehicles instrumented with data acquisition systems and equipped with different ADAS have been provided by different manufacturers to drivers for everyday driving. The FOT is organised by four operational test centres (vehicle management centres) across Europe: Sweden, France, Italy, and Germany.

The goal of the evaluation task is to assess the societal and individual impacts of the ADAS that are tested in the euroFOT project.

This deliverable describes the methodology for the impact assessment and evaluation of user related aspects in euroFOT. Data analysis methods are described for each of the work packages undertaken within Sub-Project 6 (SP6) of the project:

- User Acceptance and User-Related Aspects Evaluation (WP 6300);
- Impact Assessment (traffic safety, traffic efficiency and environment; WP6400) and
- Socio-Economic Cost Benefit Analysis (WP6500).

euroFOT investigates ADAS that are already present in the market or are mature enough to be tested as commercial functions. The following eight functions were selected:

- Longitudinal functions:
    - Adaptive Cruise Control (ACC) and Forward Collision Warning (FCW) together in one bundle (counted as one function)
    - Speed Regulation System (SRS): Speed Limiter (SL) and Cruise Control (CC)
- Lateral functions:
    - Lane Departure Warning (LDW) and Impairment Warning (IW) (bundle)
    - Blind Spot Information System (BLIS)
- Other functions:
    - Curve Speed Warning (CSW),
    - Fuel Efficiency Advisory (FEA)
    - Navigation System (SafeHMI)

Based on the analysis of the objective as well as subjective data (questionnaires) the pre-defined hypotheses in euroFOT were tested in order to answer the research questions related to user acceptance and user related aspects. This Deliverable presents the results of the analysis related to the following research questions:

1. What features of the function, in terms of usability (e.g. accessibility, readability, controllability, compatibility while driving) influence acceptance?
2. What features of the function, in terms of usefulness, influence user acceptance?
3. Does acceptance change with experience?
4. Does trust in the function change with experience?
5. Do drivers find the function more user-friendly with experience?
6. Does frequency of usage of the function change with experience?

Overall, the analysis on user related aspects showed a positive effect on acceptance and driving behaviour. The main findings are listed below:

1. In both cars and trucks, **ACC+FCW** have a very high acceptance, being quite stable over time. Moreover, comfort and safety when driving with the systems active are also perceived as higher. Driver behaviour is influenced by the system, as the drivers feel subjectively that the driving is safer. However, driver's overall satisfaction in the case of FCW decreased after driving with the system.

2. For the **Speed Regulation System** (SL+CC), the positive expectations drivers had at the beginning of the FOT remained. Usage was quite stable during FOT, and no significant changes in workload were reported. Behavioral Changes were also observed during FOT, whereby headways increased, large accelerations were less frequent and fuel consumption decreased. The speed analysis indicates that using CC alone increased speeding on all roads apart from motorways, while SL reduced these events by up to 50%.

3. **BLIS** acceptance scores were very high: over 90% of the rankings were positive, with the system deemed particularly useful on motorways. The scores were quite stable over time. Around 80% of the drivers reported that BLIS increases safety.

4. **LDW** was ranked as quite useful and effective for increasing driving safety, providing an objective higher usage of turning indicators. However, overall satisfaction with the system was relatively low (when compared with other systems) and decreased over time. Results are different in this case in the Italian case, where only few drivers did not trust the system. Some drivers also experienced a higher workload and, despite rating the system as "quite easy to use", found the acoustic warning quite annoying.

5. **CSW was ranked positively** in terms of usability and acceptance. Around 75% of the drivers feel that safety increased when using CSW, finding it most useful on rural roads.

6. In the case of the use of **navigation systems,** it was found to be used in 40% of all driving time, especially on unfamiliar and long trips. Driving behaviour improved in terms of safety, as no specific safety critical situations were observed when handling the systems. This handling (manual input) usually occurs in low demand situations, and involves a decrease in speed and an increase of time gap to the lead vehicle. Collected data demonstrate that navigation systems have the potential to reduce driving time, distance and fuel consumption, even though they are not reducing time spent in congestions. In any case, built-in navigation systems are ranked higher in acceptance than mobile devices.

7. **In the case of IW**, it is rated as highly positive in terms of acceptance, satisfaction and usefulness, with these ratings being highly stable over time. Many drivers feel it increases safety, especially on motorways. Trust in the system was equally high, and did not change with time.

These results have clear implications for the design, execution, and data analysis of future FOT's and can, therefore, be used as guidelines for future researches in the field.

1 Introduction

1.1 Objectives

This document provides an overview of the analysis of the hypothesis formulated within euroFOT with a specific focus on user related aspects. The ADAS evaluated in the framework of euroFOT were either already commercial functions in the market, or mature enough to be tested as commercial functions. For this purpose, test vehicles, being supplied by European manufacturers, were equipped with several different data acquisition systems (DAS) to monitor as many aspects of individual real-world driving behaviour as possible (e.g. by using CAN-data, video, GPS). In addition, questionnaires were administered to gain deeper insight into drivers' perceptions of ADAS. The functions of interest are:

- Longitudinal: Adaptive Cruise Control (ACC), Forward Collision Warning (FCW), Speed Limiter (SL), Cruise Control (CC)
- Lateral: Lane Departure Warning (LDW), Impairment Warning (IW), Blind Spot Information System (BLIS)
- Others: Safe Human-Machine-Interaction (SafeHMI; navigation system), Curve Speed Warning (CSW), Fuel Efficiency Advisor (FEA)

The FOT is organised and managed by four Vehicle Management Centres (VMCs) across Europe: Sweden, France, Italy, and Germany (with two operation centres). All in all, data from almost 1000 vehicles (cars and trucks) with different ADAS have been gathered, which means that a wide range of data will be available for analysis and a detailed understanding of the impacts of ADAS can be gained.

Sub-Project 6 (SP6) has the goal to analyse the data that have been gathered and handed over by SP5. This evaluation includes

- the analysis of all user related aspects and user acceptance (WP6300), as well as
- the identification of system impacts on traffic and driving safety, traffic efficiency and on environment (WP 6400).

The data requested, including data-quality assurance needs, have been defined by SP6 in advance.

This Deliverable provides the first assessment on the user acceptance and user related aspects of the above mentioned functions. The assessment has followed the FESTA (Field opErational teSt supporT Action) methodology, which has been adapted to the specific needs of euroFOT. For example, the SPs did not start one after another, but were running in parallel, which led to strong interactions between the work packages.

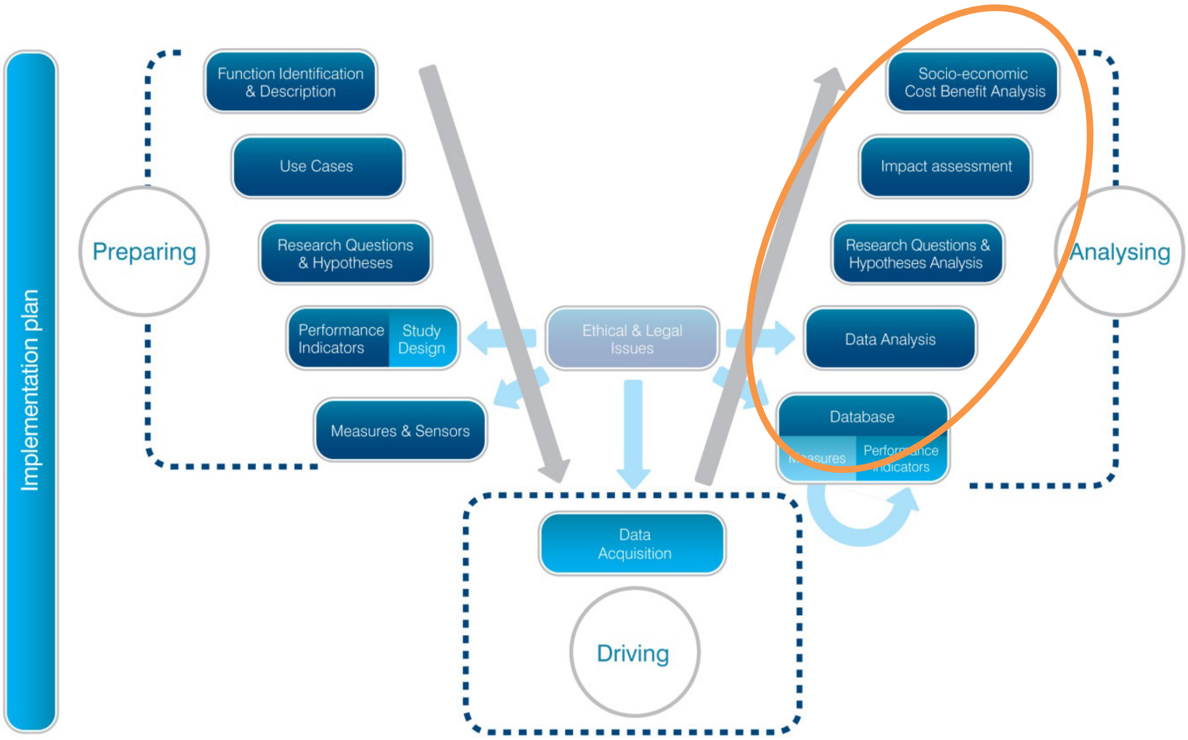


Figure 1: FESTA-V

Therefore, a first definition of Research Questions, Hypothesis and Performance Indicators (defined in SP2, SP4 and refined in SP6) has been prepared. The overall methodology of the different tasks in SP6 including the analysis on user related aspects is presented in D6.2 "Analysis methods for user related aspects and impact assessment on traffic safety, traffic efficiency and environment".

The assessment of user related aspects is based largely on hypotheses testing. This deliverable describes hypotheses testing from a behavioural point of view. The assessment will be done using performance indicators, situational variables and events [D6.2].

The main research questions for the user related aspects are:

1. What features of the function, in terms of usability (e.g. Accessibility, readability, controllability, compatibility while driving) influence acceptance?
2. What features of the function, in terms of usefulness, influence user acceptance?
3. Does acceptance change with experience?
4. Does trust in the function change with experience?
5. Do drivers find the function more usable with experience?
6. Does frequency of usage of the function change with experience?

To answer these research questions and to test the derived hypotheses for each function, objective as well as subjective data has been analysed. The objective data (derived from the vehicle CAN and video recordings) is collected by means of data loggers from the instrumented vehicles, while the subjective data (derived from questionnaires and driver interviews) is gathered by means of time-based questionnaires which are provided at certain points of the experiment (start of FOT, end of baseline phase, end of treatment phase etc.). As it is explained in D4.2 the questionnaires used in euroFOT were designed to measure the next constructs: subjective mental workload, perceived usefulness, perceived satisfaction, perceived social acceptability, affordability, trust, perceived ease of use, self report misuse/abuse, social influence, behavioural intention, experience with in-vehicle technologies, experience with technologies, experience with other technologies, attitude toward target behaviours, demographic data, personality, travel patterns, driving behaviour and user practice. The constructs evaluated in each questionnaire are described below:

Non-participation Questionnaire (D4.2, Annex 5):

- Reasons why drivers not participate

Screening Questionnaire (D4.2, Annex 6):

- Driving experience and travel patterns
- Demographics
- Health impairment issues
- Availability
- Experience with technology

Time 1 Questionnaire (D4.2, Annex 7):

- Accident record and travel patterns
- Driver attitudes
- Sensation seeking
- Consent forms

Time 2 Questionnaire (D4.2, Annex 8):

- Acceptability expectations of the system
- Subjective mental workload
- Driving behaviour

Time 3 Questionnaire (D4.2, Annex 9):

- System acceptability
- Subjective mental workload

Time 4 Questionnaire (D4.2, Annex 10):

- Driver attitudes and behaviour
- System acceptability
- Subjective mental workload

Questionnaires were harmonized between all VMCs and the analysis was conducted at each test site according to the obtained data (e.g. the impact of Adaptive Cruise Control (ACC) was investigated using data collected by Ford, VW, MAN, Volvo Cars and Volvo as it can be found in p. 46). The final results of each tested hypothesis, divided according to the tested functions, can be found in the Annex of this document.

1.2 Interaction with other SPs

The most important interactions with other subprojects and work packages are described below:

- SP2 (In-vehicle systems for driving support): In this Subproject, the requirements and specifications for testing the selected functions have been provided and hypotheses have been developed. Based on these specifications and hypotheses, the test subjects and practical requirements for running an FOT have been defined (see Deliverable 2.1 - Specifications and Requirements for Testing In-vehicle Systems for Driving Support [2]).
- SP3 (Data Management): In this Subproject the best suited data acquisition systems for data collection during the FOT have been specified and the installation process has been defined. The requirements and strategies for data storage, upload/download and the development of a data analysis tool have been provided. Relevant deliverables are Deliverable D3.1 – Selection Procedure for Data Acquisition, Sensors and Storage for euroFOT [3]; Deliverable D3.2 – Base Functionality Data Analysis Software – Updated Version [4]; Deliverable D3.3 – Data Management in euroFOT [5].
- SP4 (Methodology and experimental procedures): The work of SP4 determined what kind of data has been collected in which experimental setting and thus strongly influences the results of WP5600.
    - In WP4300, the relevant performance indicators describing driving behaviour, system usage and acceptability, as well as traffic safety, traffic efficiency and impacts on traffic environment have been identified, selected, and defined. This applies both for subjective and objective performance indicators (Deliverable D4.1 – Report on specification of performance indicators [6]). In order to measure the subjective performance indicators, a common, standardised questionnaire pack has been developed, which contains general and VMC specific items and which has been adapted to the specific requirements of each of the VMCs in SP5. For the objective data, a list with defined performance indicators has been created.
    - In WP4400 the experimental procedures have been defined: e.g. selection of participants, experimental design, and the duration of the FOT (Deliverable D4.2 – Report on specification of experimental procedures [7]).
- SP5 (Vehicle and Test Management Centre): It is the responsibility of SP5 to coordinate the VMCs, to prepare and guarantee a smooth performance of the FOT and to execute the FOT in accordance with the other SPs.

In addition to this document, relevant documents of SP6 are Deliverable D6.1 – Final Evaluation Results, D6.2 – Analysis methods for user related aspects and impact assessment on traffic safety, traffic efficiency and environment , D6.4 – Final results: impacts on traffic safety, D6.5 – Final results: impacts on traffic efficiency, D6.6 – Final results: impacts on environment, D6.7 – Overall Cost-Benefit study and D6.8 – FOT Data.

1.3 Organization of the document

This document is arranged as follows:

- Chapter 2 describes the data that has been collected by the VMCs. These data have been previously released in D5.3, "Final delivery of data and answers to questionnaires", but has been updated for D6.3.
- Chapter 3 is the core chapter of this deliverable, and summarises the results of the hypothesis testing. Results are presented separately for each function, merging the results when functions are tested in different VMCs. Note that the information here included is a summary of the overall data, which can be found in the Annex.
- Chapter 4 provides the main conclusions of the analysis from a behavioural point of view.
- Chapter 5 is the final summary of this deliverable.

As stated, a deep analysis of the different formulated hypothesis is included in the Annex. This Annex is also divided by functions.

2 Description of the FOT

This chapter summarises for each VMC the information related to the data collected during FOT operation, including the baseline phase (driving without the tested functions). This information is an update of that presented in D5.3, and includes:

- Overview of tested functions
- Participant characteristics: number, age, gender
- Experimental design
- Overview of the collected data

2.1 French VMC

The French VMC has been carried out to study two complementary systems:

i. The speed limiter (SL) which allows the driver to choose the maximum speed at which the vehicle travels. The vehicle speed is limited unless the driver turns the system off or kicks down hard on the accelerator pedal to accelerate voluntarily beyond the selected speed limit.

ii. The cruise control (CC) that allows the driver to choose a constant speed at which to travel (i.e. cruise speed). The vehicle engine automatically regulates a constant speed.

	Renault Clio	Renault Laguna
SL	✓	✓
CC	✓	✓

In this study, SL and CC were regarded as two different systems without any possible interactions since when one was in use, the other was deactivated. This was assumed for the experimental design and the statistical analysis (non-bundled functions).

The fleet consists of a total of 40 vehicles:

- 35 customer cars through Renault Dealers (14 Clio III and 21 Laguna III)
    - CTAG data logger was used to collect CAN and radar data.
- 5 cars (owned by CEESAR) were instrumented with additional sensors: 3 Laguna III and 2 Clio III
    - Those 5 cars was equipped with video cameras (4 channels) and distraction monitoring (single camera eye tracker)
    - The DAS in those cars was also based on the CTAG data logger, in order to ensure standardisation of data handling.

The experiment was conducted with 35 participants (see distribution in figure 3: 27 men and 8 women). The age mean was 49 years (see distribution in figure 2) and the mean of mileage declared by the drivers was about 18000 km / year (see distribution in figure 4). Participants were recruited through the Renault Dealers network in the west of Paris.

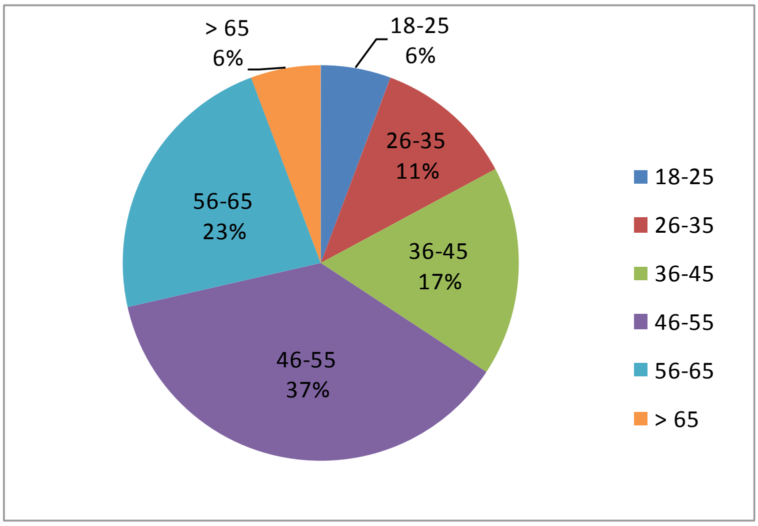


Figure 2: Age distribution of the French VMC

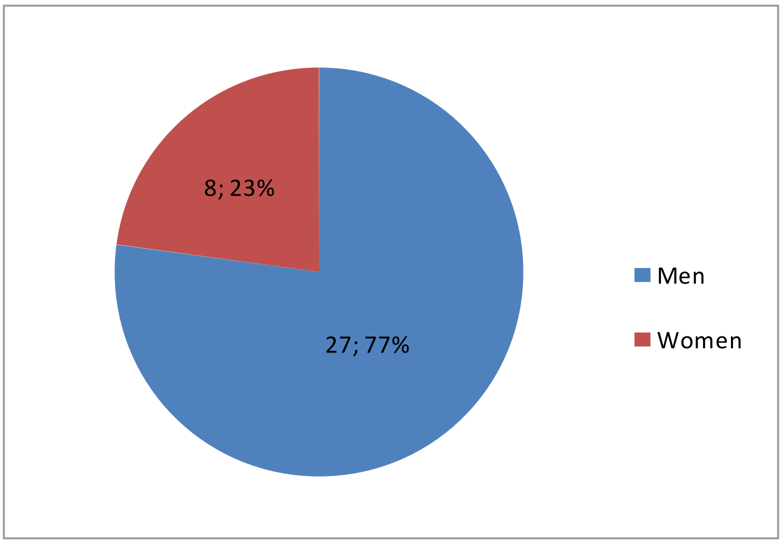


Figure 3: Gender distribution of the French VMC

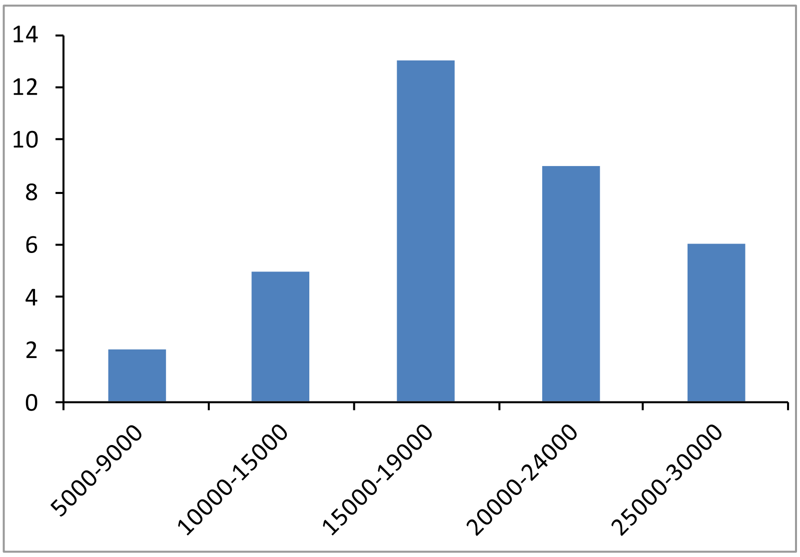


Figure 4: Mileage of the French VMC

The mean average mileage is about 18000 km / year.

Month 1	Month 2	Month 3	Month 4	Month 5	Month 6	Month 7	Month 8	Month 9	Month 10	Month 11	Month 12
Baseline			Treatment					Treatment			

Figure 5: Experimental design on the French VMC

The experimental design included both baseline and treatment phases. During the baseline phase (3 months) the drivers were asked to not use the systems. During the treatment phase (9 months) the drivers used the system. The 5 high level instrumented passenger cars were owned by CEESAR and rotated among all the 35 drivers. They were loaned for a few weeks to each of them, both during baseline (2 weeks at the end) and treatment phase (two weeks at the middle and two weeks at the end) as defined by the experimental plan (yellow phases), see Figure 5.

To summarise:

- During the baseline: Vehicles were driven without using the system (speed limiter and cruise control are off). For each driver, this included 10 weeks with his/her own car with "light instrumentation", and two weeks with one of CEESAR's heavily instrumented cars.
- During treatment: Vehicles were driven for a period of 9 months with the system available. This period included two 2-weeks periods using a highly instrumented vehicle.

During the experiment, several questionnaires developed in SP4 were handed out to the drivers in four time intervals (see the figure below). This allowed an analysis of possible changes in the perception of usability, usefulness, acceptance etc. of the systems.

The "Time 1 questionnaire", was used to gather background information on participants (e.g. demographics, health/impairment issues, travel patterns, accidents record, attitudes towards driving behaviours, sensation seeking).

The "Time 2 questionnaire" was designed to gather the driver's expectation before using the system in terms of system acceptability, (perceived effectiveness, perceived usefulness, perceived satisfaction, affordability, trust, intention, social influence) and the subjective mental workload of baseline driving.

The Time3a and Time 3b questionnaires were designed to record after 4 months of driving with system available, subjective measures of system acceptability, (perceived effectiveness, perceived usefulness, perceived satisfaction, trust, intention, and social influence) and subjective mental workload of driving.

The Time4 questionnaire was designed to record at the end of experiment information about driving habits and behaviour, attitudes towards driving behaviours, system acceptability, (perceived ease of use, perceived effectiveness, perceived usefulness, perceived satisfaction, social acceptability, affordability, trust, intention, social influence) and the subjective mental workload of driving.

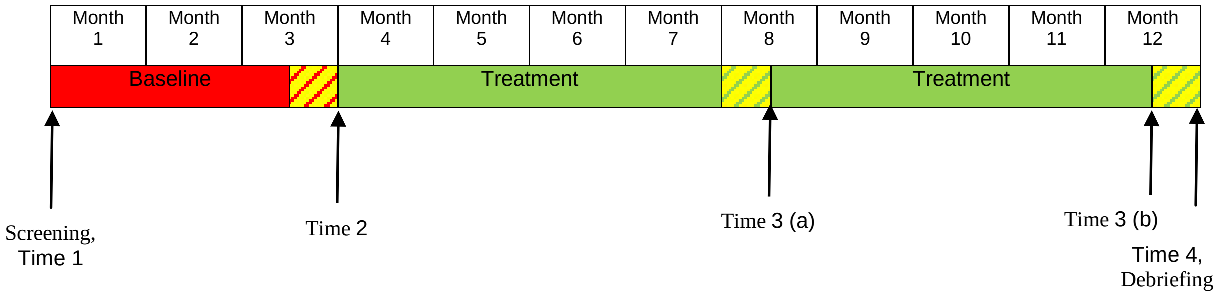


Figure 6: Timeline questionnaire distribution within the French VMC

The data collected consists of more than 540000 kilometres and 12780 hours of driving.

Table 1: Available objective data at the French VMC

Baseline							
Overall amount of data (MB, TB)	***316 GB***						
Overall km driven	***158549***						
Drivers							
N drivers overall	***35***	N drivers complete	***35***	N drivers incomplete	***0***	Drop-outs	***0***
Driving months							
N Overall driving months	***132***	N driving months complete	***132***	N driving months incomplete	***0***	N driving months missing	***0***
Trips							
N overall trips	***12778***	N trips complete	***12614***	N trips incomplete	***164***	N trips missing	***0***

Treatment							
Overall amount of data (MB, TB)	***574 GB***						
Overall km driven	***369289***						
Drivers							
N drivers overall	***35***	N drivers complete	***25***	N drivers incomplete	***10***	Drop-outs	***0***
Driving months							
N Overall driving months	***313***	N driving months complete	***301***	N driving months incomplete	***0***	N driving months missing	***12***
Trips							
N overall trips	***29 936***	N trips complete	***29 050***	N trips incomplete	***886***	N trips missing	***0***

With regards to the subjective data (questionnaires), these have been the main figures:

Table 2: Available subjective data at French VMC

Pre-FOT						**pre-treatment/ end of baseline**	
Non-participation		***Screening***		***Time 1***		***Time 2***	
N handed out	0	N handed out	49	N handed out	35	N handed out	35
N filled in & returned	0	N filled in & returned	49	N filled in & returned	35	N filled in & returned	35
N missing	0	N missing	0	N missing	0	N missing	0
Response rate (%)	0	Response rate (%)	100	Response rate (%)	100	Response rate (%)	100

During treatment				***End of trial***			
Time 3 (a)		***Time 3 (b)***		***Time 4***		***Earlier finish of FOT***	
N handed out	35	N handed out	25	N handed out	35	N handed out	35
N filled in & returned	34	N filled in & returned	25	N filled in & returned	35	N filled in & returned	35
N missing	1	N missing	0	N missing	0	N missing	0
Response rate (%)	97	Response rate (%)	100	Response rate (%)	100	Response rate (%)	0

2.2 German 1 VMC

The German1 VMC consists of three vehicle manufacturers (Ford, MAN, VW) which provide altogether 200 vehicles equipped with different ADAS. The following table provides an overview of the tested ADAS at German1 VMC.

Table 3: Tested ADAS at German1 VMC

	Ford	MAN	VW
ACC+FCW	✓	✓	✓
LDW		✓	✓
CSW	✓		

For each operation site an adapted experimental design has been defined, in order to consider the specific basic conditions. In general the experimental design consisted of a baseline phase (system off) as well as a treatment phase (system on). The first three months of the field operational test served as the baseline phase while data on driving performance (e.g. vehicle speed, acceleration) were collected. The duration of the treatment phase differed between Ford, MAN and VW. In the treatment phase the recording of the performance data continued while the drivers used the systems as they usually would do. No further instructions were given to the drivers. Comparisons between recorded driving behaviour in the baseline and treatment phase were made per participant, in order to test the pre-defined hypothesis.

All 200 vehicles are equipped with a data acquisition system that enables recording of vehicle data from up to 4 CAN-Buses. The data is wirelessly transmitted to a centralized server system, where it has been processed and analysed.

FORD (ACC & FCW)

The experimental design for Ford is presented in Figure 7.

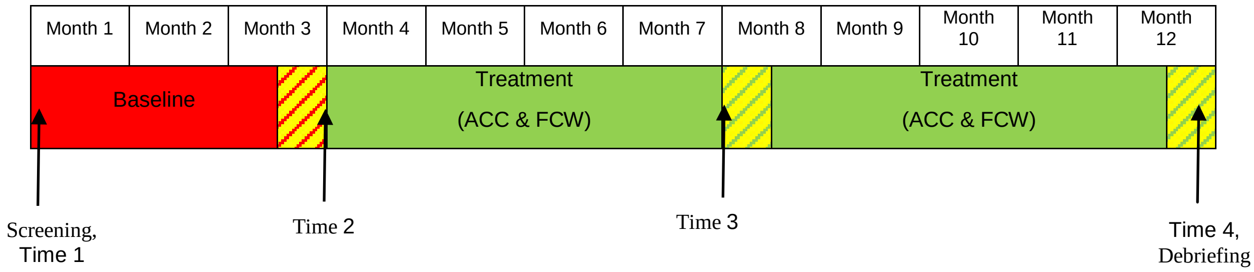


Figure 7: Experimental design defined for Ford

The experimental design of Ford consists of a three month baseline phase. The remaining nine months are used as treatment phase, in which the tested functions (ACC and FCW) are available and can be used by the drivers. Six time-based questionnaires are provided to the drivers within the 12 month of data collection. Two questionnaires are provided at the beginning of the field test (Screening and Time 1) and one questionnaire at the end of the baseline phase (Time 2). During the treatment phase two questionnaires (Time 3 and Time

4) are collected for the analysis of the driver related aspects. At the end of the trial a debriefing questionnaire is handed-out. This experimental design involved 98 series-production vehicles from Ford equipped with ACC and FCW.

Two additional vehicles are equipped with a Curve Speed Warning (CSW) function. For these two vehicles a specific FOT is conducted. Due to the experimental conditions a hypothesis testing based on the comparison of baseline against treatment phase is not applicable for the CSW. Hence the analysis is based on the distributed questionnaires (Time 1 and Time 4).

Data from (n=989) non-professional drivers of the Ford vehicles equipped with ACC&FCW is available. The drivers are the owner of the vehicles used in the FOT and have been recruited when buying a car equipped with the ACC&FCW. Most of drivers are male (n=79; 80%), and (n=11; (11%) of the drivers are female (9% did not respond). The average age of the drivers in the German 1 VMC (Ford) is around 40 years (SD=17.58); the youngest driver is 27 years old, and the eldest driver is 80 years old. The different age categories with more drivers are 36-45 (n=30; 33%) years and 46-55 (n=29; 32%) years (see Figure 8).

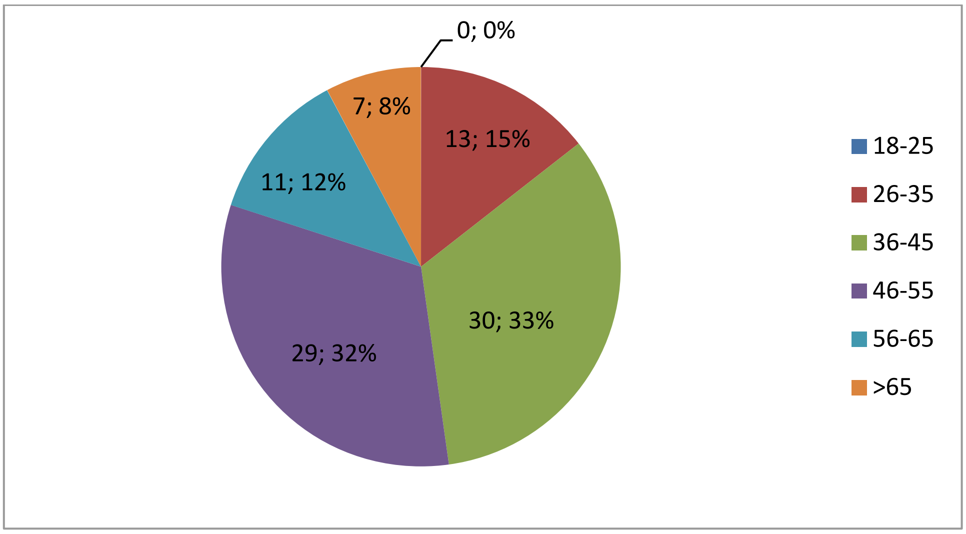


Figure 8: Age distribution of the German 1 VMC (Ford) test drivers

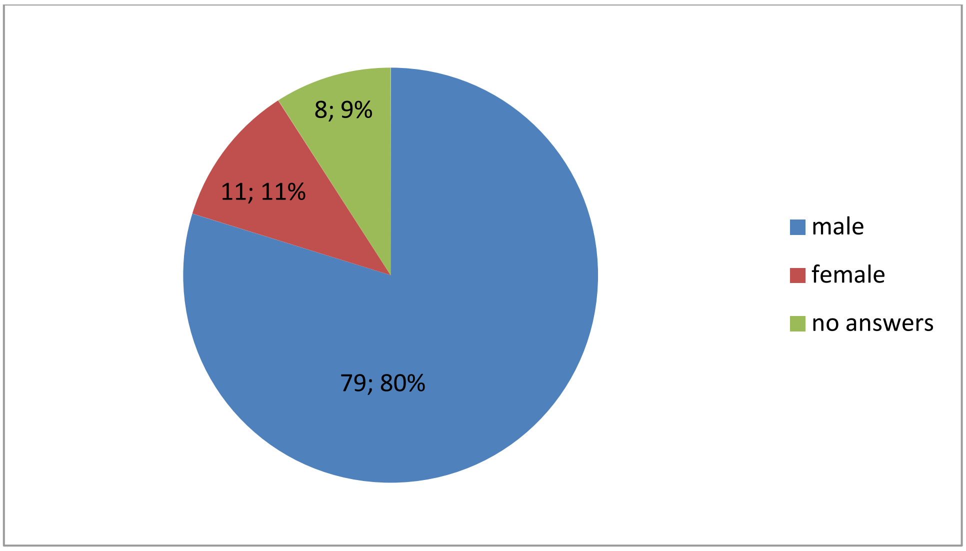


Figure 9: Gender distribution of the German 1 VMC (Ford) test drivers

Test drivers of the German 1 VMC (Ford) group indicate to drive, on average, nearly 26000 kilometres (M=25470; SD=14709) each year. Most of the participants drive more than 30000 kilometres per year (n=37; 37%). The rest of the sample (n=52), drive between 10000 and 24000 kilometres per year.

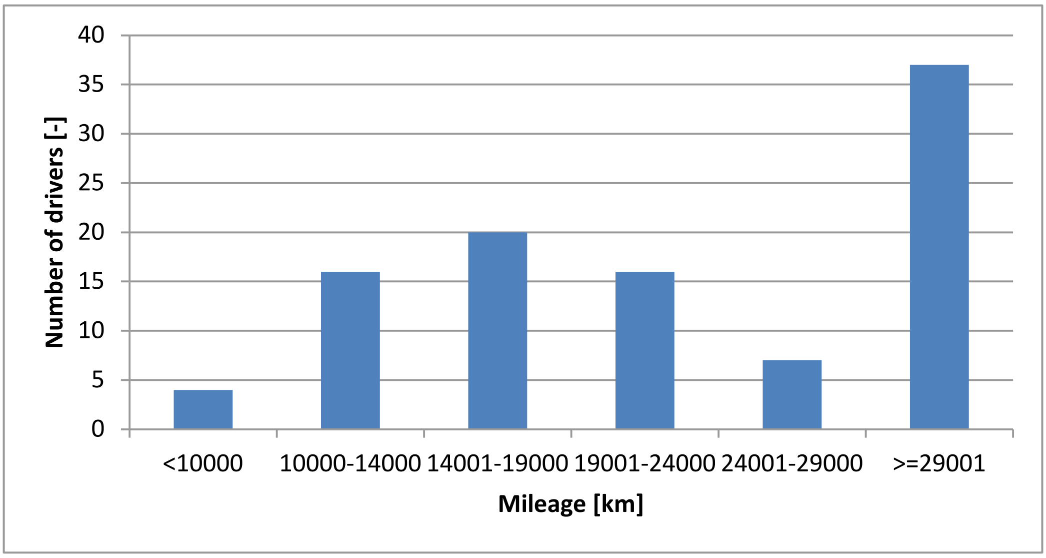


Figure 10: Distribution of annual mileage [in km] of the German 1 VMC (Ford) test drivers

The following tables provide an overview of the Ford fleet.

Table 4: Mileage at German I VMD (Ford Vehicles)

Situational Variables	Conditions	Baseline all data		Treatment all data		Treatment (ACC active)	
		Mileage [km]	[%]	Mileage [km]	[%]	Mileage [km]	[%]
overall	overall	440560	100.0	1428563	100.0	470843	33.0
Weather	good weather	382581	86.8	1277543	89.4	420805	29.5
	adverse weather	57973	13.2	151006	10.6	50034	3.5
Road type	motorway	238840	54.2	766731	53.7	378682	26.5
	rural road	80710	18.3	259577	18.2	50094	3.5
	urban road	76873	17.4	246221	17.2	19552	1.4
Lighting	dark	100230	22.8	325622	22.8	107824	7.5
	daylight	340329	77.2	1102940	77.2	363018	25.4

Table 5: Available objective data at German I VMC (Ford vehicles)

Baseline							
Overall amount of data (MB, TB)	***233,3 GB***						
Overall km driven	***440.560***						
Drivers							
N drivers overall	***100***	N drivers complete	***100***	N drivers incomplete	***NA***	Drop-outs	***NA***
Driving months							
Trips							
N overall trips	***19420***	N trips complete	***19420***	N trips incomplete	***NA***	N trips missing	NA
Treatment							
Overall amount of data (MB, TB)	***756.7 GB***						
Overall km driven	***1.428.563***						
Drivers							
N drivers overall	***100***	N drivers complete	***100***	N drivers incomplete	***NA***	Drop-outs	***NA***
Driving months							
Trips							

The available data based on the collected questionnaires is presented in the following tables. Altogether 480 questionnaires have been collected and analysed for the Ford vehicles (ACC and FCW). The information provided by the questionnaires is detailed below:

Within "Time 1 questionnaire", drivers provided information about background information in terms ofas demographics, health/impairment issues, travel patterns, accidents record, attitudes towards driving behaviours, sensation seeking.

The driver's expectation before using the system in terms of system acceptability, (perceived effectiveness, perceived usefulness, perceived satisfaction, affordability, trust, intention, socialand social influence) and the subjective mental workload of baseline driving was obtained through "Time 2 questionnaire".

The "Time 3 questionnaire" was designed to gather information on subjective measures of system acceptability, (perceived effectiveness, perceived usefulness, perceived satisfaction, trust, intention, and social influence) and subjective mental workload of driving after 4 months of driving within the treatment phase.

Finally, the "Time 4 questionnaire" was designed to record at the end of experimental phase information about driving habits and behaviour, attitudes towards driving behaviours, system acceptability, (perceived ease of use, perceived effectiveness, perceived usefulness, perceived satisfaction, social acceptability, affordability, trust, intention, social influence) and the subjective mental workload of driving.

Table 6: Available subjective data at German I VMC (Ford vehicles)

Pre-FOT						**pre-treatment/ end of baseline**	
Non-participation		***Screening***		***Time 1***		***Time 2***	
N handed out	0	N handed out	989	N handed out	989	N handed out	989
N filled in & returned	0	N filled in & returned	956	N filled in & returned	956	N filled in & returned	956
N missing	0	N missing	3	N missing	3	N missing	3
Response rate (%)	N/A	Response rate (%)	97	Response rate (%)	97	Response rate (%)	97

During treatment				***End of trial***			
Time 3 (a)		***Time 3 (b)***		***Time 4***		***Earlier finish of FOT***	
N handed out	98	N handed out	N/A	N handed out	98	N handed out	8
N filled in & returned	96	N filled in & returned	N/A	N filled in & returned	89	N filled in & returned	7
N missing	2	N missing	N/A	N missing	9	N missing	1
Response rate (%)	98	Response rate (%)	N/A	Response rate (%)	91	Response rate (%)	88

In the case of CSW, the sample is different from the other functions. The two Ford vehicles equipped with CSW were rotated among several drivers employed at Ford. Altogether information relating to 30 drivers is available; average age of the drivers is 40 years old (M=41.91; SD=8.129) and more 90% the sample, their age are between 36 years and 55 years (n=21; 92%). The youngest driver is 24 years old, and the eldest driver is 57 years old. The total of the sample, more of 50% are male (n=19; 56%) and 9% of the sample are female.

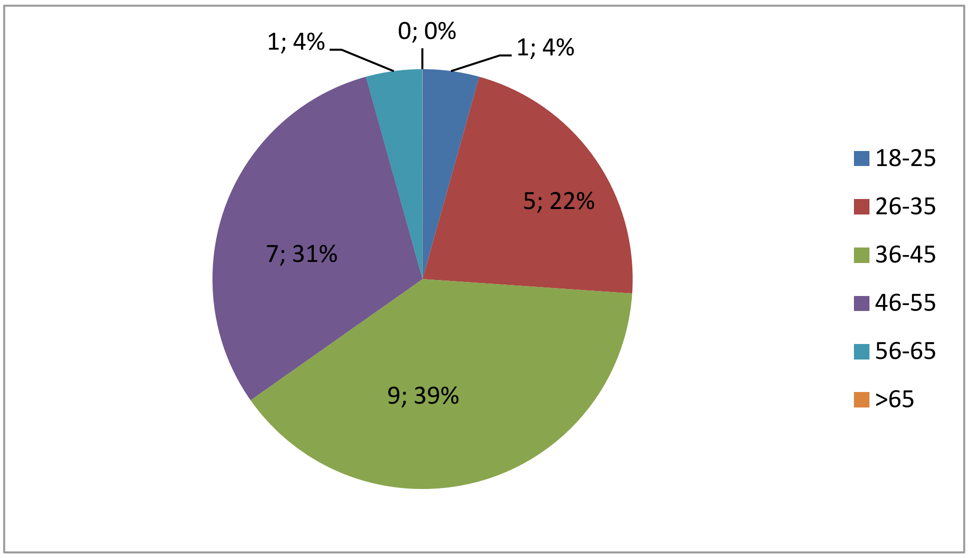


Figure 11: Age distribution of the German 1 VMC (FORD - CSW) test drivers

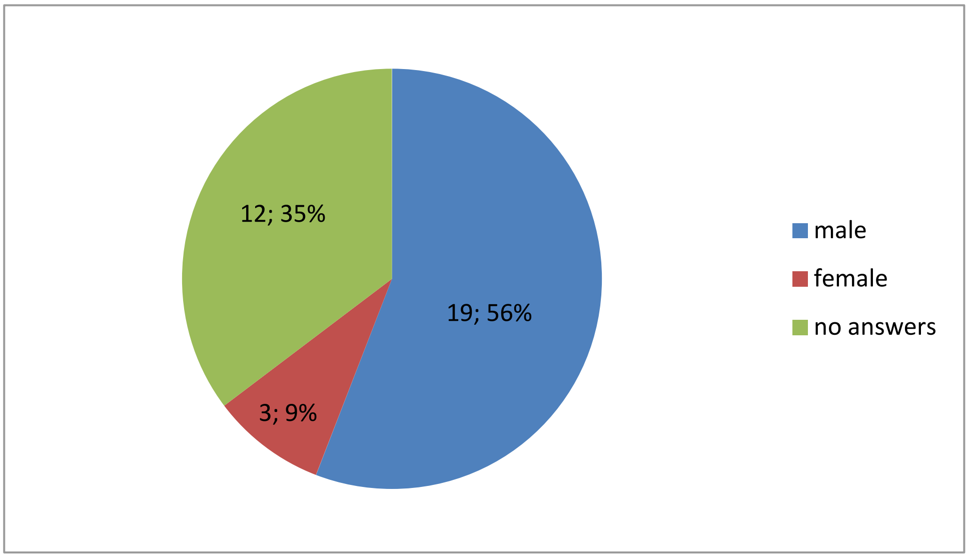


Figure 12: Gender distribution of the German 1 VMC (CSW) test drivers

Test drivers of the German 1 VMC (FORD - CSW) group indicate to drive, on average, around 18000 kilometres each year. Most of the participants drive less than 10000 kilometres per year (n=9; 30%). For the rest of the sample, around 23% drive more 29001 kilometres.

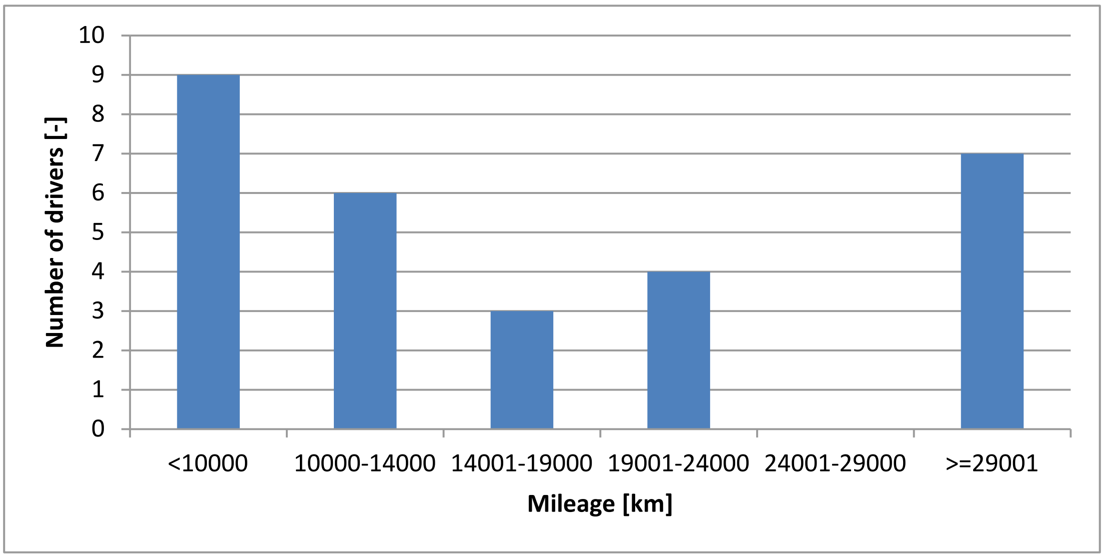


Figure 13: Distribution of annual mileage [in km] of the German 1 VMC (FORD - CSW) test drivers

Test questionnaires that have been distributed are displayed in the following table:

Table 7: Available subjective data at German I VMC (FORD – CSW)

Pre-FOT						**pre-treatment/ end of baseline**	
Non-participation		***Screening***		***Time 1***		***Time 2***	
N handed out	0	N handed out	33	N handed out	33	N handed out	N/A
N filled in & returned	0	N filled in & returned	30	N filled in & returned	30	N filled in & returned	xx
N missing	0	N missing	3	N missing	3	N missing	xx
Response rate (%)	100	Response rate (%)	91	Response rate (%)	91	Response rate (%)	xx

During treatment				***End of trial***			
Time 3 (a)		***Time 3 (b)***		***Time 4***		***Earlier finish of FOT***	
N handed out	N/A	N handed out	N/A	N handed out	33	N handed out	0
N filled in & returned	N/A	N filled in & returned	N/A	N filled in & returned	30	N filled in & returned	0
N missing	N/A	N missing	N/A	N missing	3	N missing	0
Response rate (%)	N/A	Response rate (%)	N/A	Response rate (%)	91	Response rate (%)	100

Volkswagen (VW)

The experimental design of VW is similar to the Ford design. Three months of baseline data collection was followed by a three month treatment phase.

The questionnaires were distributed as follows:

- Screening questionnaire (background info such demographics, personal data, travel patterns and experience with in-vehicle systems): at the beginning of the FOT
- Time1 (measures after familiarisation of the participant in driving new vehicle without assistance: driver attitudes, accident record, travel patterns and sensation seeking), Time2 questionnaire (ratings on self-reported workload and driving behaviour): at the end of the baseline period (after three months), before the beginning of the treatment phase
- Time3 questionnaire (acceptability and workload measures): halfway-through the treatment phase (after 6 weeks in the treatment phase)
- Time4 (composed by acceptability and workload items), Debriefing questionnaire: after the end of the treatment phase (after 3 months in the treatment phase)

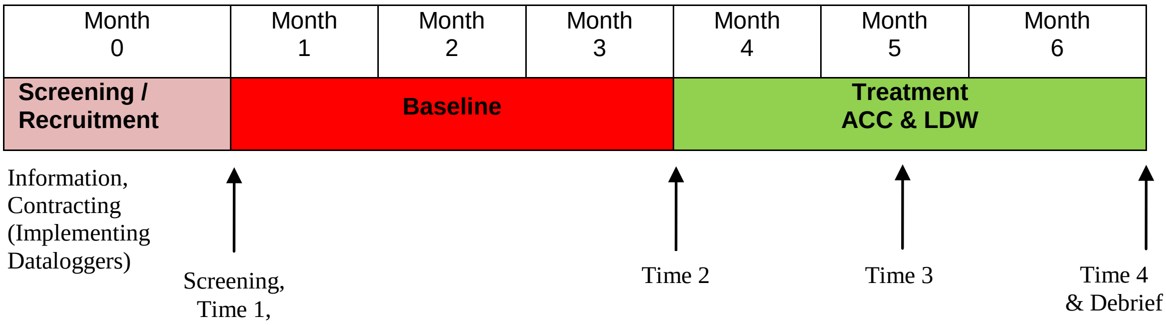


Figure 14: Timeline for questionnaire administration at the German VMC (VW)

Questionnaires were administered by the "Volkswagen Probandenpool" (subject pool). Drivers were rewarded twice for participating: After 3 months (end of baseline), and after finishing the study. Incentives were delivered by Volkswagen-Shop Wolfsburg.

For the test drivers of the German 1 VMC (Volkswagen), information about 32 drivers is available; average age of the drivers is 50 years old (M=50,03; SD=9.85) and nearly 80% the sample are between 36 years and 55 years (n=12; 39%). The youngest driver is 34 years old, and the eldest driver is 74 years old. The most of drivers are male (n=30; 94%) and only one participant is female.

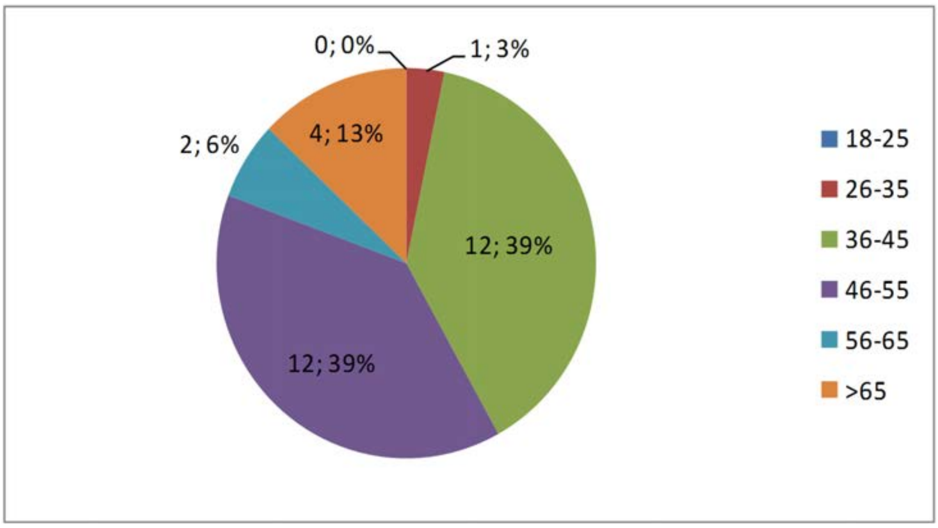


Figure 15: Age distribution of the German 1 VMC (Volkswagen) test drivers

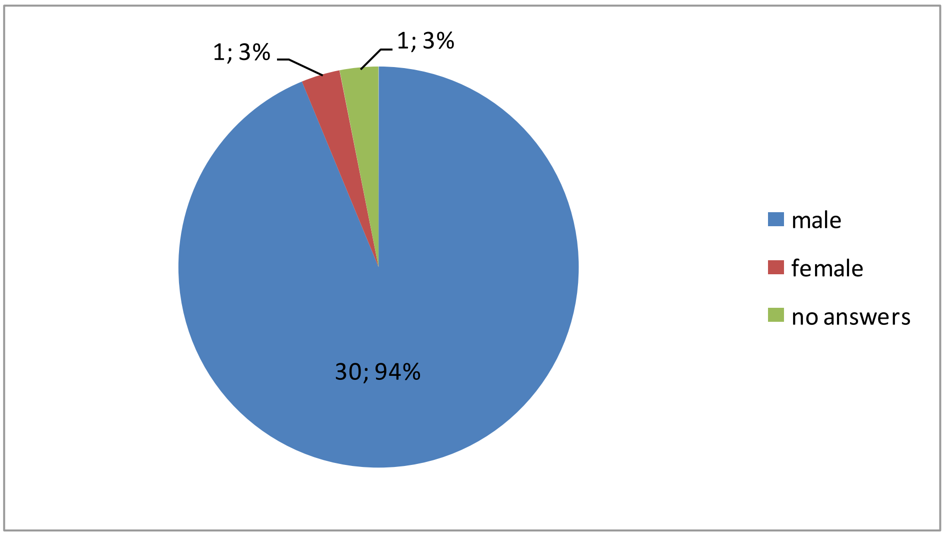


Figure 16: Gender distribution of the German 1 VMC (Volkswagen) test drivers

Test drivers of the German 1 VMC (Volkswagen) group indicate to drive, on average, nearly 26000 kilometres each year. Most of the participants drive more than 30000 kilometres per year (n=12) and 9 participants drive between 19000 and 24000 kilometres.

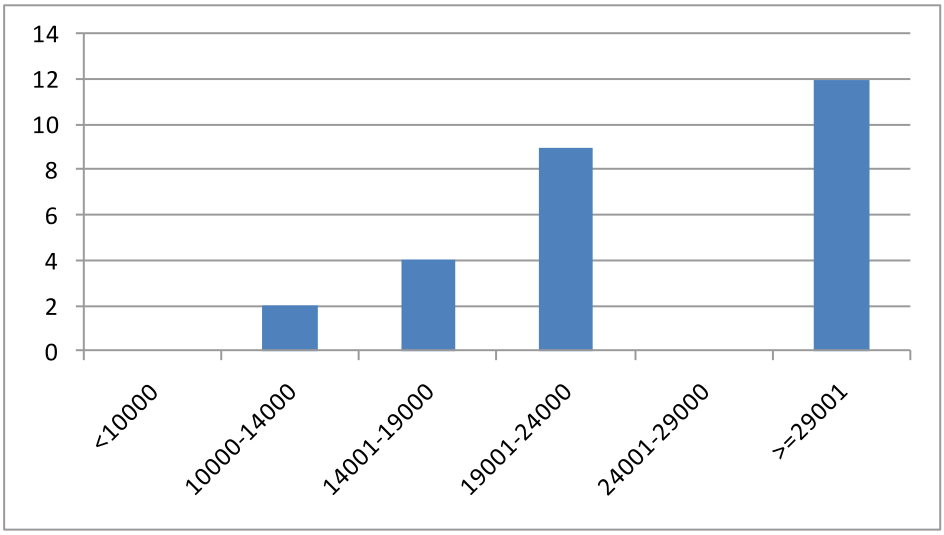


Figure 17: Distribution of annual mileage [in km] of the German 1 VMC (Volkswagen) test drivers

Collected data can be summarised as follows:

Table 8: Available objective data at German I VMC (VW vehicles)

Baseline							
Overall amount of data (MB, TB)	***49,5 GB***						
Overall km driven	153370						
Drivers							
N drivers overall	26	N drivers complete	***26***	N drivers incomplete	***0***	Drop-outs	***0***
Driving months							
Trips							
N overall trips	***11309***	N trips complete	***11309***	N trips incomplete	***NA***	N trips missing	***NA***
Treatment							
Overall amount of data (MB, TB)	***53,15 GB***						
Overall km driven	154503						
Drivers							
N drivers overall	***26***	N drivers complete	***26***	N drivers incomplete	***0***	Drop-outs	***0***
Driving months							
Trips							
N overall trips	***12778***	N trips complete	***12778***	N trips incomplete	***NA***	N trips missing	***NA***

Regarding subjective data, the main figures are displayed in the tables below.

Table 9: Available subjective data at German I VMC (VW vehicles)

Pre-FOT						**pre-treatment/ end of baseline**	
Non-participation		***Screening***		***Time 1***		***Time 2***	
N handed out	94	N handed out	32	N handed out	32	N handed out	32
N filled in & returned	32	N filled in & returned	32	N filled in & returned	32	N filled in & returned	32
N missing	64	N missing	0	N missing	0	N missing	0
Response rate (%)	34	Response rate (%)	100	Response rate (%)	100	Response rate (%)	100

During treatment				***End of trial***			
Time 3 (a)		***Time 3 (b)***		***Time 4***		***Earlier finish of FOT***	
N handed out	32	N handed out	xx	N handed out	32	N handed out	xx
N filled in & returned	32	N filled in & returned	xx	N filled in & returned	32	N filled in & returned	xx
N missing	0	N missing	xx	N missing	0	N missing	xx
Response rate (%)	100	Response rate (%)	xx	Response rate (%)	100	Response rate (%)	xx

MAN

At the MAN site, ACC and LDW are tested in a fleet of 60 trucks. The experimental design consists of a three month baseline phase and two different treatment phases. Within the first treatment phase (B1) the effect of a single function is tested. In the following second treatment phase (B2) the effect of the combination of ACC and LDW is tested. To enable testing of the two functions separately the fleet of 60 trucks is divided into two fleets consisting of 30 trucks each, see experimental design below.

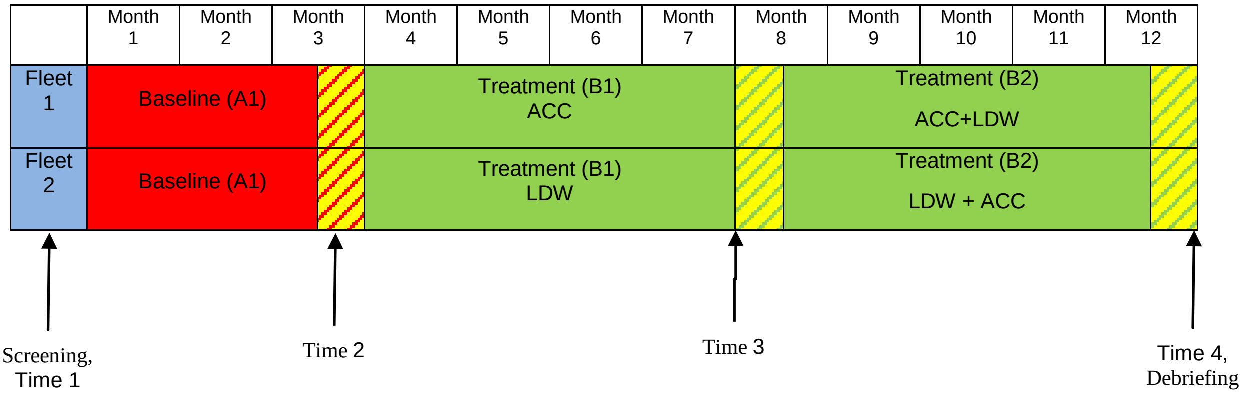


Figure 18: Timeline for questionnaire administration at German I VMC (MAN Vehicles)

After the three month baseline period (A1) 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 (B2) both functions will be activated and available for the drivers. During the whole experimental phase data is collected from the instrumented vehicles.
For the test drivers of the German 1 VMC (MAN), information about (n=46) drivers is available; which most of drivers are male (n=71; 41%), and (n=2; 3%) of the drivers are female. Average age of the drivers in the German 1 VMC (MAN) is around 50 years (M=48.94; SD=10.875) and the youngest driver is 26 years old, and the eldest driver is 76 years old. The different age categories with more drivers are 36-45 (n=9; 29%) years and 46-55 (n=13; 42%) years.

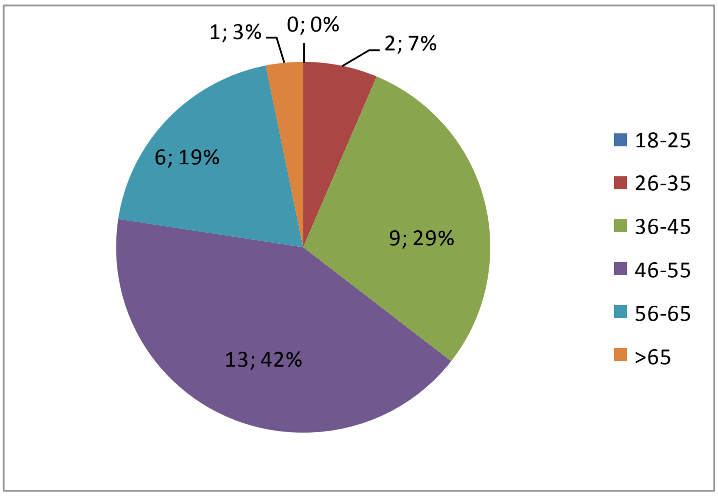


Figure 19: Age distribution of the German 1 VMC (MAN) test drivers

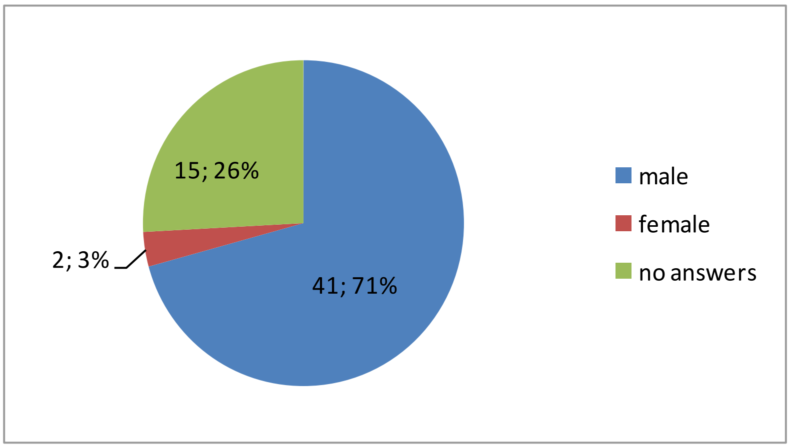


Figure 20: Gender distribution of the German 1 VMC (MAN) test drivers

Test drivers of the German 1 VMC (MAN) group indicate to drive more 100000 kilometres (M=140638; SD=37263) each year. Most of the participants drive more than 190000 kilometres per year (n=40).

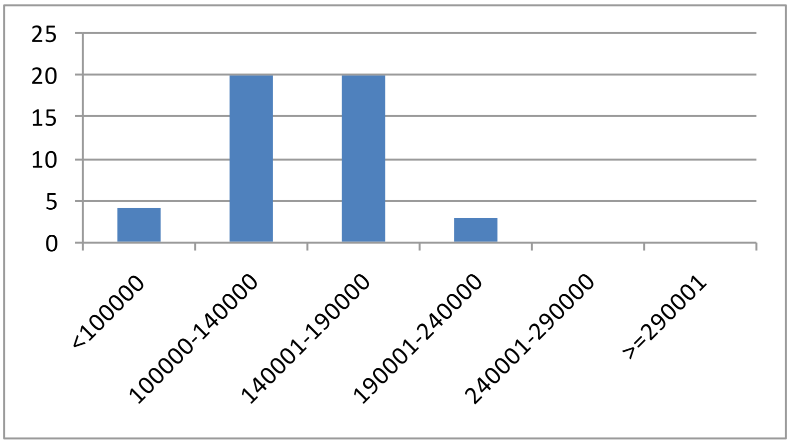


Figure 21: Distribution of annual mileage [in km] of the German 1 VMC (MAN) test drivers

Within the 12 month data collection phase, five time-based questionnaires are handed-out. Two questionnaires are provided at the beginning of the field test (Screening and Time 1 questionnaire). Time 2 questionnaires were handed-out at the end of the baseline phase for both fleets. After the first treatment phase (A1) Time 3 questionnaires for ACC were provided to Fleet 1 and Time 3 questionnaires for LDW to Fleet 2. At the end of the data collection phase (month 12) both fleets received the Time 4 questionnaire for ACC and LDW.

In the following tables an overview of MAN fleet collected data is provided.

Table 10: Mileage at German I VMC (MAN: 6 vehicles used for data analysis)

	Mileage [km]			
	Overall	Motorway	Rural	Urban
Baseline	97471	51174	35931	7558
Treatment All	85473	56928	20435	7519
Treatment (ACC Active)	27565	21926	5136	502

Table 11: Available objective data at German I VMC (MAN vehicles - overall)

Baseline							
Overall amount of data (MB, TB)	***450 GB***						
Overall km driven	974720 (estimated)						
Drivers							
N drivers overall	***60***	N drivers complete	***FOT is still running***	N drivers incomplete	***0***	Drop-outs	***0***
Driving months							
Trips							
N overall trips	***23051***	N trips complete	***23051***	N trips incomplete	***0***	N trips missing	***0***
Treatment							
Overall amount of data (MB, TB)	***350 GB***						
Overall km driven	1863540 (estimated)						
Drivers							
N drivers overall	***60***	N drivers complete	***FOT is still running***	N drivers incomplete	***0***	Drop-outs	***0***
Driving months							
Trips							

Regarding subjective data, the following information can be extracted in Table 12: Questionnaires provided information about pre-study measures of the participants and background information (Screening questionnaire), measures after familiarisation of the participants driving a new vehicle without the tested assistance system, driver attitudes, accident record, travel patterns and sensation seeking (Time 1 Questionnaire), pre-trial acceptability, ratings on self-reported workload and driving behaviour (Time 2 Questionnaire).

Table 12: Available subjective data at German I VMC (MAN vehicles)

Pre-FOT						**pre-treatment/ end of baseline**	
Non-participation		***Screening***		***Time 1***		***Time 2***	
N handed out	N/A	N handed out	66	N handed out	66	N handed out	57
N filled in & returned	N/A	N filled in & returned	60	N filled in & returned	60	N filled in & returned	57

N missing	N/A	N missing	6	N missing	6	N missing	0
Response rate (%)	N/A	Response rate (%)	90	Response rate (%)	90	Response rate (%)	100

2.3 German 2 VMC

In the German 2 VMC, navigation systems are analysed with data collected by BMW and Daimler. Three experimental conditions were compared:

- Driving without navigation system
- Driving with mobile navigation system
- Driving with built-in navigation system

	BMW	Daimler
Navigation System	✓	✓

Month 1	Month 2	Month 3	Month 4	Month 5	Month 6	Month 7	Month 8	Month 9	Month 10	Month 11	Month 12
Period 1			Period 2			Period 3			Period 4		
base	Built-in	mobile	Built-in	Mobile	Base	Mobile	Base	Built-in	Base	Mobile	Built-in

Figure 22: Experimental design at the German 2 VMC (BMW and Daimler). Depicted randomization of experimental conditions is only an example.

The order of the three experimental conditions has been balanced between the drivers. A repeated measure design has been chosen so that each driver participated in each experimental condition.

In total 110 drivers participated in the FOT. Table 13 shows the number of drivers for which objective and subjective data is available for the analysis.

Table 13: Number of drivers available for the data analysis

	BMW	Daimler	Overall
Number of drivers questionnaire data	51	59	110
Number of drivers with 3 months of objective data	42	57	99

Questionnaire data is available for N=64 drivers (incl. n=4 drop-outs) by Daimler and N=51 BMW test drivers (no drop-outs). Of those, N=5 drivers are female.

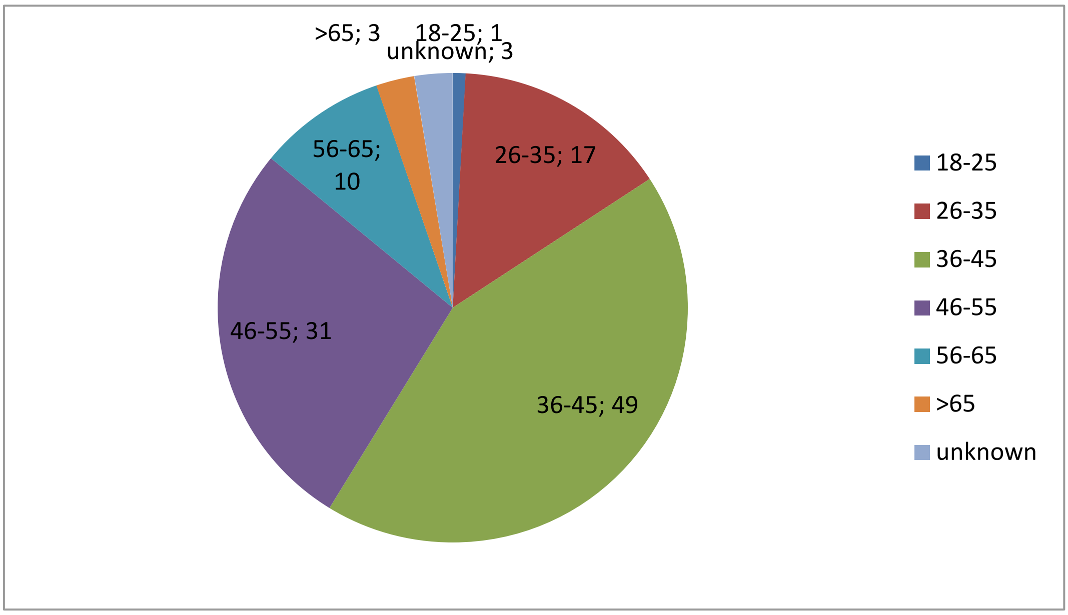


Figure 23: Age distribution of the test drivers participating in the German 2 VMC.

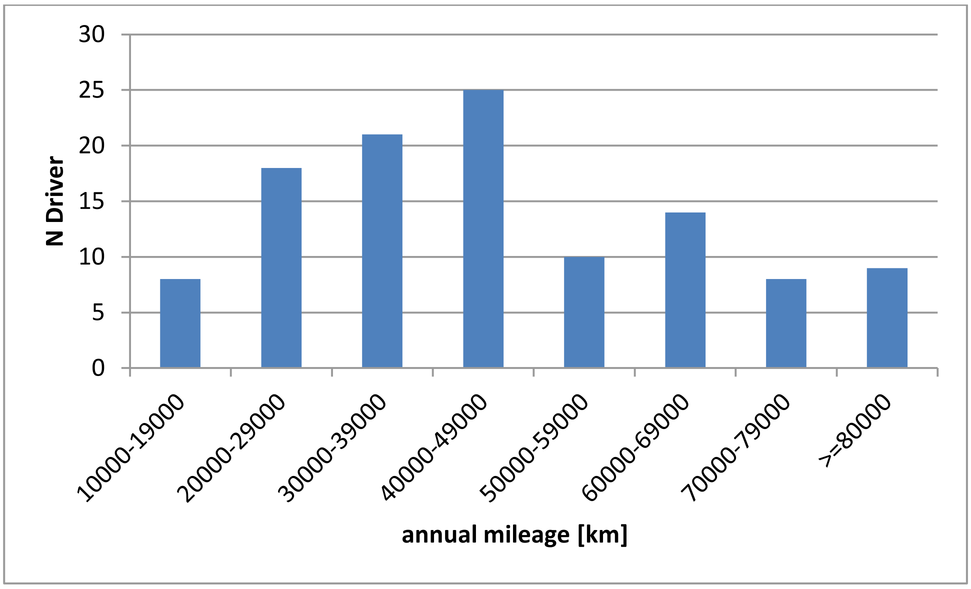


Figure 24: Distribution of annual mileage [in km] of test drivers participating in the German 2 VMC.

The following tables provide an overview of all questionnaires available for analysing the impact of navigation systems on driving.

Before treatment, screening and "Time 1 Questionnaire" were gathered for obtaining information about background info and to get measures after familiarisation of the drivers without assistance system including driver attitudes, accident record, travel patterns and sensation seeking

Moreover, drivers filled in "Time 2 Questionnaire" (pre-trial acceptability, ratings on self-reported workload and driving behaviour), "Time 3 Questionnaire" (with items regarding to acceptability and workload measures) and "Time 4 Questionnaire" (for evaluating acceptability and workload).

Table 14: Available data from questionnaires handed out before treatment

Non-participation		*Screening*		*Time 1*	
N handed out	N/A	N handed out	115	N handed out	115
N filled in & returned	N/A	N filled in & returned	115	N filled in & returned	115
N missing	N/A	N missing	0	N missing	0
Response rate (%)	N/A	Response rate (%)	100	Response rate (%)	100

Table 15: Available data from questionnaires handed before, during and after the conditions baseline, mobile and built-in navigation system

Baseline						*Mobile navigation system*					
T2		*T3*		*T4*		*T2*		*T3*		*T4*	
N handed out	113	N handed out	112	N handed out	114	N handed out	114	N handed out	113	N handed out	111
N filled in & returned	113	N filled in & returned	108	N filled in & returned	113	N filled in & returned	111	N filled in & returned	104	N filled in & returned	111
N missing	0	N missing	4	N missing	1	N missing	3	N missing	9	N missing	0
Response rate (%)	100	Response rate (%)	96	Response rate (%)	99	Response rate (%)	97	Response rate (%)	92	Response rate (%)	100

Table 16: Questionnaire data from debriefing questionnaires and from drop outs.

Built in navigation system					
T2		*T3*		*T4*	
N handed out	110	N handed out	110	N handed out	110
N filled in & returned	110	N filled in & returned	102	N filled in & returned	110
N missing	0	N missing	8	N missing	0
Response rate (%)	100	Response rate (%)	92	Response rate (%)	100

Table 17: gives an overview over the number of kilometres and hours of driving on which the analysis for navigation systems is based.

Debrief		*Exit interview/ drop-outs*	
N handed out	110	N handed out	4
N filled in & returned	108	N filled in & returned	4
N missing	2	N missing	0
Response rate (%)	98	Response rate (%)	100

Table 18: Description of objective data used for the analysis

	Baseline	Built-in	Mobile	Overall
Mileage overall [km]	295514	332825	290821	919161
Mileage motorway [km]	200329	229329	190128	619786
Mileage rural [km]	45530	51532	49268	146331
Mileage urban [km]	49373	51670	51108	152151
Duration overall [h]	4359	4768	4324	13453
Proportion navi active overall [%]	0.00%	47.14%	32.95%	40.39%
Duration motorway [h]	1 748.6	1 972.3	1 643.9	5 364.8
Proportion navi active motorway [%]	0.00%	72.84%	47.95%	61.53%
Duration rural [h]	763	846	818	2428
Proportion navi active rural [%]	0.00%	40.71%	29.40%	35.15%
Duration urban [h]	1824	1920	1841	5586
Proportion navi active urban [%]	0.00%	24.31%	21.51%	22.94%

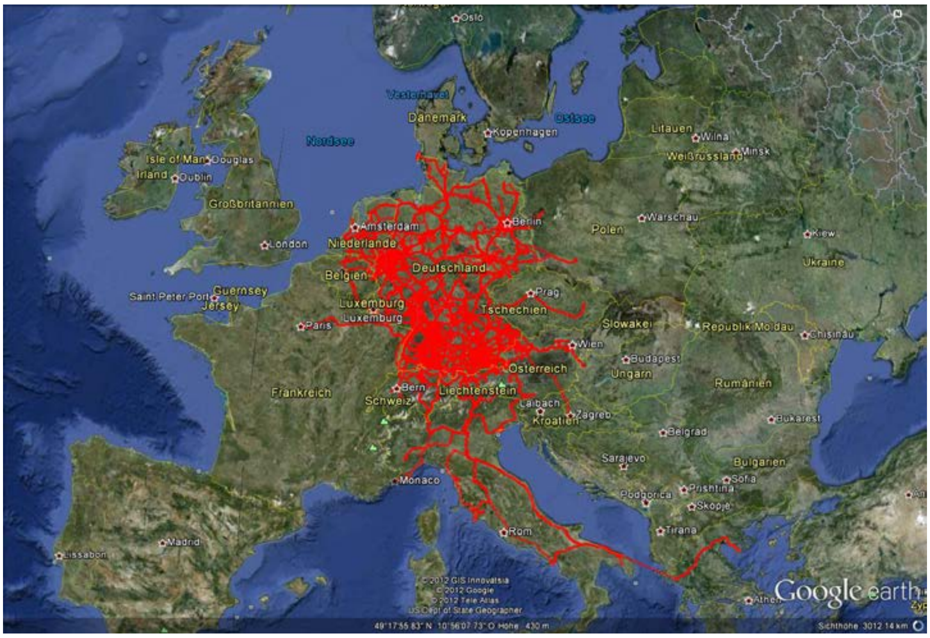


Figure 25: Plot of all trips in the data base of the German 2 VMC

2.4 Swedish VMC

The ADAS functions to be tested within the Swedish VMC were:

- FCW and FCW with Brake support: This function detects and tracks other vehicles (travelling in the same direction) in front of the vehicle and provides a warning to the driver when the evaluation of trajectories and relative speed of the subject vehicle and the obstacle show a high probability of a collision.
- ACC: This function supports the driver in selecting and then automatically maintaining a chosen speed and distance to the vehicle in front. The function adjusts the speed according to a lead vehicle and accelerates and decelerates automatically

- LDW: The function warns the driver when the vehicle is unintentionally departing from its intended lane.
- Blind Spot Information System (BLIS): This function continuously monitors the rear blind spots on both sides of the vehicle. When an obstacle is detected in the blind spot, the information or a warning is issued to the driver.
- Impairment Warning (IW): The function is intended to attract the driver's attention when they start to drive less consistently, e.g. becomes distracted or starts to fall asleep.

The functions were tested both in Volvo Passenger Vehicles (VCC) and Volvo Trucks (Volvo).

	VCC	Volvo
FCW	✓	✓
ACC	✓	✓
LDW	✓	✓
BLIS	✓	
IW	✓	

VCC

Two vehicle types were used by VCC: V70 and XC70 (diesel engines with automatic transmission), in total 100 cars.

At VCC, questionnaires have been sent out to all participants (main drivers as well as secondary drivers). In total, there are 205 registered drivers of the initial 100 cars. There was two drop-outs leaving 98 cars as potential contributors to the questionnaires.

Driver sample 1 consists of Main Drivers only, i.e. 98 persons. Gender distribution is 88% male and 12% female. Mean age of this sample is m=48.5 years (sd=7.3), with most of the drivers being 46 to 55 years old and none of the drivers being younger than 26 years or elder than 65 years (see Figure 26).

For driver sample 1 it was considered mandatory to fill in the questionnaires.

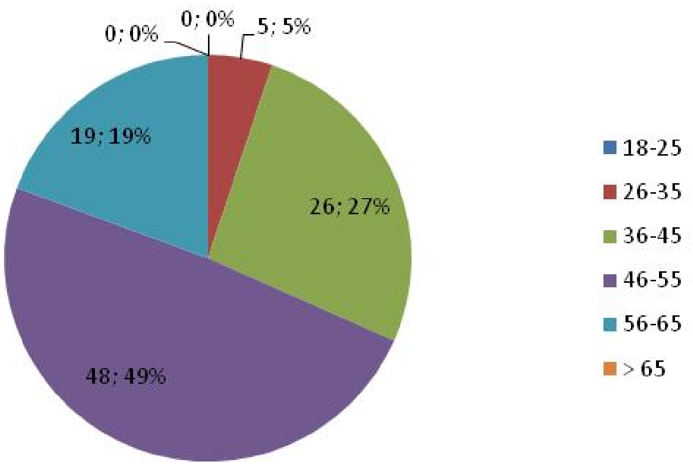


Figure 26: Age distribution of the VCC test drivers (main drivers; n=98)

Annual median driving distance is 25000 kilometres and average driver license possession is m=30.5 years.

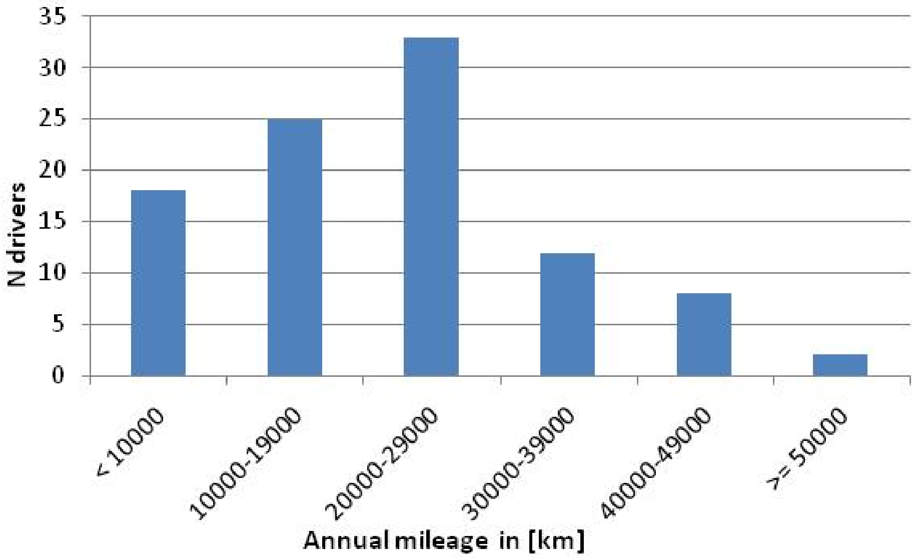


Figure 27: Distribution of annual mileage [in km] of the VCC test drivers (main drivers; n=98)

Driver sample 2 consists of all drivers, main as well as secondary, in total 195 persons. In this group the gender distribution is 58% male and 42% female. The mean age is m=45.3 years with most of the drivers being 46 to 55 years old (see Figure 28). None of the drivers is older than 65 years. Some of the secondary drivers are between 18 and 25 years old.

For secondary drivers, filling in the questionnaire was voluntary.

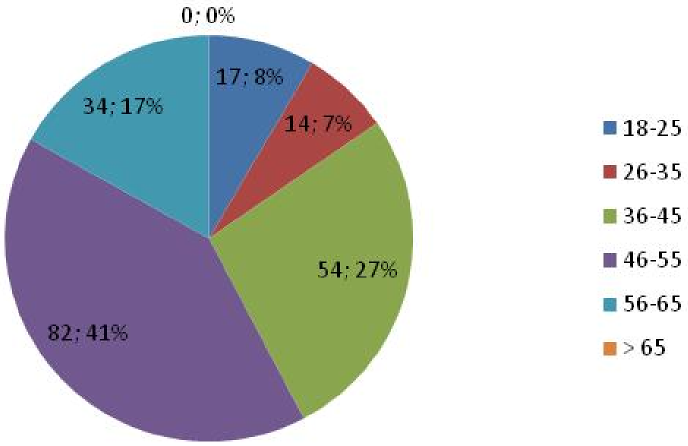


Figure 28: Age distribution of the VCC test drivers (all drivers; n=205)

Annual average driving distance is 15000 kilometres and average driver license possession is 26.3 years. In total, there are two drop-outs within driver sample 1 and 22 within driver sample 2.

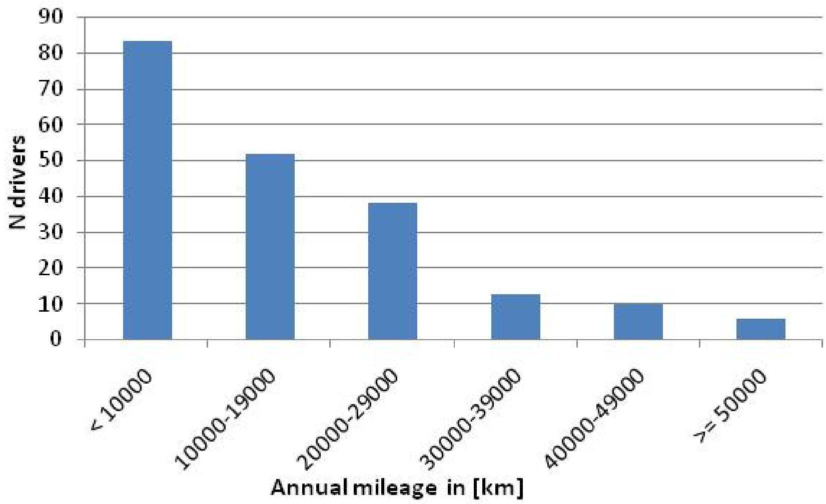


Figure 29: Distribution of annual mileage [in km] of the VCC test drivers (all drivers; n=205)

A dependent design has been chosen, and each of the vehicles was supposed to participate for 12 to 14 months in the FOT (see Figure 53 for an overview):

- Baseline: without systems of interest, duration 4 months
- Treatment: with systems of interest, duration 8 to 10 months

Month 1	Month 2	Month 3	Month 4	Month 5	Month 6	Month 7	Month 8	Month 9	Month 10	Month 11	Month 12-14
Baseline				Treatment FCW, ACC, LDW, IW + BLIS							

Figure 30: Experimental design at the Swedish VMC (VCC car)

The numbers in table 17 are taken from the uploaded data in the Oracle Database at VCC. Since it became obvious that not all data could be used for the euroFOT analysis, because of the very time consuming up-loading process, it was decided at the end of 2011 to freeze a specific dataset to be used for the euroFOT analysis. Hence, the data that was used in the final statistical analysis represented 50% of total collected data and consists of 3 month Baseline and 3 month Treatment of driving data.

Table 19: Available objective data (VCC)

Baseline							
Overall amount of data (GB)	***462***						
Overall km driven	***399820***						
Drivers							
N drivers overall	***195***	N drivers complete	***193***	N drivers incomplete	***NA***	Drop-outs	***2***
Driving months							
N Overall driving months	***3***	N driving months complete	***3***	N driving months incomplete	***NA***	N driving months missing	***NA***
Trips							
N overall trips	***27599***	N trips complete	***27599***	N trips incomplete	***NA***	N trips missing	***NA***
Treatment							
Overall amount of data (GB)	***638***						
Overall km driven	***553293***						
Drivers							
N drivers overall	***193***	N drivers complete	***193***	N drivers incomplete	***NA***	Drop-outs	***NA***
Driving months							
N Overall driving months	***3***	N driving months complete	***3***	N driving months incomplete	***NA***	N driving months missing	***NA***
Trips							
N overall trips	***39146***	N trips complete	***39146***	N trips incomplete	***NA***	N trips missing	***NA***

Both VCC and Volvo test drivers were asked to fill in questionnaires at five times during their participation in the euroFOT project (see Figure 31 below for an exemplary time line of questionnaire administration):

- Questionnaire 1 was administered before the tested systems were activated in the vehicles in order to obtain measures of driver attitudes, accident record, travel patterns, and sensation seeking.
- Questionnaire 2 aims to determine pre-trial acceptability. Additionally, ratings on self-reported workload and driving behaviour are taken.
- In Questionnaire 3, acceptability and workload measures are taken. It was administered twice during the treatment phase, i.e. when the ADAS were activated in the vehicles.
- Questionnaire 4 aims to determine acceptability and workload in more depth and is to be administered at the end of the data collection.

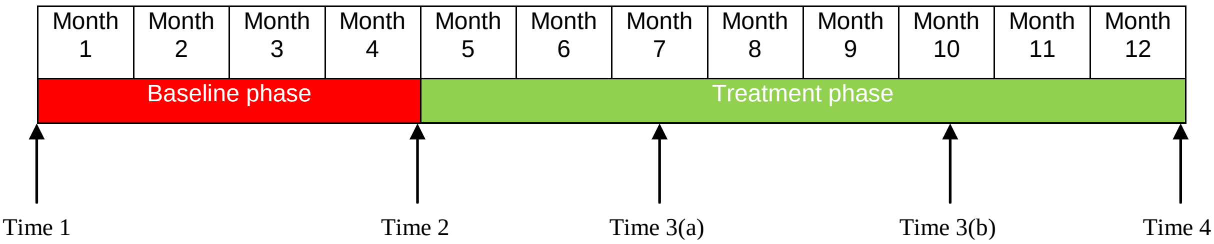


Figure 31: Actual timeline for questionnaire administration at the Swedish VMC

Table 20: Available data from questionnaires handed out before treatment (VCC, Driver sample 1)

Pre-FOT						**pre-treatment/ end of baseline**	
Non-participation		***Screening***		***Time 1***		***Time 2***	
N handed out	N/A	N handed out	N/A	N handed out	98	N handed out	98
N filled in & returned	N/A	N filled in & returned	N/A	N filled in & returned	98	N filled in & returned	98
N missing	N/A	N missing	N/A	N missing	0	N missing	0
Response rate (%)	N/A	Response rate (%)	N/A	Response rate (%)	100	Response rate (%)	100

Table 21: Available data from questionnaires handed out during and after treatment (VCC, Driver sample 1)

During treatment				***End of trial***			
Time 3 (a)		***Time 3 (b)***		***Time 4***		***Debrief***	
N handed out	**98**	N handed out	**98**	N handed out	**98**	N handed out	**98**
N filled in & returned	***91***	N filled in & returned	***92***	N filled in & returned	***96***	N filled in & returned	**80**
N missing	***7***	N missing	***6***	N missing	***4***	N missing	**18**
Response rate (%)	***92,9***	Response rate (%)	***93,9***	Response rate (%)	***98***	Response rate (%)	**82**

Table 22: Available questionnaire data from drop-outs (VCC, Driver sample 1)

Exit interview/ drop-outs	
N handed out	N/A
N filled in & returned	N/A
N missing	N/A
Response rate (%)	N/A

VOLVO

Two vehicle types are used by Volvo: FH6x2 and FH4x2. The functions under investigation are:

- FCW and FCW with Brake support
- ACC
- LDW

A dependent design has been chosen and each of the vehicles was supposed to participate for 12 months in the FOT (see figure 32 for an overview):

- Baseline: driving without systems of interest, but with regular cruise control activated; duration 4 months
- Treatment: driving with FCW, ACC and LDW; duration 8 months

Month 1	Month 2	Month 3	Month 4	Month 5	Month 6	Month 7	Month 8	Month 9	Month 10	Month 11	Month 12
Baseline				Treatment: ACC+FCW, LDW							

Figure 32: Experimental design at the Swedish VMC (Volvo trucks)

The Volvo trucks fleet is subdivided into two independent groups: The Dutch fleet (n=15 trucks) and the UK fleet (n=15 trucks).

For the AB VOLVO a quite large amount of drivers at the UK fleet was planned to be driving the 15 equipped vehicles and therefore signed the consent forms. For the Dutch fleet, fewer drivers were planned to drive the equipped vehicles and thus only those originally considered were informed and were asked to give their consent to participate in the study. For both fleets a sub-set of the drivers has been identified as euroFOT drivers and has responded to the questionnaires; however, it is clear that there is a considerable amount of vehicle data from a larger group of drivers.

Fifty-two drivers in total were in the end considered for the questionnaires. All drivers are male. The common questionnaires were considered to be very lengthy as well as to some extent intrusive. In order to still guarantee a decent response rate, a smaller portion of the questions had to be removed from the questionnaires for the professional truck drivers of the Volvo sample. Information on age is missing for ten of the UK drivers and mileage for all UK drivers. The average age of all drivers is 48 years old.

The age distribution from is presented in the below graph (Figure 33).

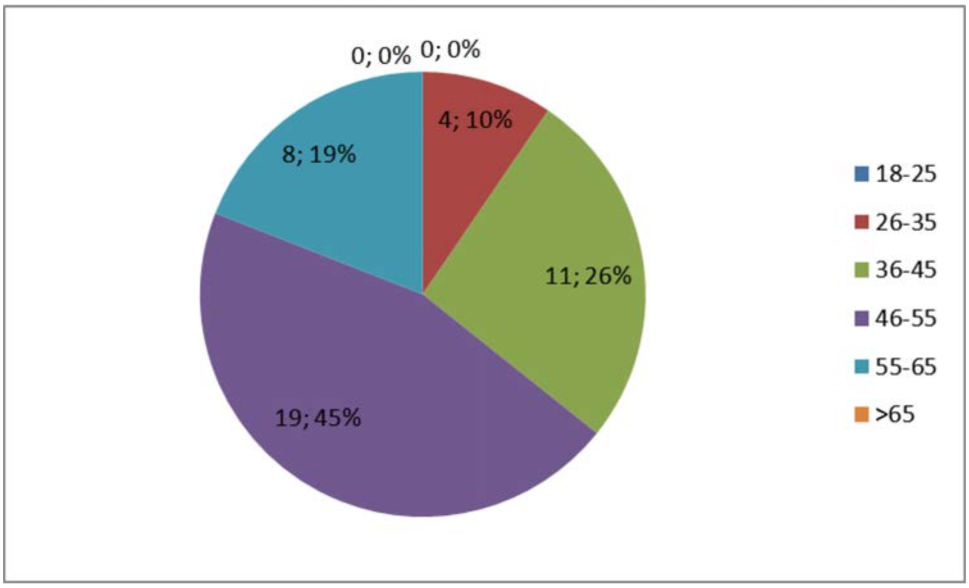


Figure 33: Age distribution of 42 out of the 52 AB VOLVO test drivers

The UK drivers have held their driving licences for personal vehicle (B) and heavy truck with trailer (CE) in average for 32 and 22 years, respectively. The Dutch drivers have held their driving licenses for personal vehicle (B) and heavy truck with trailer (CE) in average for 31 and 30 years, respectively. The Dutch drivers indicate to drive, on average, m=141000 km per year, with the minimum being 110000 km and the maximum 160000 km (sd=15000). The majority of the drivers drove between 130000-150000 km per year.

At the time of the Questionnaire 1, 37 professional truck drivers from the UK fleet were informed, signed the consent form and responded to the questionnaire. The mean age was 48 years old (sd=8.7) and they have held their driving licences for personal vehicle (B) and heavy truck with trailer (CE) in average for 32 and 22 years, respectively. Information about the annual mileage is not available for the drivers of the UK fleet. For the Dutch fleet 16 professional truck drivers were informed, signed the consent form, and answered the questionnaire. The mean age was 47 years old (sd=10.5) and they have held their driving licenses for personal vehicle (B) and heavy truck with trailer (CE) in average for 31 and 30 years, respectively. All drivers are male. The Dutch drivers indicate to drive, on average, m=141000 kilometres per year, with the minimum being 110000 kilometres and the maximum 160000 kilometres (sd=15000).

Table 23: Available objective data (Volvo)

<table>
<tr><th colspan="8">Baseline</th></tr>
<tr><td>Overall amount of data in Infobright DB</td><td>1.0TB</td><td colspan="6" rowspan="2"></td></tr>
<tr><td>Overall km driven</td><td>733813</td></tr>
<tr><td colspan="8">Drivers</td></tr>
<tr><td>N drivers overall</td><td>51</td><td>N drivers complete</td><td>51</td><td>N drivers incomplete</td><td>0</td><td>Drop-outs</td><td>0</td></tr>
<tr><td colspan="8">Driving months</td></tr>
<tr><td>N Overall</td><td>165</td><td>N driving</td><td>165</td><td>N driving</td><td>0</td><td>N driving</td><td>0</td></tr>
</table>

driving months		months complete		months incomplete		months missing	
Trips							
N overall trips	***15983***	N trips complete	***15983***	N trips incomplete	***0***	N trips missing	***0***
Treatment							
Overall amount of data in Infobright DB	***1.1TB***						
Overall km driven	***806390***						
Drivers							
N drivers overall	***49***	N drivers complete	***49***	N drivers incomplete	***0***	Drop-outs	***0***
Driving months							
N Overall driving months	***198***	N driving months complete	***198***	N driving months incomplete	***0***	N driving months/days missing	***0***
Trips							
N overall trips	***17233***	N trips complete	***17233***	N trips incomplete	***0***	N trips missing	***0***

From “Time 1 Questionnaire” measures regarding to driver attitudes, accident record, travel patterns and sensation seeking are provided. “Time 2 Questionnaire” determined pre-trial acceptability, ratings on self reported workload and driving behaviour. “Time 3 (a/b) Questionnaire” and “Time 4 Questionnaire” reported about acceptability and workload measures.

Table 24: Available data from questionnaires handed out before treatment (Volvo)

Pre-FOT				**pre-treatment/ end of baseline**	
Screening		***Time 1***		***Time 2***	
N handed out	N/A	N handed out	52	N handed out	52
N filled in & returned	N/A	N filled in & returned	52	N filled in & returned	28
N missing	N/A	N missing	0	N missing	24
Response rate (%)	N/A	Response rate (%)	100	Response rate (%)	54

Table 25: Available data from questionnaires handed out during and after treatment (Volvo)

During treatment				***End of trial***			
Time 3 (a)		***Time 3 (b)***		***Time 4***		***Debrief***	
N handed out	52	N handed out	52	N handed out	52	N handed out	N/A
N filled in & returned	28	N filled in & returned	***29***	N filled in & returned	***12***	N filled in & returned	N/A
N missing	24	N missing	***23***	N missing	***40***	N missing	N/A
Response rate (%)	54	Response rate (%)	***56***	Response rate (%)	***23***	Response rate (%)	N/A

2.5 Italian VMC

The Italian VMC in the euroFOT project evaluates the LDW system. The system provides feedback through a torque applied through the steering wheel when the vehicle leaves the lane without the turn indicator being activated.

Test vehicles are Lancia Delta equipped with the LDW optional feature called *Driving Advisor.*

	Lancia Delta
LDW	✓

The Italian FOT involved n=570 customers of Lancia Delta over a period of nine months. Two groups of users are compared:

- LDW group: n=280 vehicles equipped with LDW;
- Control group: n=290 vehicles not equipped with LDW.

Italian VMC carries out a subjective field test in which drivers are asked to fill-in periodical questionnaires self-reporting their experience and perception about the LDW system (i.e. five periodical questionnaires, weekly and event registers). Project participants drive their own cars in regular conditions. No driving guidelines are provided to users concerning their participation in euroFOT project.

Vehicles are equipped with no Data Acquisition System and no extra sensors. Operational Centres did not need to meet face-to-face with the project participants and no installation or extra maintenance is required for vehicles.

In the LDW group drivers were asked to not use the LDW for the first three months in order to ensure a baseline period. In the subsequent treatment period they were free to use the system at their discretion (six months). This will allow a within subject analysis in the LDW Group in order to detect changes in the self-reported measures over time. The comparison of the LDW and the control group ensures a between subjects analysis.

Figure 34: Italian VMC experimental design

All questionnaires were available in both paper-based and web-based versions. An on line tool has been also used for data entry procedures in order to translate in digital form the manually filled paper-based questionnaires.

During all test period, the driver liaison centre of euroFOT Italian test site has provided support and information through phone and emails to users about the project.

LDW group

For the LDW group sample, information of n=158 drivers is available from the Time 1 questionnaire. Most of the test drivers in the LDW group are male (n=143; 90 %). Only n=15 (9 %) of the drivers are female. N=32 project participants do not live in Italy. Average age of the drivers in the LDW group is m=53 years, with the youngest driver being 27 years old, and the eldest driver being 86 years old. Although most of the drivers are between 56 and 65 years old (n=45; 28.7 %), drivers are rather equally distributed over the different age categories.

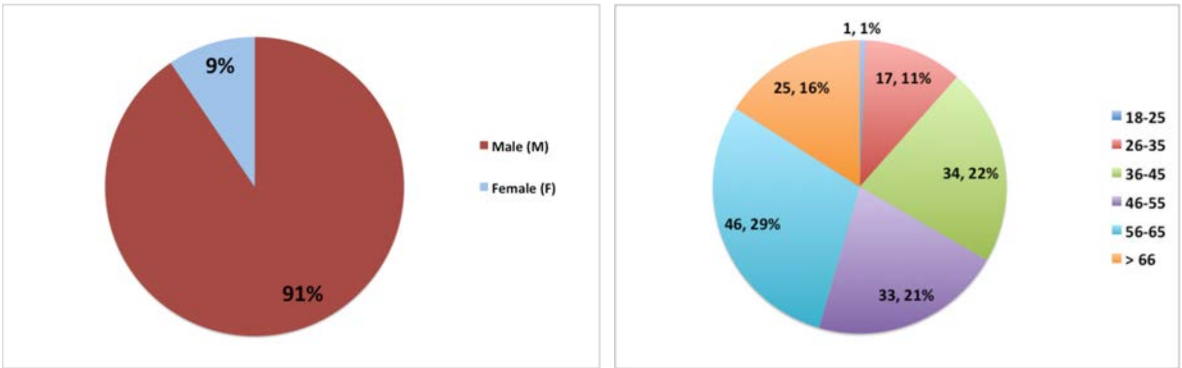


Figure 35: Gender and age distribution of the Italian VMC test drivers (LDW group; n=158)

Test drivers of the LDW group indicate to drive, on average around 26.000 km each year. Most of the participants drive more than 30000 kilometres per year (n=42; 26.8 %), but again, annual mileage is rather equally distributed among the different categories.

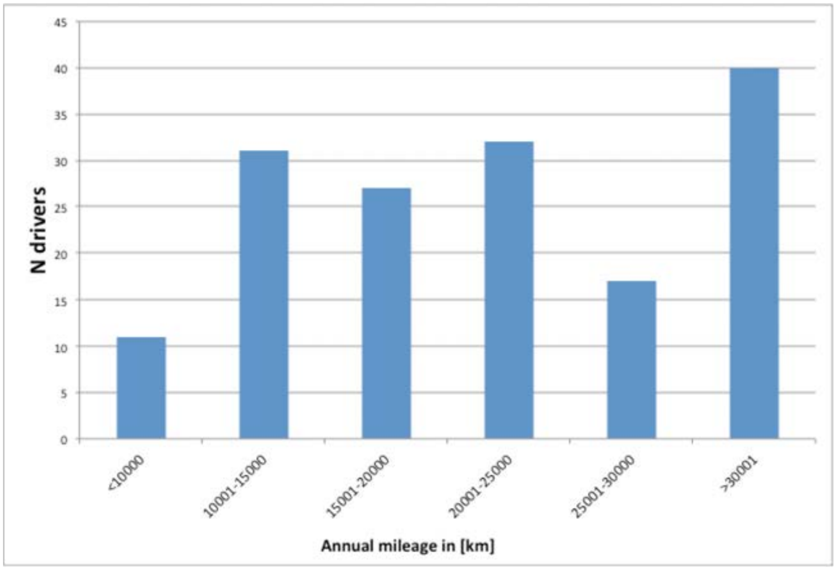


Figure 36: Distribution of annual mileage [in km] of the Italian VMC test drivers (LDW group; n=158)

Control group

For the control group, information about n=254 drivers is available. In the control group – as in the LDW group – most of the drivers are male (n=226; 89%). N=28 (11%) of the drivers are female. Average age of the drivers in the control group is 47 years, with the youngest driver being 22 years old, and the eldest driver being 76 years old. Drivers are equally distributed among the different age categories.

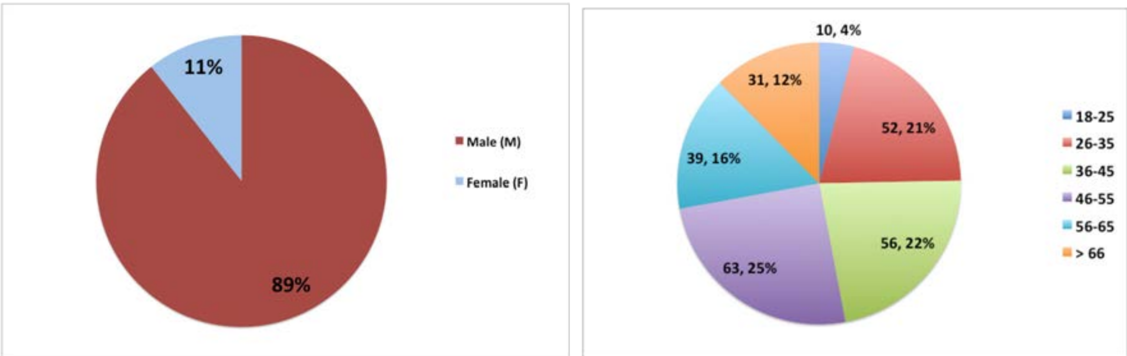


Figure 37: Gender and age distribution of the Italian VMC test drivers (control group; n=254)

Test drivers in the control group indicate to drive, on average, around 28.000 km per year. Most of the participants drive more than 30000 kilometres per year (n=104; 26.8 %).

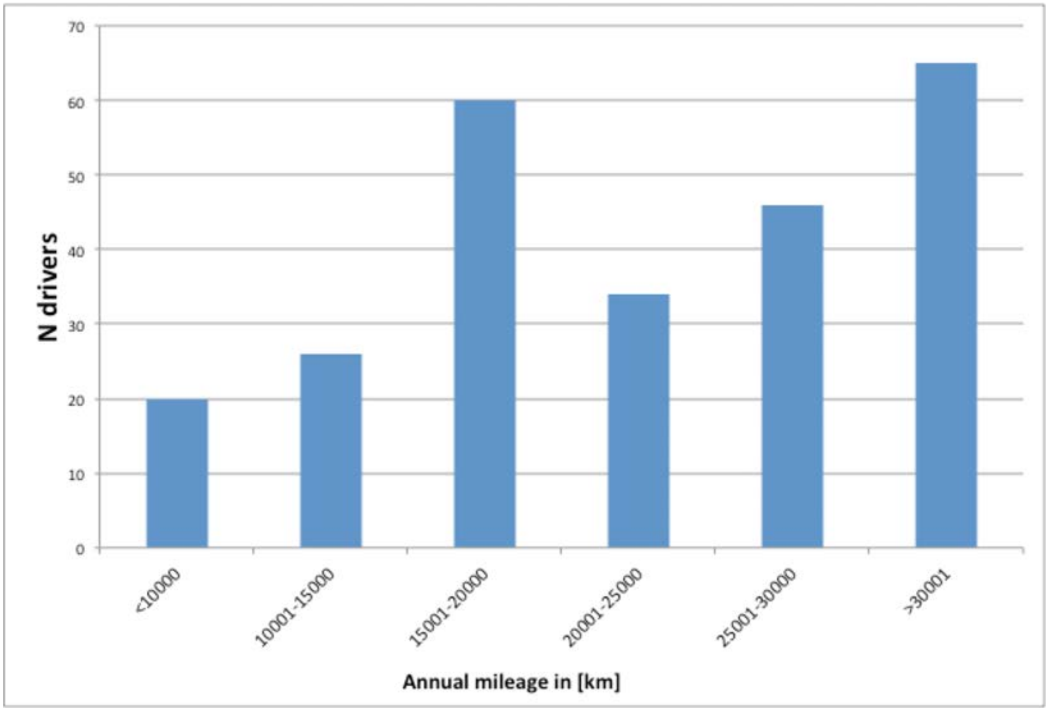


Figure 38: Distribution of annual mileage [in km] of the Italian VMC test drivers (control group; n=254)

The following data was collected for both groups:

LDW group

Table 26: Available data from questionnaires handed out before treatment (Italian VMC, LDW group)

PRE-FOT		Start FOT		End of baseline	
Screening		***Time 1***		***Time 2***	
N handed out	866	N handed out	282	N handed out	269
N filled in & returned	280	N filled in & returned	158	N filled in & returned	148
N missing	586	N missing	124	N missing	121
Screening rate (%)	32,33	Response rate (%)	56,03	Response rate (%)	55,02
		N Weekly Diary	95	N Weekly Diary	75
		N Event Register	43	N Event Register	16

Table 27: Available data from questionnaires handed out during treatment (Italian VMC, LDW group)

During treatment				***End of trial***	
Time 3 (a)		***Time 3 (b)***		***Time 4 and debrief***	
N handed out	249	N handed out	*245*	N handed out	*243*
N filled in & returned	147	N filled in & returned	145	N filled in & returned	136
N missing	102	N missing	100	N missing	107
Response rate (%)	59,04	Response rate (%)	59,18	Response rate (%)	55,97
N Weekly Diary	59	N Weekly Diary	59	N Weekly Diary	42
N Event Register	8	N Event Register	3	N Event Register	1

Table 28: Available data from drop-outs (Italian VMC, LDW group)

Exit interview/ drop-outs	
N LDW group drop-outs	37
Reason: N disposal of the vehicle	9
Reason: N time	14
Reason: N health issues	5
Reason: N other	9

Control group

Table 29: Available data from questionnaires handed out during baseline (Italian VMC, control group)

PRE-FOT		**Start FOT**			
Screening		***Time 1***		***Time 2***	
N handed out	895	N handed out	290	N handed out	290
N filled in & returned	290	N filled in & returned	253	N filled in & returned	243
N missing	595	N missing	37	N missing	47
Screening rate (%)	32,40	Response rate (%)	87,24	Response rate (%)	83,79

Table 30: Available data from questionnaires handed out during baseline (Italian VMC, control group)

				End of trial	
Time 3 (a)		***Time 3 (b)***		***Time 4 and debrief***	
N handed out	290	N handed out	290	N handed out	290
N filled in & returned	247	N filled in & returned	255	N filled in & returned	250
N missing	43	N missing	35	N missing	40
Response rate (%)	85,17	Response rate (%)	87,93	Response rate (%)	86,21

Table 31: Available data from drop-outs (Italian VMC, control group)

Exit interview/ drop-outs	
N Control group drop-outs	1
Reason: N disposal of the vehicle	1
Reason: N time	0
Reason: N health issues	0
Reason: N other	0

For the Italian test site, about 546 MB of data has been collected. These data contain scanned questionnaire files uploaded and raw data stored into the database. These questionnaires provided information about background information (Screening Questionnaire), driver attitudes, accident record, travel patterns and sensation seeking (Time 1 Questionnaire), ratings on self-reported workload and driver behaviour (Time 2 Questionnaire) and acceptability and workload measures (Time 3 a/b and Time 4).

Drivers recruited at the beginning of the FOT totalled 570 (i.e. 280 in the LDW group and 290 in the Control Group). The performed analyses involve different subset of this data. Some statistical analyses need to involve just users filling in all the periodical questionnaires administered during the FOT. These analyses aim to investigate the trend of users' perception during the FOT execution and to evaluate possible changes over time. In order to ensure statistical consistency, the analysis needs to be performed on values per each user as aggregated data could be misleading.

In that case, the subset of data includes 345 drivers (i.e. 119 for LDW group and 226 for Control Group).

The total amount of driven Km by project participants during the FOT execution can be estimated. Vehicles were not equipped by Data Acquisition System in the Italian test site and mileage was based only on data self-reported by users.

The average mileage during the FOT was about 16000 km per user (this estimation comes from a raw calculation performed on LDW users' self-reported data about km travelled by the vehicle at the FOT start and at the FOT end). Excluding drop-outs, 532 users were active at FOT end, thus Italian test site could estimate that more than 8000000 km were driven during FOT execution

Table 32: Italian test site - Overview of collected data

	Processed	Used for analysis
Amount of data	546,3 MB	-
Km driven	>8000000	-
Number of drivers	570	345

2.6 Integration of data

Integration of data has followed a function-based approach. The following table indicates how the different functions have been analysed depending on the test site:

	French	German I	German II	Swedish	Italian
ACC		✓		✓	
FCW		✓		✓	
CC / SL	✓				
BLIS				✓	
LDW		✓		✓	✓
CSW		✓			
Navigation System			✓		
IW				✓	

Therefore, integration for CC/SL, BLIS, CSW, Navigation System and IW functions was not necessary, as only data from one VMC was available.

However, for ACC, FCW and LDW functions, integration was requested:

- For ACC and FCW, integration of data among Swedish and German I VMCs was requested. Common working groups were established, and shared conclusions were extracted from the available data.
- In the case of LDW, integration of Swedish and German I VMCs data was carried over in the same way as the one described for ACC and FCW. Italian VMC data was not integrated due to the different nature of this VMC, with only subjective data coming from questionnaires available.

In Chapter 3 the results of the analysis is described based on a function distribution.

3 Function analysis

The analysis of the function answers he following research questions, as stated in D6.2:

1. What features of the function, in terms of usability (e.g. accessibility, readability, controllability, compatibility while driving) influence acceptance?
2. What features of the function, in terms of usefulness, influence user acceptance?
3. Does acceptance change with experience?
4. Does trust in the function change with experience?
5. Do drivers find the function more usable with experience?
6. Does frequency of usage of the function change with experience?

In the following sub-chapters, a summary on the main findings after the analysis of the results is provided. In the Annex, detailed information provided by hypothesis can be found.

3.1 ACC

The results of testing on user related aspects for ACC can be summarised as follows:

- Acceptance, defined in terms of perceived usefulness and driver satisfaction, is very high.
- Acceptance is also stable, i.e. it does not increase or decrease over time.
- Close to 80 % of drivers state that driving comfort increases when they use ACC.
- 94 % of drivers feel that ACC increases safety.
- ACC is perceived as most useful on motorways in normal traffic.
- ACC influences driver behaviour in a way that increases safety.

3.1.1 Data used for analysis

The impact of Adaptive Cruise Control (ACC) was investigated using data collected by Ford, VW, MAN, Volvo Cars and Volvo.

Drivers experienced two conditions; 1) driving without the system (baseline condition) and 2) driving with the system available for use (treatment condition). The mileage covered in baseline and treatment is shown in Table 33.

Note that while subjective data (i.e. questionnaire responses) were collected during the full duration of the project, due to delays in the collection of objective data, the objective data analysis is based on 3 months of baseline and at least 9 months of treatment data.

The drivers and data for which objective and subjective data is available for the analysis of this particular system can be found in the tables below.

The table below gives an overview over the number of kilometres of driving on which the analysis for ACC is based.

Table 33: Number of drivers available for the data analysis.

The number of respondents varied somewhat for the different questions.

	Mileage		**Number of drivers**	
	Baseline	Treatment	$N_{passenger\ cars}$	N_{trucks}
Overall	727114 km	623615 km	174	53
Motorway	676924 km	602866 km	174	53
Rural	24983 km	12228 km	64	-
Urban	25207 km	8521 km	64	-

3.1.2 Research questions

As for all other systems in euroFOT, the focus of the analysis was on usage and acceptance of the system, along with its subjectively experienced impact on driving.

As ACC takes over longitudinal control when engaged and thus has the potential to reduce driver workload, particular attention was paid to investigating what drivers do in this situation. One can e.g. hypothesise that engagement in secondary tasks might increase, or that visual attention to the forward roadway might be lower when critical situations occur.

3.1.3 Results

Below are the results of the hypothesis testing on user related aspects. To facilitate reading, not all results are presented. Rather, short summaries are provided for each area, along with some specific examples of interesting data. For more thorough analysis of each hypothesis, refer to the Annex.

3.1.3.1 Driver behaviour

ACC influenced driver behaviour in several ways. First, a number of “typical” driving behaviours are listed below where each can be considered as related to driving with ACC. The analysis shows how frequent they are among drivers. The number in parenthesis is the frequency of participants that answered that they did the following when using ACC either quite often or frequently.

- Used ACC to control speed and avoided using the throttle (64 %)
- Used ACC so you can stretch your legs, thus taking them further away from the pedals (39 %).
- Used ACC in order to have longer time to perform other tasks (e.g. eating changing radio) (13 %).

There were also changes in the objective data that reflect altered driver behaviour while using ACC[1]. These can be described in terms of two key aspects of driving style; average speed and average THW. Both showed increases in the analysis of the FOT data for passenger cars (see

Figure 39 and Figure 41) and trucks (Figure 40 and Figure 42).

[1] Note that in the objective data analysis, ACC and FCW are treated as a bundle rather than as separate functions. The following results are hence also valid for FCW.

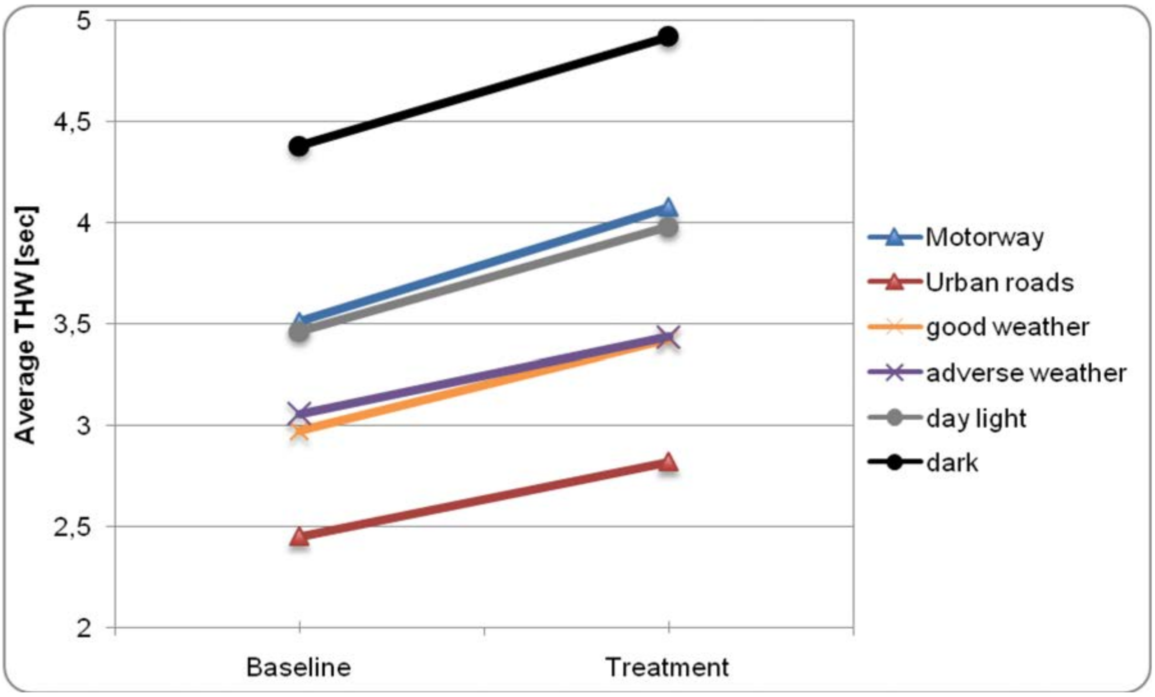


Figure 39: Changes in average THW for passenger cars

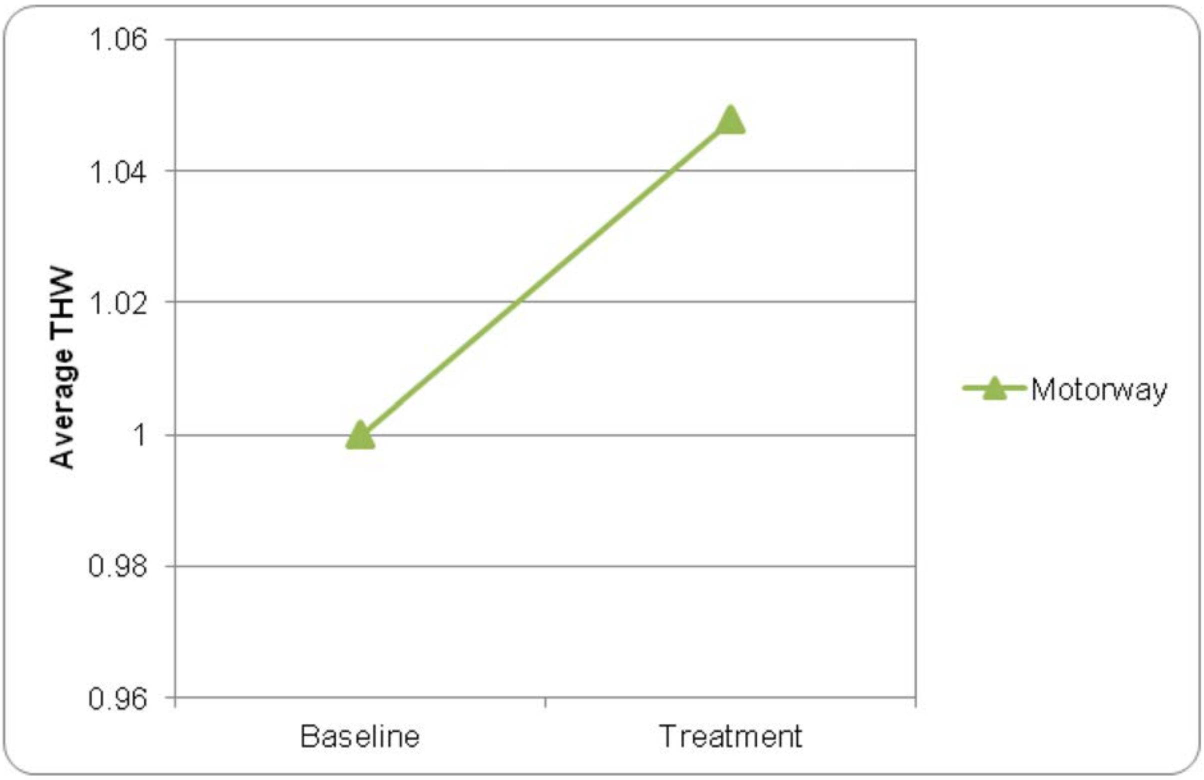


Figure 40: Changes in average THW for trucks

For cars, average THW increased with about 15% within the different considered conditions, though no significant results could be found for rural roads. For trucks, we observed a 4.78% increase in motorways. This is likely due to the fact that the adjustable time gap for ACC has a lower limit which prevents drivers from driving too close (whether intentionally or unintentionally) to the lead vehicle. This is also reflected by the high reduction in the number of critical THW's and harsh braking manoeuvres associated with unintended close approaching situations.

An additional explanation for higher THW values could be caused by the discrete number of settings of the ACC system. If the desired THW of the driver is in between two of the selectable time gap settings of the system, the driver may chose the higher setting for more comfortable and safe driving. However, this factor is difficult to quantify without further investigation in a follow up project since the quantification requires a comparison of the selected time gaps within the treatment phase to very similar driving situations in baseline conditions (in terms of traffic density, lighting and weather conditions, speed, etc.).

Driver related changes in the average speed for passenger cars can be seen in Figure 41 and Figure 42 for trucks. In all analysed situations increases in average speed vary between 0.65% and 4.99% (0.87% for trucks in motorways). Regarding the absolute values on urban roads it has to be noticed that only urban roads where driving higher speeds is possible (e.g. urban bypasses) were analysed based on a speed related filtering criterion. The increase in average speed is influenced by the driver's choice when to use the system, e.g. in situations with possibly less traffic density that they rate as "safe" and which allow therefore higher average speeds. Even though, the reasons for the increase in average speed are difficult to explain and quantify, one can summarise that drivers seem to use ACC in specific situations that allow higher average speeds.

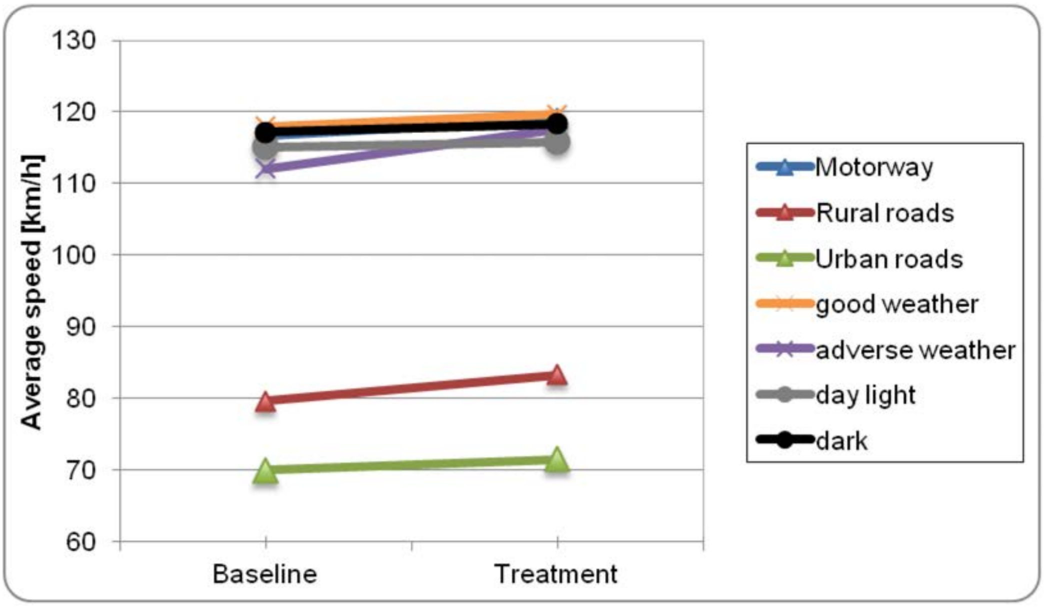


Figure 41: Changes in average speed for passenger cars

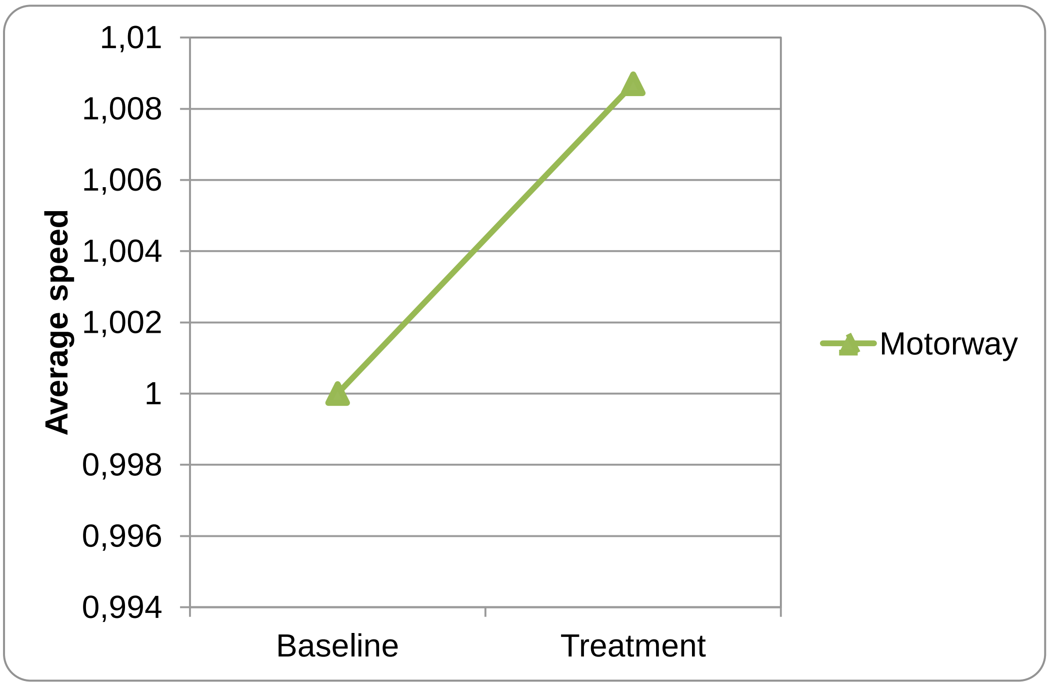


Figure 42: Changes in average speed for trucks

A third indicator which is also directly related to the driving style is the average fuel consumption. This indicator is mainly attributed to efficiency or environment, but can additionally give insights into driving behaviour since it is highly affected by changes in the variation and choice of speed, acceleration behaviour, etc. It can be seen in Figure 43 that the highest reduction can be found on urban and rural roads (around -6% and -9%). For trucks, the reduction was around -2% on motorways (Figure 44). As discussed before these values are influenced by the situational choice of the ACC usage and give therefore insights on how and when the driver uses the system, but complicate the evaluation of the fuel saving potential provided by the system.

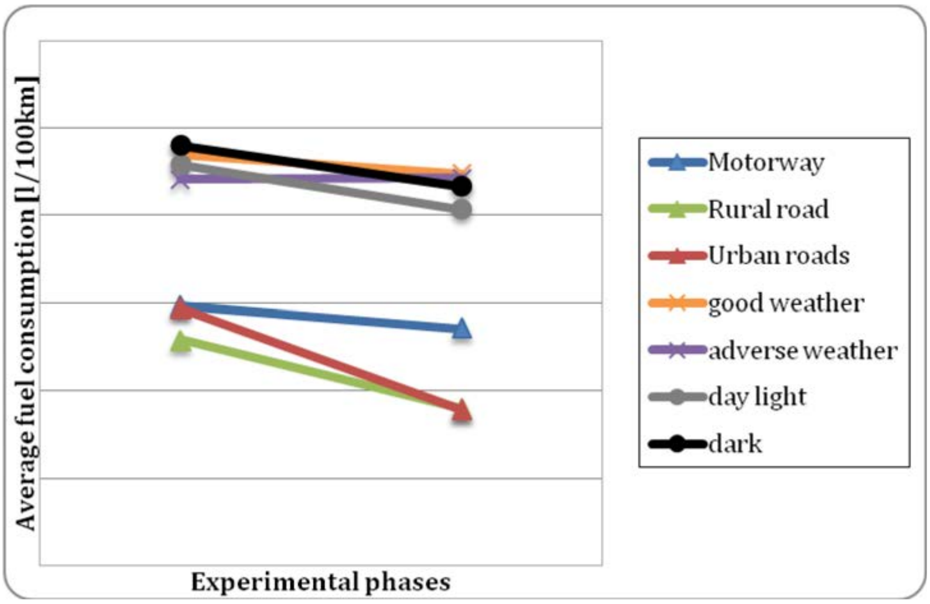


Figure 43: Changes in average fuel consumption for passenger cars

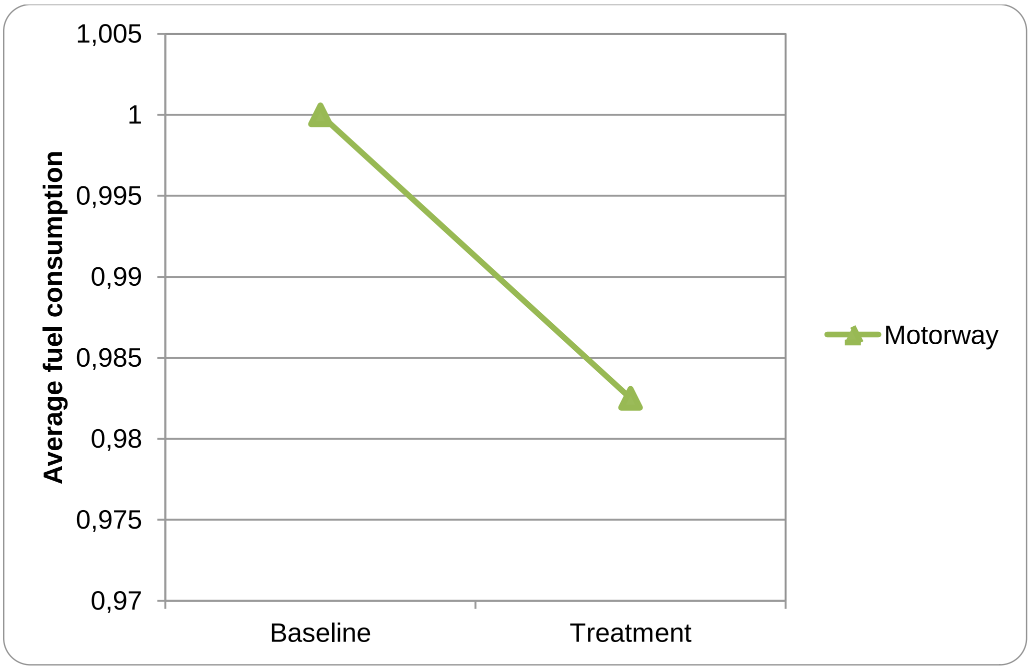


Figure 44: Changes in average fuel consumption for trucks

The previously mentioned aspects of the driver behaviour influence of course also indicators for driving safety and efficiency. Changes in the distance behaviour of the driver affect e.g. safety aspects like the number of critical THW's, the number of harsh braking manoeuvres and incidents. These driver behavioural related changes on safety aspects will be presented in section 0.

3.1.3.2 Workload

When using ACC, drivers reported highest workload when driving on motorways with heavy traffic and/ or bad weather, and when driving on roads with changing speed limits. Under these driving conditions they reported average workloads between some efforts and rather much effort, and this remained stable over the duration of the trial.

However, given the nature of these results, they likely reflect the workload associated with negotiating the traffic conditions rather than that ACC requires more effort to use under these conditions.

3.1.3.3 User Acceptance

User acceptance is evaluated in accordance with the Van der Laan scale. In this scale the participants rates 9 items on a scale ranging from -2 to +2.

The nine items are:

- **useful**
- pleasant
- **good**
- nice
- **necessary**
- likeable
- **assisting**
- desirable
- **raising alertness**

Five of these items are considered to be usefulness (**bold**) issues and four are related to satisfaction. Acceptance is the average of all nine items.

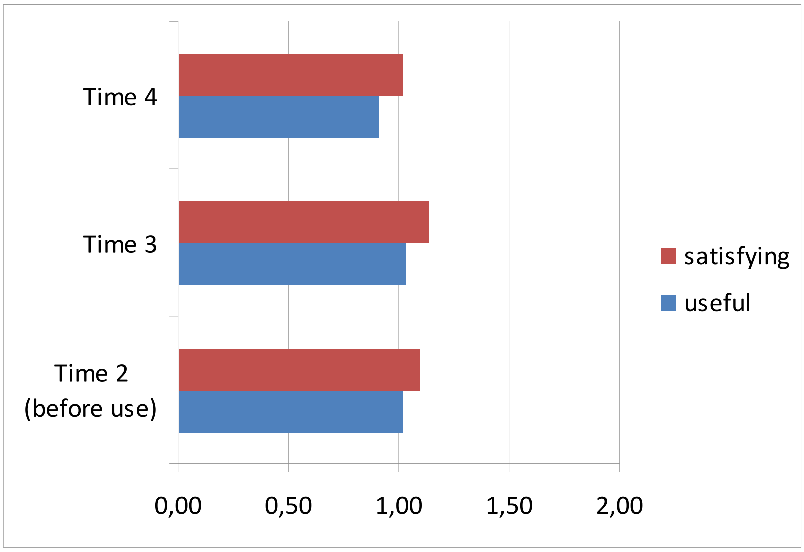


Figure 45: Acceptance rating in terms of usefulness and satisfaction.

Acceptance level of the ACC system is positive. There is no significant difference between the rating before use and after use which indicates that the system fulfils the expectations from the drivers. Furthermore, there are no significant changes in perceived satisfaction and usefulness over time with use.

Perceived usefulness was further analysed for the drivers that scored positively on acceptance. These drivers were asked to specify during which driving conditions they found the system most useful.

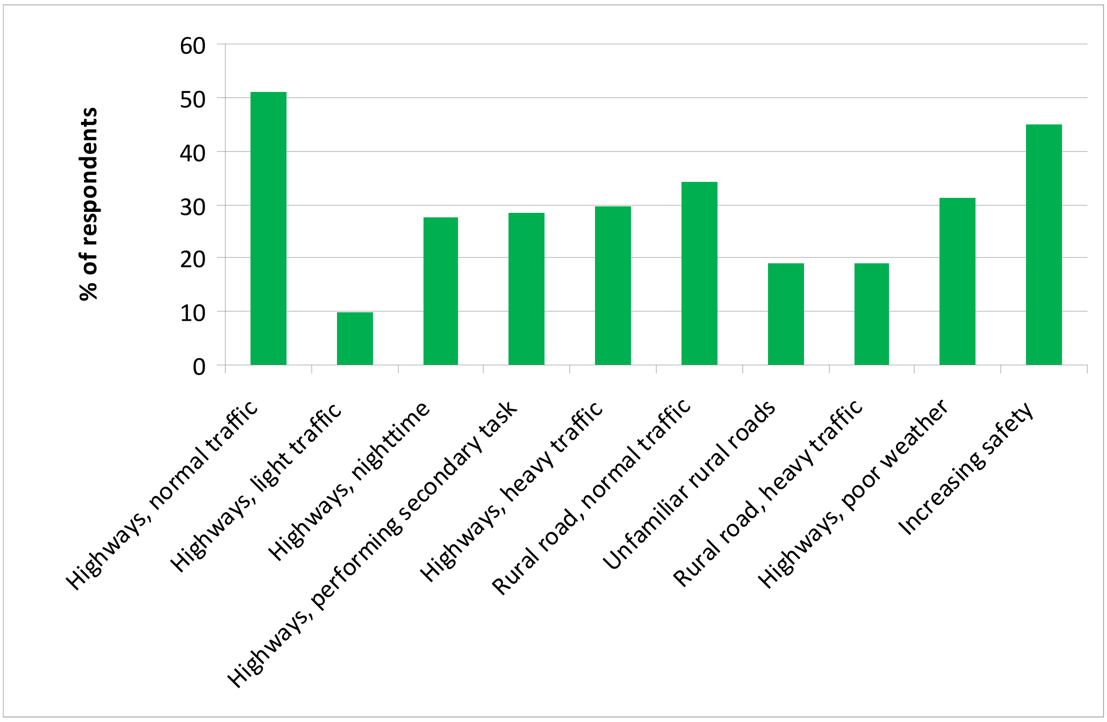


Figure 46: Acceptance rating in terms of usefulness and satisfaction.

45 % of the drivers felt that the system increased driving safety. They found it most useful in normal traffic, primarily on motorways but also on rural roads. Almost 30 % found it useful when performing a secondary task.

Analysis was also undertaken to establish how certain features of usability influence acceptance. In general the drivers found the system very easy to use. Only issues related to visual information and warnings received lower scores.

A summary of the results for the different hypotheses on the use of ACC is shown in the table below.

Table 34: Overview of results for the hypotheses on user acceptance of ACC.

Hypothesis category	Type of measure	Performance indicator	Result		Relative Increase / Decrease
			At the beginning of treatment phase	At the end of treatment phase	
Acceptance	Self-reported	Perceived increase of comfort of driving		Yes: 77 % of all drivers	→→
	Self-reported	Perceived increase of safety of driving		Yes: 94% of all drivers	→→
Trust	Self-reported	Average trust			No change
	Self-reported	Confidence			←←

3.1.3.4 Usage

The results of the objective measures for the total data set (over all factors) confirm the hypothesis “ACC use increases over time”. There is a significant increase of ACC use in the last month of the treatment phase compared to the first month of the treatment. This finding appears for both performance indicators used for the evaluation of this hypothesis: duration of traveling with active ACC and frequency of ACC activations. It is concluded, that the drivers seem to get used to the positive perception of the ACC system and use the system longer and more often over time.

However, only one third of the drivers answered that they changed usage of the system during the FOT. Typically they used the system to keep a safe distance to the car ahead. The major part of the drivers did not report on a change of their practices in using the ACC. This leads to the assumption that most of the drivers were not aware of their increased use of ACC.

Table 35: Overview of results for the hypotheses on usability of ACC

Hypothesis category	Type of measure	Performance indicator	Result		Relative Increase / Decrease
			At the beginning of treatment phase	At the end of treatment phase	
Usage	Objective measure	Percentage of travel time travelled with active ACC	19 %	25 %	+31 % →→
	Objective measure	Number of ACC activations per hour travelled	1.1	1.6	+53 % →→
	Objective measure	Number of overriding per hour travelled with active ACC	29.2	26.2	-10 % ←
	Self-reported	Change of user practices in using the ACC		No change: 63 % of all drivers	

The increased use of ACC is in line with the perceived increase of safety and comfort which has been self-reported by the drivers. In contrast, self-reported ratings on trust did not change over time and thus did not reflect the positive perception related to safety and comfort. Confidence which is a sub-criterion of trust even decreased thus expressing that the drivers had higher expectations than the system could fulfill.

The hypothesis on overriding the ACC "The driver changes the use of ACC over time by increasing the occurrence of overriding the ACC function by using the accelerator pedal" was not confirmed by the results of the objective data. The number of overridings did not change over time, except for a slight decrease at the end of the treatment phase. The decline of overriding may be an indication for the perceived increase of comfort related to the automatic functions of the ACC, i.e. accelerating, braking, and keeping a certain distance to the vehicle ahead. However, the objective results indicate that drivers learned quickly how to override the ACC and use overriding when required and weather conditions allowed. It appears that as if overriding does not pose big problems to the drivers. The reason might be that drivers have always been used to increase vehicle speed by using the accelerator pedal.

3.1.3.5 Safety & efficiency

Driver related changes caused by the use of the ACC also affect safety and efficiency. In section 3.1.3.1 the increases in average THW and speed were discussed. As mentioned positive safety effects were observed. Especially, the changed distance behaviour leads to a reduction of critical situations in the longitudinal vehicle movement.

Figure 47 and Figure 48 show the significant reduction of event where the THW falls below 0.5 seconds per 100 km for cars and trucks, respectively. For cars, the reductions vary between 63% on urban roads and 82% on rural roads. On motorways the number is reduced by 73%. For trucks, the reduction varies between 49% and 57% depending on the weight (on motorways only). They show that when using the ACC, drivers engage in less dangerous close approaching manoeuvres compared to baseline driving (whether or not such a manoeuvre is intended or unintended).

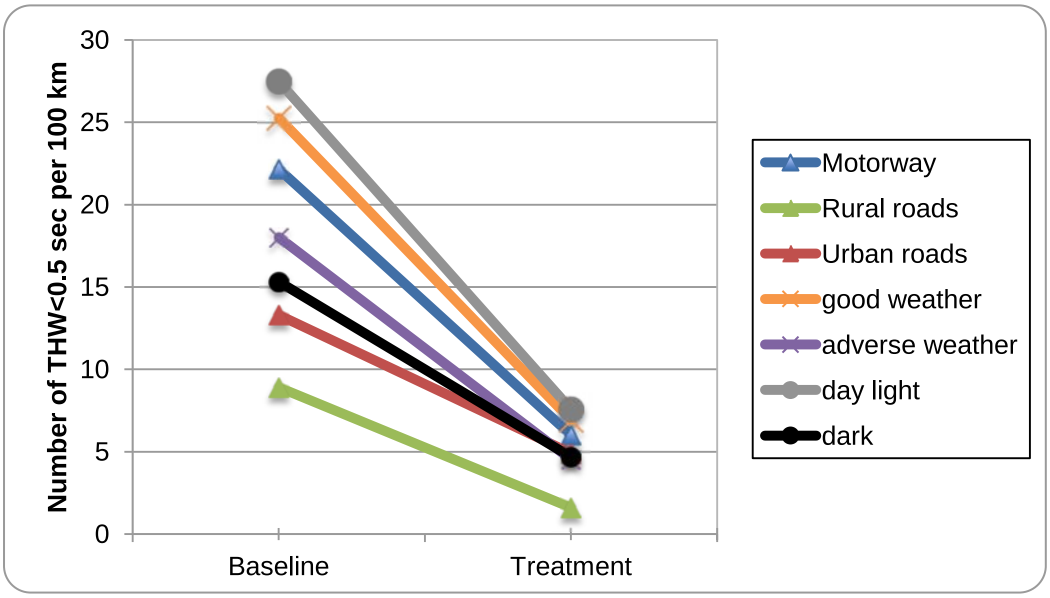


Figure 47: Change in critical THW events (< 0.5 sec) per 100 km for passenger cars

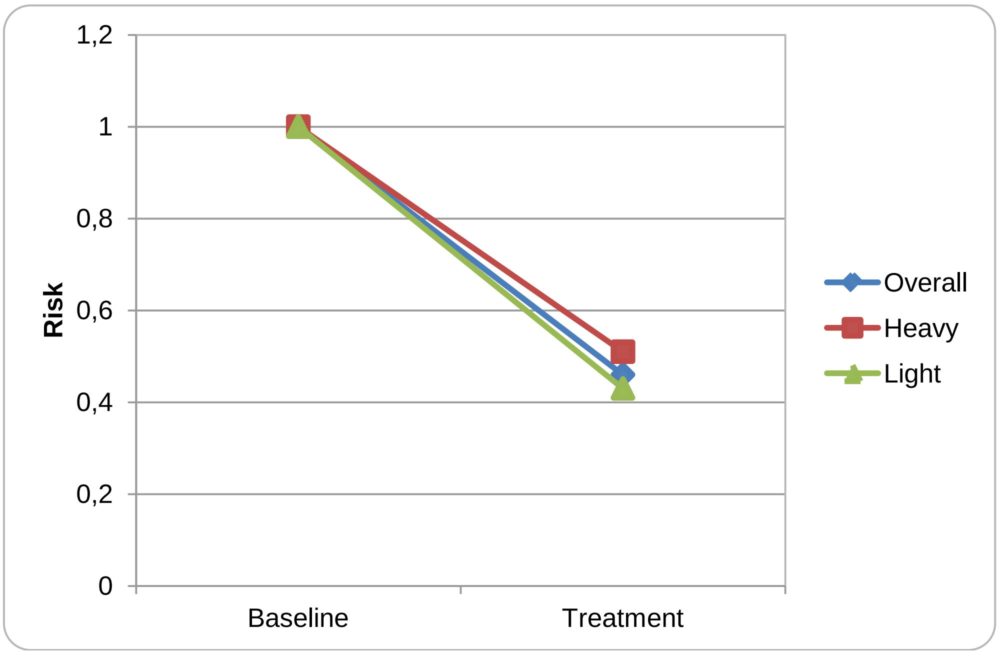


Figure 48: Change in critical THW events (< 0.5 sec) per 100 km for trucks

Less harsh braking manoeuvres were observed in the treatment phase. The reductions in high decelerations can be seen in

Figure 49 and Figure 50 and reflect the same effect size as the critical THW's. Within the considered situations the number is lowered between 65% and almost 85% for cars and between 63% and 66% for trucks. Two reasons for the reduction in less hard braking events can be suggested: First, the lower limitation of the selectable time gap settings prevents intentional close approaching to the vehicle ahead (that might lead to critical situations in case of a braking of that vehicle) as discussed above. Second, the increase in average THW (around 0.3 seconds on motorways) results in more time to react to e.g. decelerating vehicles ahead resulting in smoother (braking) reactions.

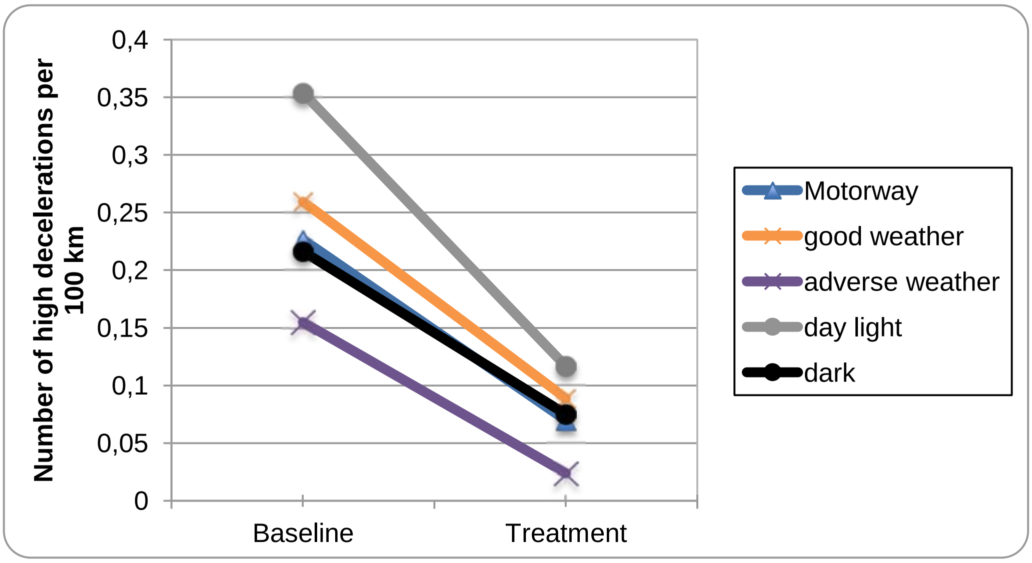


Figure 49: Change in the number of high decelerations for passenger cars

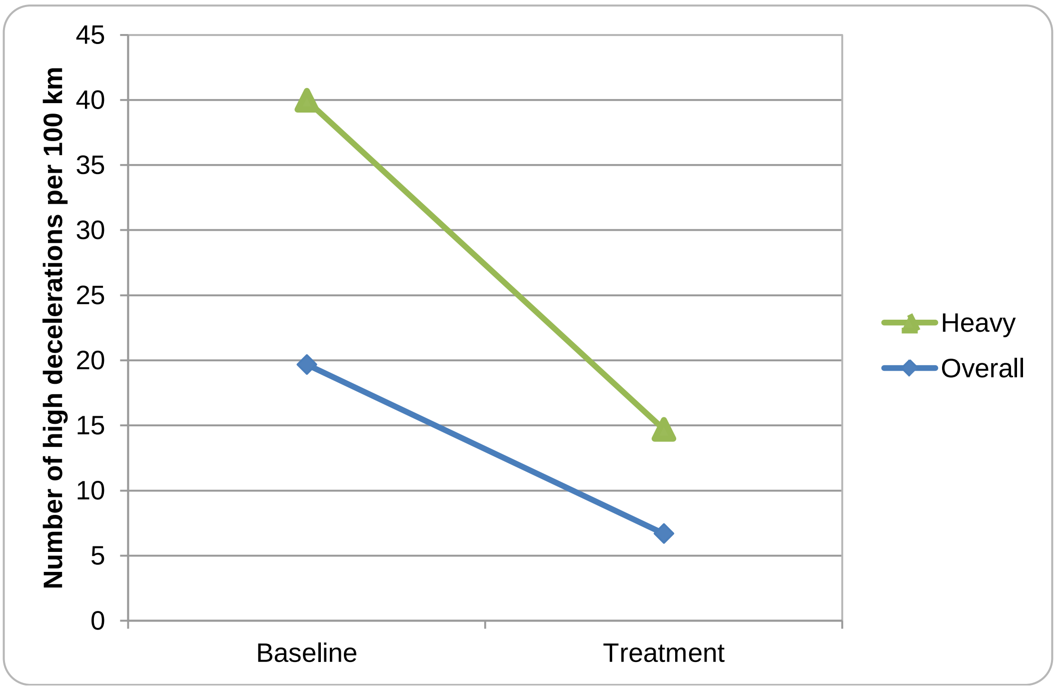


Figure 50: Change in the number of high decelerations for trucks

A safer driving style can also be seen from the reduction of incidents which is shown in

Figure 51. The incidents based on vehicle kinematics are like the number of critical THW's and harsh braking manoeuvres reduced between 71% and 82%. For trucks, the reduction was 36% (CL = 90% sig, Figure 52). Not only incidents in the longitudinal were considered but also lateral vehicle movement and indicate therefore that the driving behaviour in general is safer.

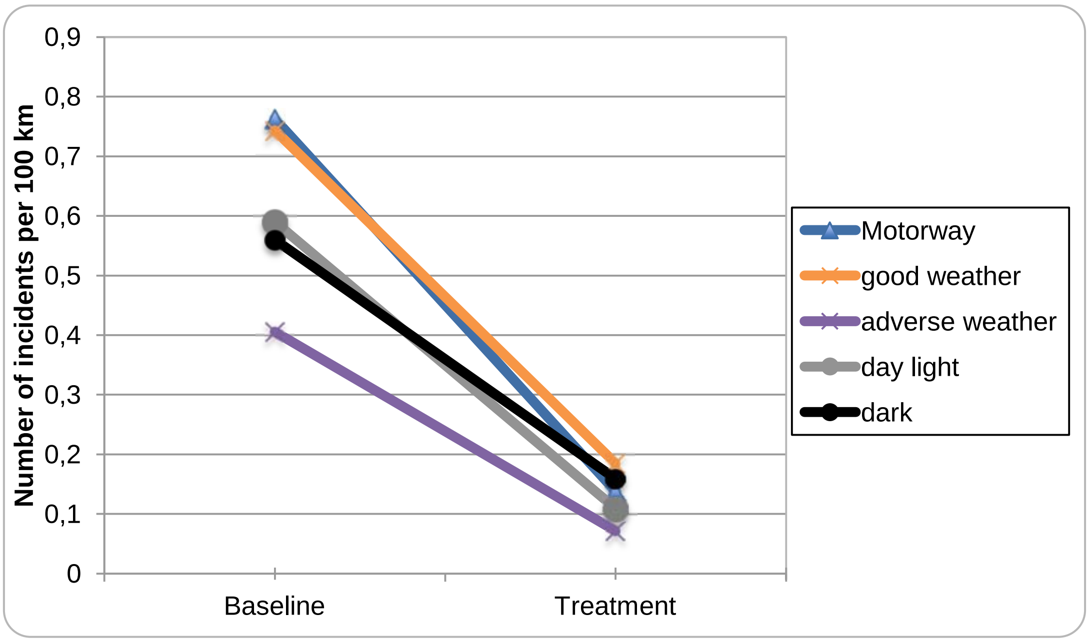


Figure 51: Change in the number of incidents per 100 km for passenger cars

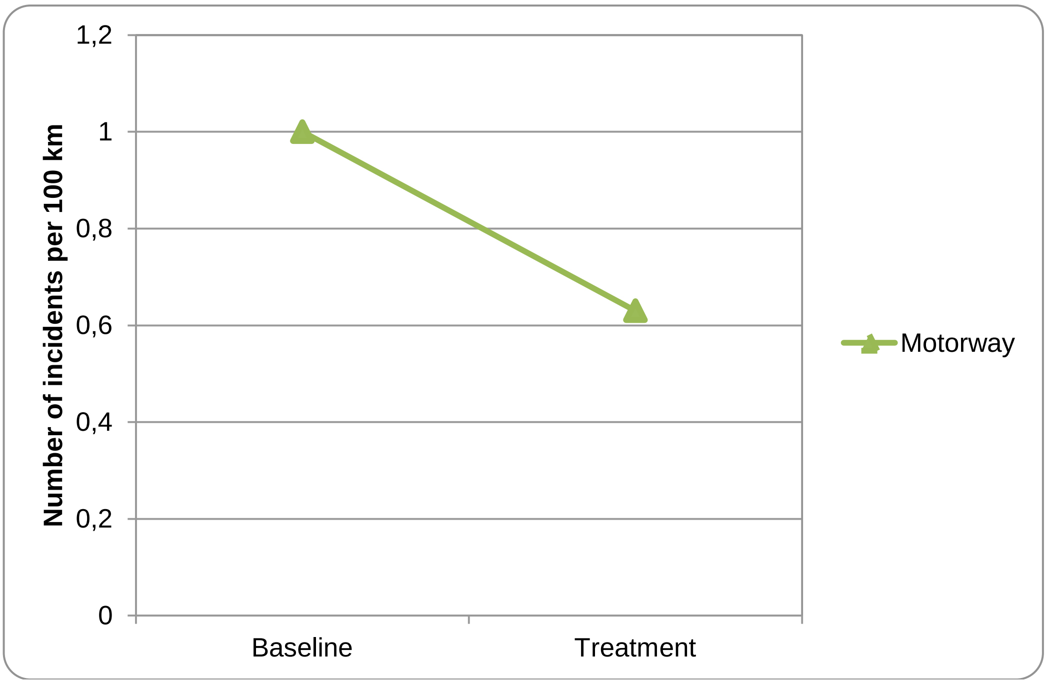


Figure 52: Change in the number of incidents per 100 km for trucks

In summary, it can be concluded based on the evaluation of the FOT data that the changes in the driver behaviour result in a safer driving when using the system. The ACC system encourages a smoother driving style that is especially based on longer distances to the vehicle ahead. More detailed information on the ACC effects on driving safety can be found in D6.4.

We also investigated hypothesised negative side effects of ACC+FCW in terms of increased secondary task engagement, attention to forward roadway and drowsiness. Given that ACC+FCW was expected to lower driver workload, one could hypothesize that secondary task engagement might increase, that visual attention to the forward roadway might decrease and that drowsy driving might increase.

Results here showed some interesting effects. First, during normal driving, car drivers were likely to engage in secondary tasks more often when using ACC+FCW. More specifically, while using ACC+FCW drivers were three times more likely to engage in visual secondary tasks, compared to baseline. However, during crash relevant events, no such difference in secondary task engagement was found. This suggests that drivers are capable of selecting to engage in secondary tasks in situations when safety is compromised. Moreover, driver's attention towards the forward roadway during crash relevant events was significantly higher when drivers were using ACC+FCW. This suggests that the ACC+FCW function is successful in redirecting driver attention to the roadway ahead through the warnings it issues in critical events. Lastly, there was no difference between baseline and treatment in terms of drowsy trip frequencies; hence, ACC+FCW presence does not seem to affect the amount of drowsy driving undertaken. For trucks, no side effect was observed. More detailed information on these effects can also be found in D6.4.

3.1.4 Discussion of results

Overall, ACC seems to be a highly appreciated and used function, that both increases driver comfort and safety. It is also a system where driver expectations were fulfilled, i.e. the scores on satisfaction and usefulness that drivers gave before gaining access to the systems matched those given during and after the trial. Hence, the currently evaluated ACC can be said to be in line both with what people want and what people actually use and like.

In terms of usage, it seems clear that drivers make the most use of ACC on motorways, as expected. Some of the expected changes in driver behaviour also occurred, e.g. drivers take their foot off the accelerator and stretch out when using ACC. For cars, engagement in secondary tasks also increased, but interestingly, only for non-critical driving episodes, not during actual critical events. This indicates that drivers do make use of the "freedom" to think and move that ACC provides when engaged, but do so in a selective and safe manner.

3.2 FCW

The results of the FOT on FCW can be summarised as follows:

- Close to 70 % of drivers feel that FCW increases safety.
- Before trying FCW, participants had very high expectations of the system. These were later somewhat diminished based on their actual experience of the system (mainly for items effective, raises confidence and trustworthy).
- Despite this, the perceived usefulness and driver satisfaction are both very high and also stable, i.e. they do not increase or decrease over time.

FCW is perceived as most useful on motorways in normal traffic.

3.2.1 Data used for analysis

Used data is the same as the one described in section 3.1.1, as FCW is analysed as a bundled function with ACC.

3.2.2 Research questions

As with all other systems in euroFOT, the focus of the analysis in on usage and acceptance of the system, along with its subjectively experienced impact on driving.

3.2.3 Results

Below are the results of the hypothesis testing on user related aspects. To facilitate the reading, not all results are presented. Rather, short summaries are provided for each area, along with some specific examples of interesting data. For a more thorough analysis of each hypothesis,refer to the Annex.

3.2.3.1 Trust

Average trust in the FCW system does not change over time, but confidence in the system did decrease significantly when drivers started to actually use FCW, which means that the driver had higher expectations regarding “raises confidence” than the system could fulfil.

3.2.3.2 Driver Behaviour

Some driving behaviours that can be considered as related to driving with FCW were analysed in terms of their frequency of occurrence. The number in parenthesis is the number of participants that answered that they drive in this way quite often or frequently.

- Used FCW because you like to receive warnings (5 %).
- Used FCW to check your reaction time (3 %).
- Used FCW in traffic jam simply to activate the system for amusement (2 %).
- Relying on FCW to warn when performing other tasks (e.g. eating, changing radio) (0 %).

In terms of changes in the objective data, it needs to be clearly pointed out that in the objective data analysis, FCW and ACC were treated as a bundle rather than as separate functions. This means that the results for ACC also apply to FCW. Rather than repeating those here, the reader is referred to the analysis of objective data as described in section 3.1.3.1 above.

3.2.3.3 Workload

In general, the driver experiences only little effort when driving with the FCW system. Over time a very small increase in workload could be detected on motorways and rural roads in normal traffic. Even with the increased workload detected the effort is still very low when measured in accordance with the RSME Mental Workload Scale.

3.2.3.4 User Acceptance

User acceptance is evaluated in accordance with the Van der Laan scale. For more details on this scale, refer to section 3.1.3.3.

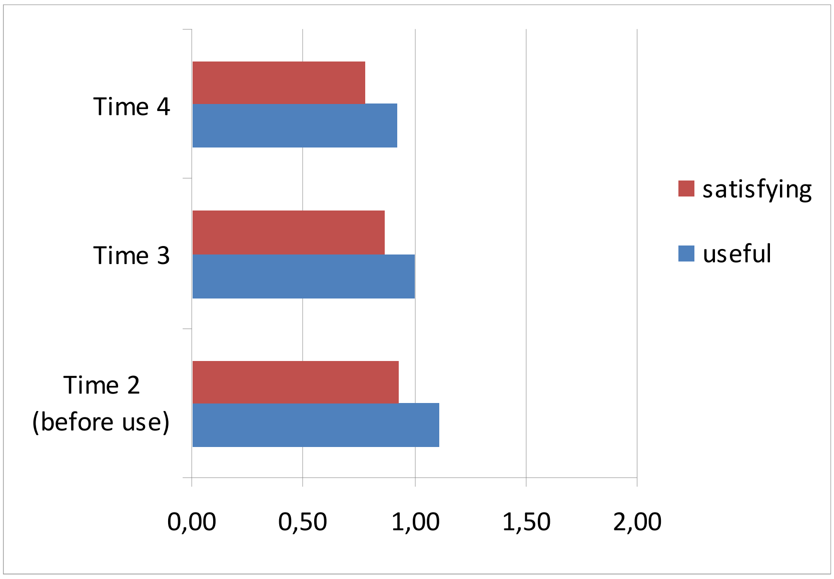


Figure 53: Acceptance rating in terms of usefulness and satisfaction

Drivers overall found FCW both useful and satisfying to use. For usefulness the expectations are not fulfilled since there is a significant decrease in the scores between T2 and T3. Over time with system use, usefulness and satisfaction remains on a high level and does not change significantly.

Perceived usefulness was further analysed for the drivers that scored positively on acceptance. These drivers were asked to specify during which driving conditions they found the system most useful.

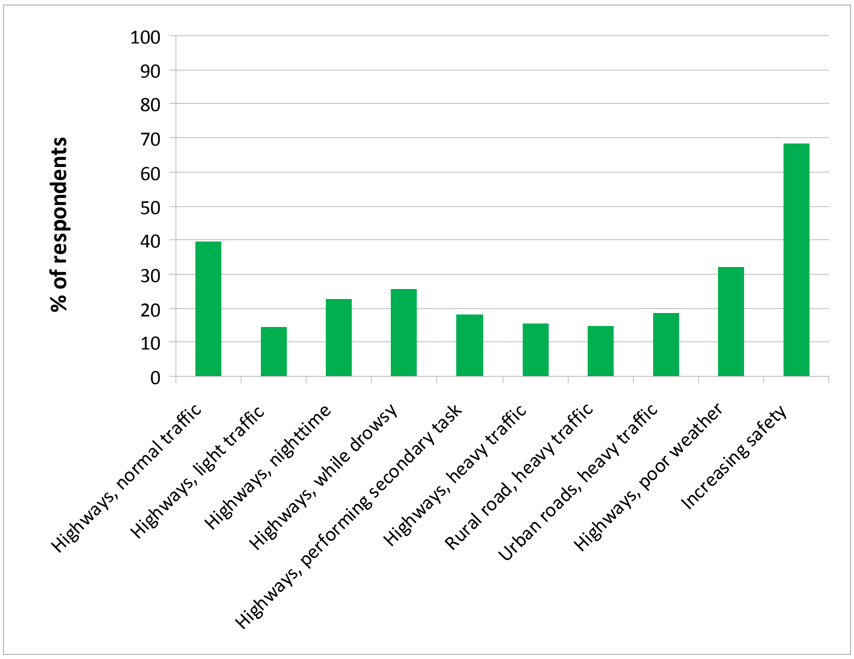


Figure 54: Usefulness under different driving conditions, rated by drivers with positive acceptance

First, it is obvious that drivers perceive the system as very important for increasing safety. Almost 60 % of the drivers point this out. Further, they found it most useful on motorways in normal traffic but also when driving on motorways in poor weather, driving while drowsy and at night time.

It was also analysed how certain features of usability under the concept of ease of use, influence acceptance. In general the drivers found the system very easy to use. There were only issues related to the timing of audible and visual warnings that scored at a lower level.

3.2.3.5 Usage

The majority of the drivers did not use the Forward Collision Warning system differently at the end of the FOT from the way they did when they first started using the system. It can be stated that user practices of the FCW system didn't change significantly over time during the FOT.

3.2.3.6 Safety & efficiency

In terms of the objective data, it needs to be clearly pointed out that in the objective data analysis, FCW and ACC were treated as a bundle rather than as separate functions. This means that the results for ACC also are valid for FCW. Rather than repeating those here, the reader is referred to the analysis of objective data as described in section 3.1.3.5 above.

3.2.4 Discussion of results

An interesting finding is that confidence in FCW did decrease significantly when drivers started to actually use the system, as compared to before they had access to it. This means that drivers had higher expectations regarding the way in which FCW should "raise confidence" than the system could fulfil, and once confronted with the system's limitations; these expectations had to be revised downwards. Despite this, most drivers perceive that the system increases safety and satisfaction and usefulness remain high throughout the study. Another way of interpreting this is that driver expectations before interacting with the system were unrealistically high. If so, it highlights the importance of managing driver expectations when these systems are introduced, in order to avoid levels of disappointment that might decrease system overall usage, and more importantly, to avoid overreliance on the system.

Drivers were not uniformly positive to the FCW's audio-visual interface, i.e. some reported that they perceived the timing of the warnings as annoying. This was perhaps to be expected, as many researchers have argued that drivers have individual comfort zones, and a following distance that is perceived as being too close for one driver may seem as a perfect distance to another. However, it reinforces the need for investigating new and creative ways of adapting warning timing to driver acceptance thresholds. A satisfied driver is more likely to respond as desired to a warning than an unsatisfied one.

On a more curious note, as could be seen under driver behaviour, a small portion of drivers seem to experiment with the system's performance capabilities. Whether this is was out of curiosity or driven by something else is unclear, but the finding merits further investigation in future studies.

3.3 CC / SL

The results of the FOT on speed limiter and cruise control can be summarised as follows:

- SL or CC is used in about 35% to 85% of driving distance according to road types. Usage is higher on motorways (130 km/h).

- No change in SL and CC usage was observed during the FOT.
- For both systems there is no systematic change of workload over the period of system usage
- For both systems, drivers have positive expectations at the beginning of the FOT and expectations are confirmed.
- The SL is perceived as increasing the driver comfort for 46 % of the drivers and the CC for 80 %. The SL is perceived as increasing the pleasure to drive for 35 % of the drivers and the CC for 63 %.
- No misuses was declared by the drivers except to select a top speed above the speed limit
- The amount of kilometres travelled and numbers of trips made do not vary significantly over time.
- The SL and CC decrease the average fuel consumption in all driving contexts.
- The function CC increases the average speed in all driving contexts (more than 10 km/h).
- The function SL increases the average speed for 2km/h in all driving contexts except for motorways (130km/h limited roads).
- The ability of the SL system to reduce critical time gap occurrences probability (odds of observing a critical time gap) is only significant for 30, 50, and 130 km/h roads and the ability of the CC system to reduce critical time gap occurrences probability is significant for all the speed limits.
- The ability of the SL system to reduce hard braking occurrences probability is only significant for 50, 70, and 90 km/h roads. The ability of the CC system to reduce hard braking occurrences probability is significant for all roads except 30km/h roads.
- CC has a clear positive influence by reducing the probability of observing a strong jerk event while driving. SL has no effect.
- CC increases the probability of exceeding the speed on most roads, but the effect is opposite on motorways. SL succeeds in reducing over speeding events, especially for high speed limits, where a reduction of up to 50% can be observed when using the system

3.3.1 Data used for analysis

The data that was used for the CC / SL analysis was all the data collected in the French VMC (see chapter 2). This data was chunked by splitting the trips according to certain values of situational variables. At the French VMC, in order to be able to study certain features of the SRS (Speed Regulation System), it was decided to keep constant among a chunk the following variables: TripID, DriverID, road type (Urban, rural, motorway), speed limit (30, 50, 70, 90, 110, 130 km/h), weather (dry or rain), and lighting (night or day). Moreover, for comparison purposes, the chunks are also sliced in 30 sec. sections, allowing up to a 10sec. minimal duration. The process ends by obtaining thousands of 10 to 30 sec. chunks each one of them being described by the list of performance indicators (PI).

Chunks are selected differently according to the research hypothesis. Criteria may vary according to the system studied, or to selection choice. Statistical analysis based on time dependent PI need to weight the data according to the chunks duration.

Chunks are always filtered before use, or before sampling from the baseline, according to the following criteria:

- Average speed >5km/h.
- Map speed limit information available

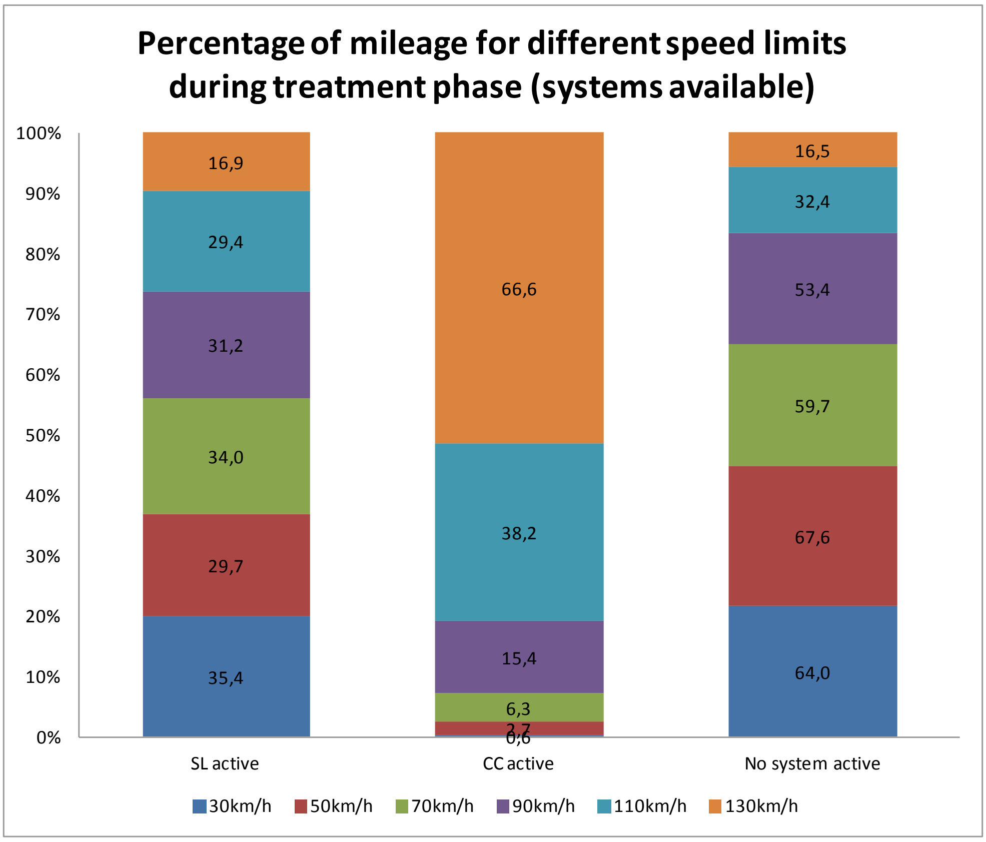


Figure 55: percentage of mileage for different speeds during treatment phase (CC / SLA)

3.3.2 Research questions

The different research questions defined for speed limiter and cruise control systems are provided in the Annex. Specific focus has been placed on driver behaviour and acceptance, while concentrating on longitudinal control hypothesis (speeding, headway, etc.).

3.3.3 Results

The results for the analysis of the CC / SLA hypotheses are as follows.

3.3.3.1 Driver Behaviour

The CC / SL system is used voluntarily, according to the driving situations chosen by drivers. Moreover, drivers tend to use more one of the two systems than the other. The cruise control is often used on motorways or freeways (>= 110 km/h) and speed limiter is often used on all roads except motorways (130 km/h).

CC usage does not vary significantly over time. A slight difference exists on 50km/h roads between only one pair of months but significance of the encountered effects is not strong enough to show a clear tendency of the CC usage over time.

SL usage does not vary significantly over time. Statistical test did not find any significant difference between pairs. There is a tendency in the graph to show an increase of SL usage rate at the end of the experiment at month 12 but it is never statistically significant. The tendency of drivers to use the system more in the last month of the treatment phase may be due to culpability (not induced by experimenter) of not using enough the system for the experiment needs.

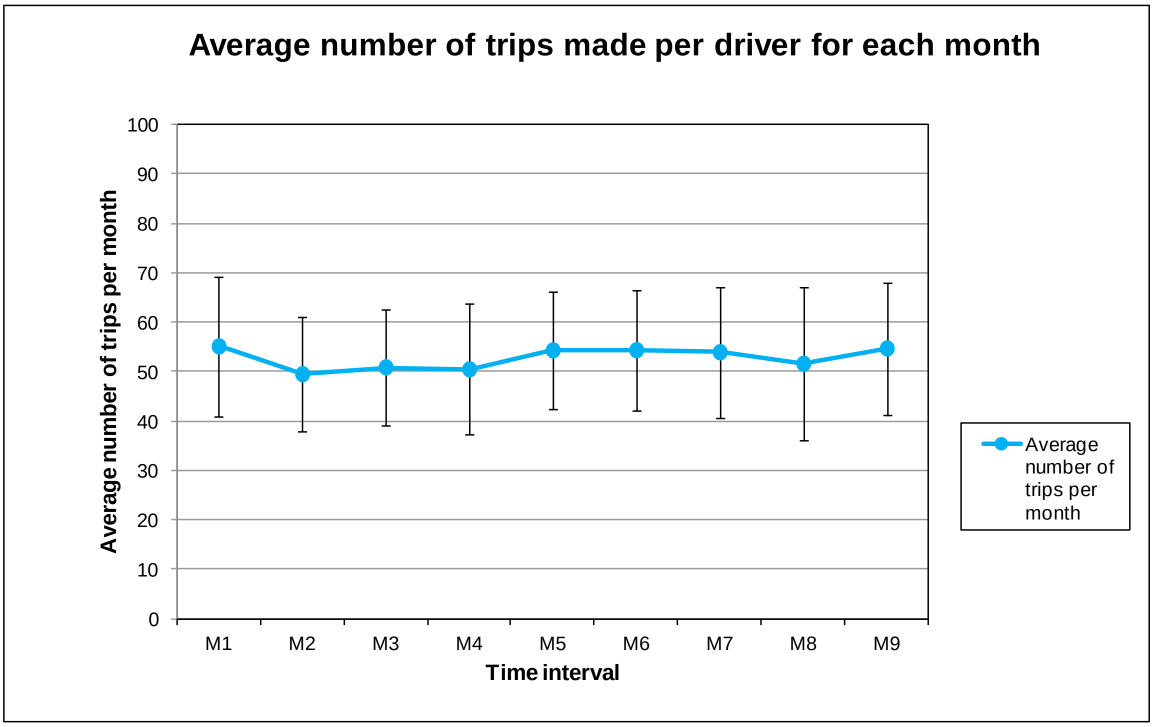


Figure 56: Average number of trips made per driver each month (CC / SLA)

The numbers of trips made do not vary significantly over time.

Analysis of variance did not find any relevant differences between months.

The number of kilometres travelled does not vary significantly over time. These objective measures are confirmed by subjective declaration of the drivers who think that their practices did not significantly change during the FOT for the two systems (63% of drivers do not change the way in which they used the two systems).

System Misuses

With the SL system drivers state that they engage in misuse behaviours only to select a top speed above the speed limit and to use buttons to adjust SL speed instead accelerator pedal. With the CC system drivers state that they engage in misuse behaviours only to select a cruise speed above speed limit and to use CC to overtake a vehicle.

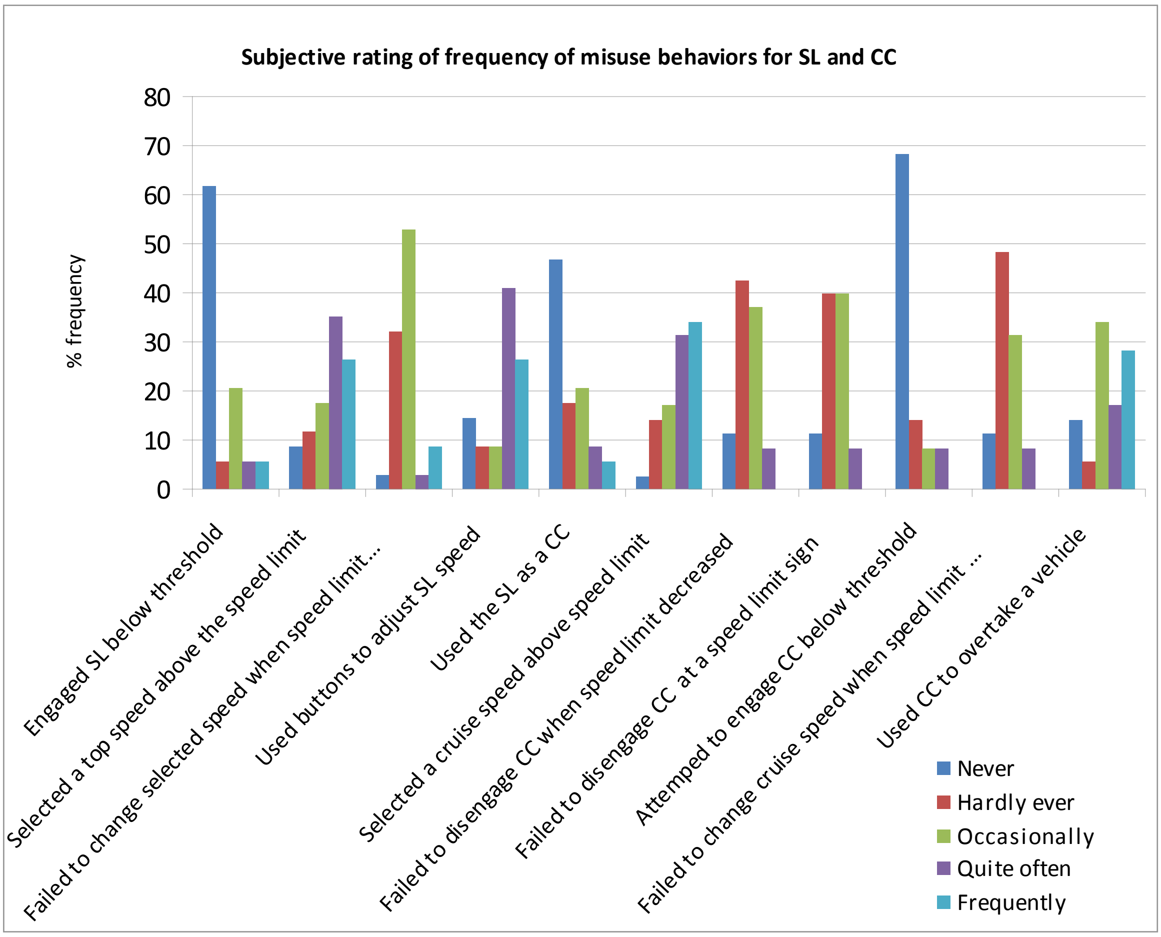


Figure 57: Subjective rating of frequency of misuse behaviours

Intersection impact

This impact was measured by calculating the odds (ratio of the probability that an event will happen to the probability that it will not happen). Intersection density (percentage of near intersection road) impact on SL use is significant for 90km/h limited roads where the odds of using the SL when intersection density is high is 82% times the odds of using SL when few intersections are encountered. The effect is less significant for 110km/h roads but in the opposite direction: A driver is 27% more likely to use the system when intersection density is high.

Intersection density impact on CC use is highly significant except on motorways (130km/h roads). The OR estimates ranges between 51 and 76%. The odds of using the system versus not using it, when intersection density is high, is approximately 60% times the odds of using it when intersection density is low.

Curve density impacts

Curve density has always a significant impact on SL use. From 50km/h to 110km/h roads the effect is similar: the odds of using the system on high curve density roads is 60% the odds of using it when few curves are encountered. SL is unlikely to be used on roads with many curves.

The effect for 130km/h roads is opposite to the others and significant, leading to the conclusion that the system is more often used when curves are present. This may be due to the ability of SL system to reduce the likelihood of being caught by speed enforcement cameras (often present on motorways in France, especially when the driving context is dangerous). Drivers may want to use it preferably when the risk of being caught when over speeding is high (curves).

Curve density has always a significant impact on CC use. On 70km/h roads, the odds of using the system when curves are highly present are 34% the odds of using it when curves are not present. The effect increases until a maximum for 130km/h roads, for which CC is almost never used when curves are present.

Sensation seekers impact

For SL, sensation seeker and over speeding factors are relevant but the interaction is not, leading to think that the amount of exceeded speed is related to the sensation seeking level of the driver, and also to the will of exceeding speed. For CC, the effects are different with a significant although small effect of the sensation seeking level. The will of over-speeding has a much more important effect on the amount of exceeded speed. The interaction is significant showing that the will of over-speeding can lead to different selected speed depending on the sensation seeking scale (sensation seekers drivers tend to exceed speed more than others when over-speeding, but not when did not intend to over-speed).

3.3.3.2 Workload

For both systems there is no systematic change in workload over the period of system usage.

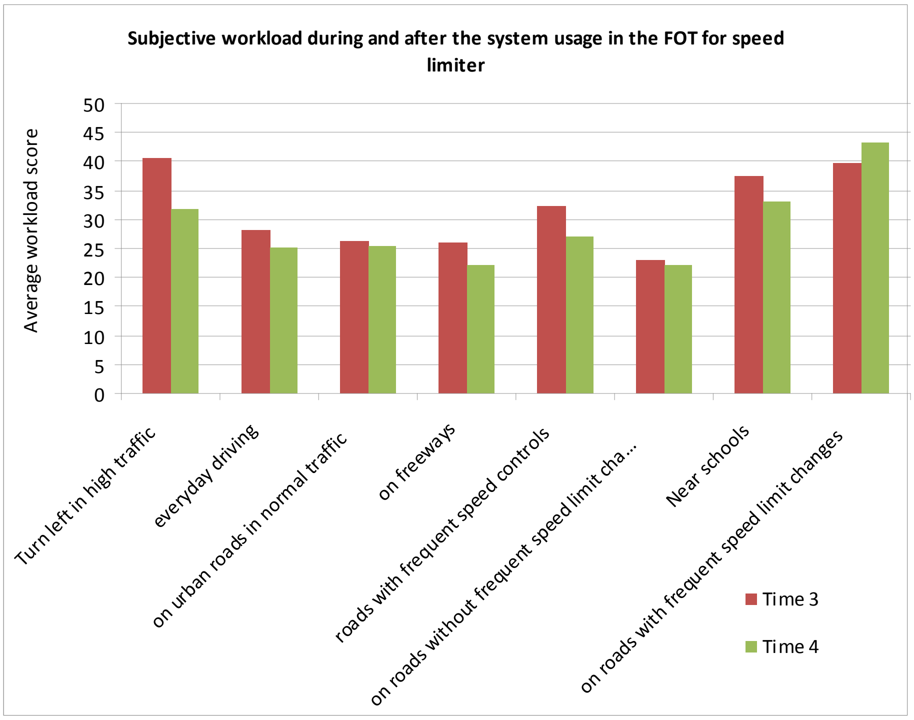


Figure 58: Subjective workload during and after the system usage in the FOT for speed limiter

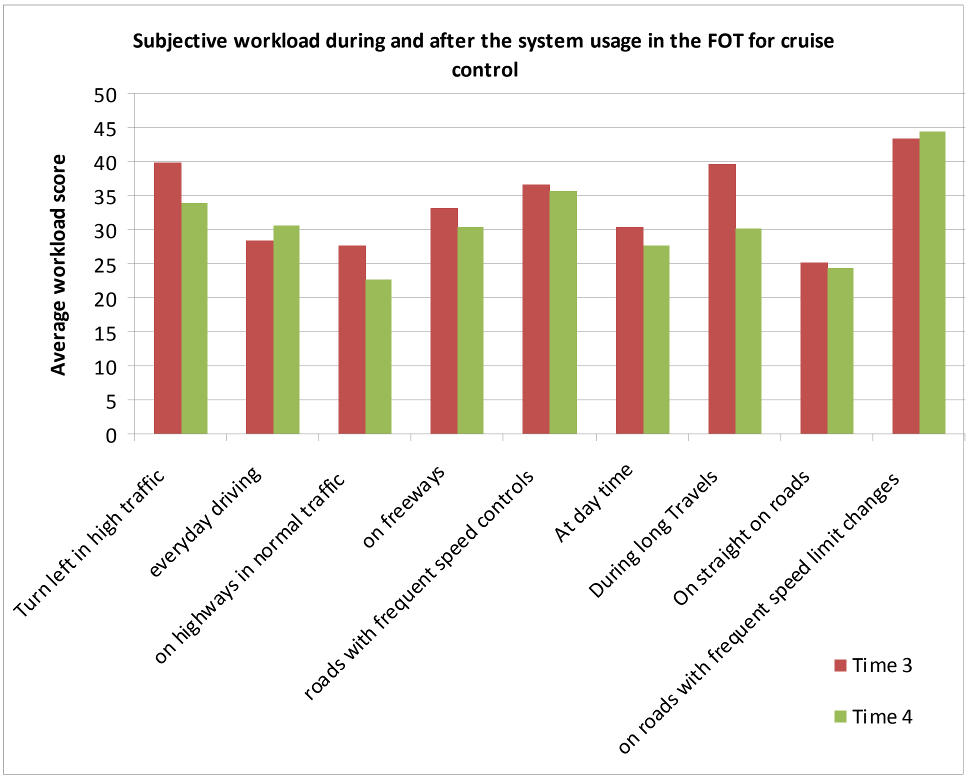


Figure 59: Subjective workload during and after the system usage in the FOT for cruise control

3.3.3.3 User Acceptance

Acceptance

For SL system, drivers have positive expectations at the beginning of the FOT and expectations are confirmed and overall there is no significant change of acceptance over time. The system was judged as necessary, good, assisting the driving and useful.

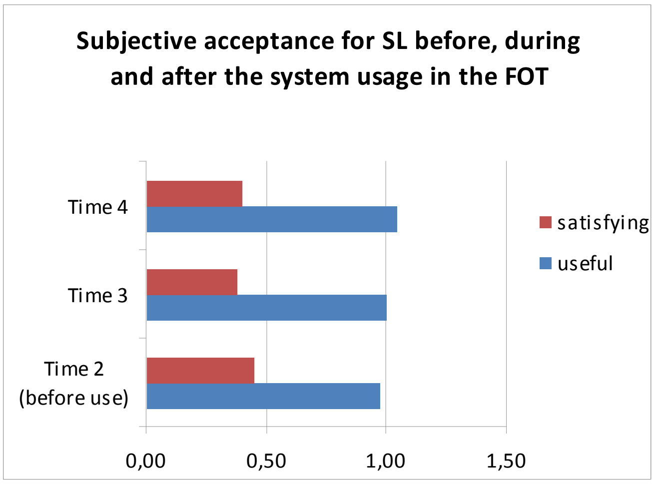


Figure 60: Subjective acceptance for the SL system during the FOT.

For CC system, drivers have positive expectations at the beginning of the FOT and expectations are confirmed. For usefulness, there is a significant change of acceptance between before use and Time 2 but no significantly change between Time 3 and Time 4. The use of the system increases the perceived utility very quickly and it remains the same until the end of the experiment. For satisfaction, there is a significant change of acceptance between before use and Time 2 but no significantly change between Time 3 and Time 4. The system was judged as necessary, good, assisting the driving desirable, pleasant and useful.

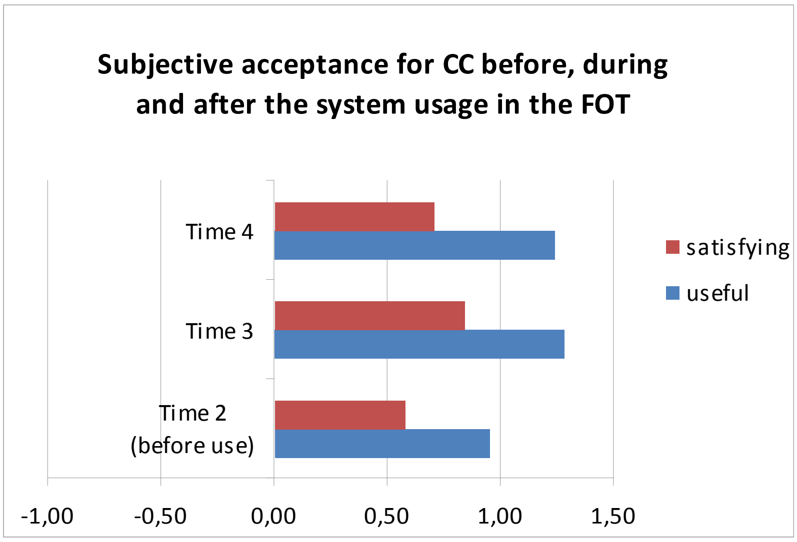


Figure 61: Subjective acceptance for the CC system during the FOT

Trust

For SL system, drivers have positive expectations at the beginning of the FOT and expectations are confirmed and overall there is no significant change in trust over time.

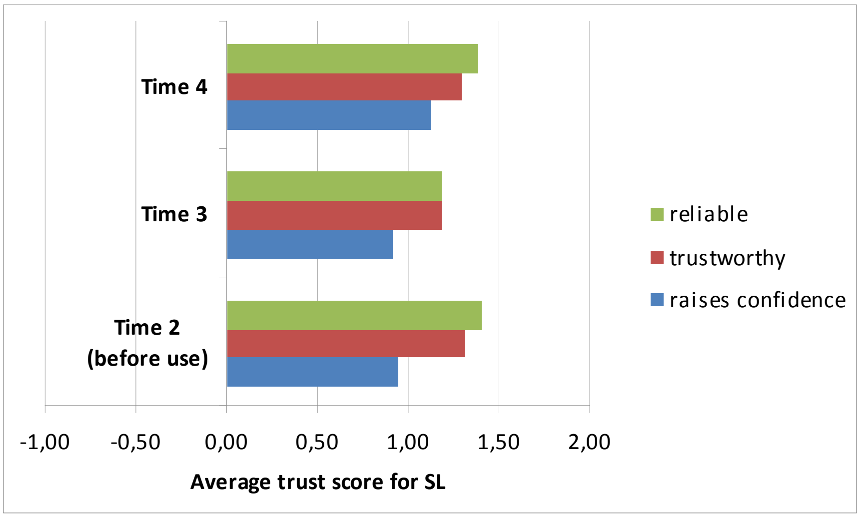


Figure 62: Average trust score for SL

For CC system, drivers have positive expectations at the beginning of the FOT and expectations are confirmed. In terms of reliability and raising confidence, there is no significant change over time. In terms of trust, there is a significant change of acceptance between before use and Time 2 but no significantly change between Time 3 and Time 4.

The use of the system increases the perceived trust very quickly and it remains the same until the end of the experiment.

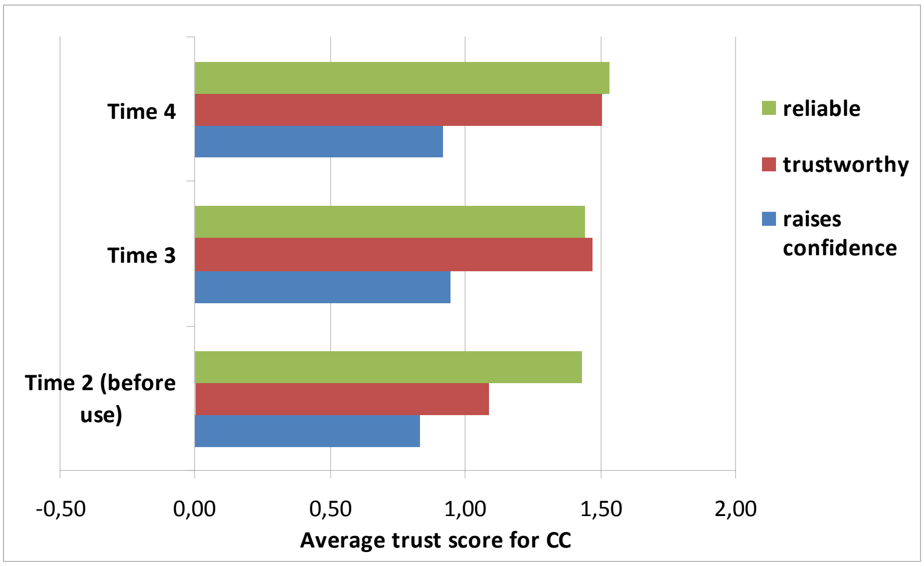


Figure 63: Average trust score for CC

3.3.3.4 Usage

Usability

The facets of usability, which influence positive acceptance, are the fact that the two systems are easy to use, to learn, to remember and to program. The systems are not distracting. The visual information is well located, easy to read and to understand. The visual warning is easy to understand. The steering wheel controls are well located, easy to find and to use. In general the system status was clear and the drivers are comfortable with system.

Table 36: Frequency of items score for positive and negative acceptance for SL and CC systems

	Speed limiter		Cruise control	
Item	**Positive**	**Negative**	**Positive**	**Negative**
Easy to use	88	22	84	25
Easy to learn	85	0	84	0
Easy to remember	85	0	84	0
Few errors	77	11	61	25
Not distracting	81	22	77	0
Easy to recover	69	22	71	0
Easy to program	88	22	77	25
Visual display well located	88	11	77	0
Visual information easy to read	88	11	84	0
Visual warning easy to understand	92	11	87	0
Visual information easy to understand	85	0	87	0
Visual information grabbed attention	73	22	58	0
Steering wheel controls well located	92	11	90	0
On/off controls well located	62	11	68	25
Steering wheel controls easy to find	92	11	84	0
Steering wheel controls easy to use	92	11	87	25

On/off controls easy to find	65	0	74	25
System status clear	81	0	81	25
Comfortable with system	92	22	81	0

The number of drivers with negative acceptance is too low to identify the items which influence acceptance.

Usefulness

The drivers perceived that the CC system is useful on motorways with normal traffic and the SL system on rural road with normal traffic. They think that the both systems increase safety and that the SL can reduce speeding fines.

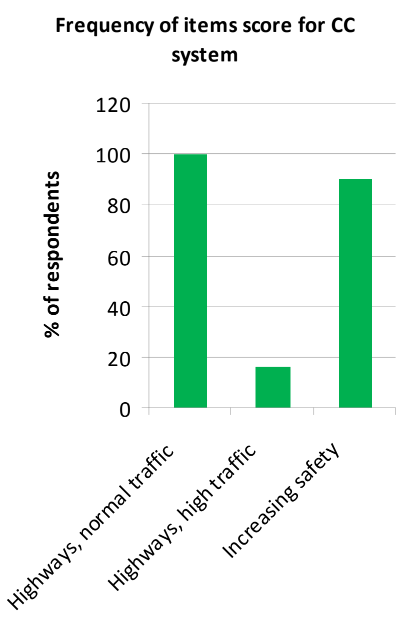


Figure 64: Frequency of items score for CC system

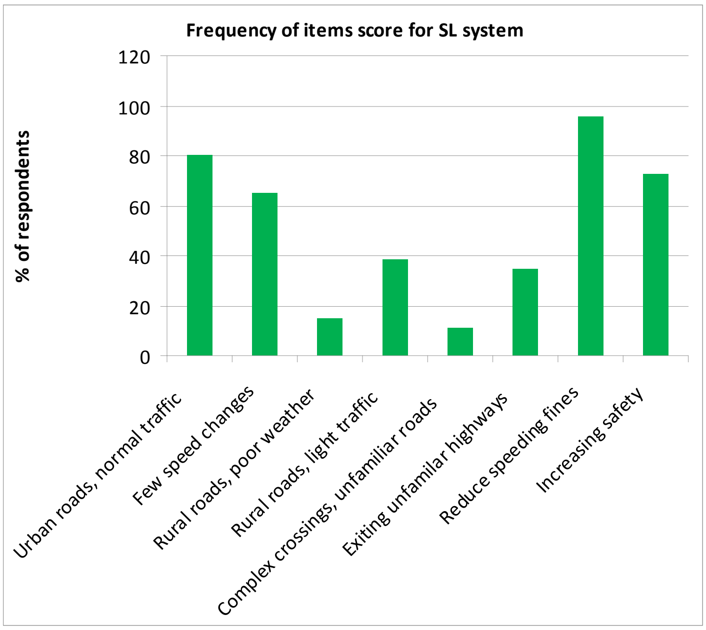


Figure 65: Frequency of items score for SL system

Comfort and pleasure to drive

The SL is perceived as increasing the driver comfort for 46 % of the drivers and the CC for 80 %. For the speed limiter system, this increase is not statistically significant (< 50%) but for the CC, this increase is significant.

The SL is perceived as increasing the pleasure to drive for 35 % of the drivers and the CC for 63 %. For the speed limiter system, this increase is not statistically significant (< 50%) but for the CC, this increase is not significant due to the low number of drivers.

Table 37: Comfort parameters per CC / SL

Item	Speed limiter	Cruise control
Comfort		
decreased comfort significantly	9	6
decreased comfort a little	9	3
no change	25	11
increased comfort slightly	21	40
increased comfort significantly	26	40
Pleasure to drive		
decreased pleasure significantly	15	9
decreased pleasure a little	12	6
no change	38	23
increased pleasure slightly	9	26
increased pleasure significantly	26	34

3.3.3.5 Safety & efficiency

Number of trip and kilometres

Numbers of trips made do not vary significantly over time. The amount of kilometres travelled does not vary significantly over time.

Average speed

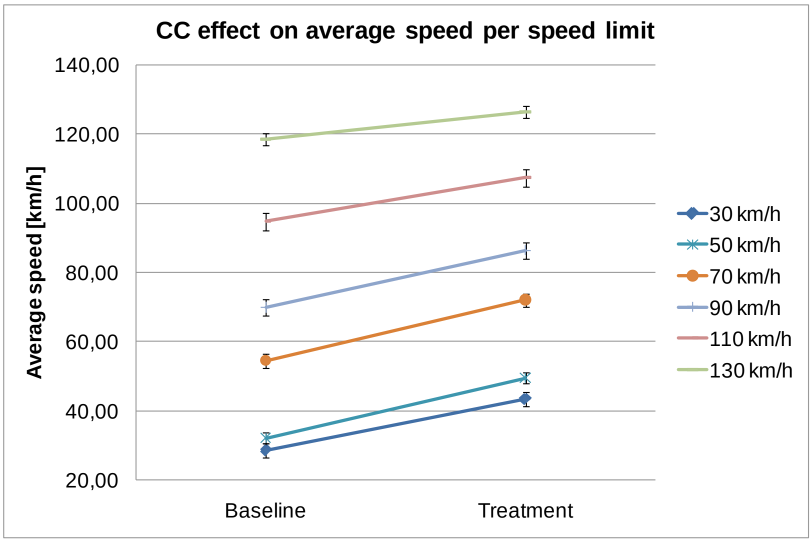


Figure 66: CC effect on average speed per speed limit

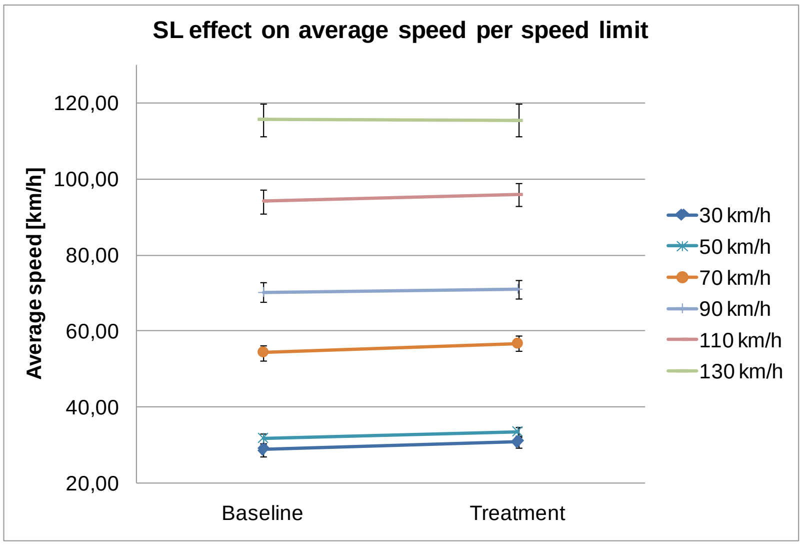


Figure 67: SL effect on average speed per speed limit

SL increases the average speed (differences range between 0.8 to 2.3 km/h) except on motorways (improved compliance with speed limit).

When used, CC increases the average speed for all the situations, with an average speed increase of more than 10km/h.

Exceeding speed limits

The effects of the SL on the over speeding events are higher for high speed limits, with a reduction of up to 50% when using the system.

From 50 to 110km/h speed limit roads the odds of exceeding the speed limit (ratio of the probability that speed limit event will happen to the probability that it will not happen) while using the CC are two to four times the odds of exceeding the speed limit in baseline conditions. The effect of CC increased the probability of exceeding the speed on most roads, but the effect is opposite on motorways (OR=0.77). High speeds like 130km/h seems to be sufficient for a French driver, or the risk of being controlled is estimated to be higher on motorways, leading to a better compliance with the speed limits.

Occurrence of strong jerks

The SL effect is likely to be a positive effect (reduction of the probability of observing a strong jerk event) although small and not significant enough on many conditions.

For CC, results are significant for all road types, showing a clear positive influence of the CC on the probability of observing a strong jerk event while driving. The probability of observing this kind of event is approximately divided by 3 when using the system.

Critical time gap occurrences

On 50 km/h, the SL system multiplies by 1.13 the odds of observing a critical time gap event when driving with the system compared to normal conditions. The same negative impact is observed on 130km/h limited roads, with the odds of observing a critical time gap event when driving with the system compared to normal conditions multiplied by 1.3. Other conditions are not significant.

The ability of the CC to modify critical time gap occurrences probability is significant for all the speed limits. On 50 km/h roads, the CC system multiplies by 0.31 the odds of observing a critical time gap event when driving with the system compared to normal conditions. The same positive impact is observed for all the speed limits, although the effect is less important for high speed limits.

Hard braking occurrences

SL system effect on hard braking occurrences is positive, with people using the system having a reduction of the odds of approximately 30%.

The ability of the CC system to modify hard braking occurrences probability is significant for all roads except 30km/h roads (not enough data for ensuring representativity). CC system effect on hard braking occurrences is positive, with people using the system having a reduction of the odds of approximately 50%.

Incident occurrences

There is no significant difference in the incident rate between baseline and treatment. We looked more precisely at the situations where system is active and adopted an EBA. Incident rate (odds) decrease significantly when driving with SL or CC active. The estimated decrease in incident rate is more important for CC (SL: OR=0,683; CC: OR=0,165).

This last effect may be due to driver's choice to use the system when traffic is free-flowing instead of the system effect itself. This effect is higher for CC usage, leading to an apparently strong positive effect, although not due to the system itself but to driver's choice to use it depending on driving situations.

Fuel consumption

The function CC decreases significantly the average fuel consumption in all driving contexts.

Factor analyses show a similar effect for all the situations, but the decrease is stronger for low speed limits values. This is due to thermal engine fuel consumption which is lower for high speeds until 90km/h. After that boundary, fuel consumption start to increase again with speed. This is in line with the increasing average speed, leading to decreasing fuel consumption.

The decrease for high speed values is very low although significant, and is certainly a consequence of improving stable speed while using CC.

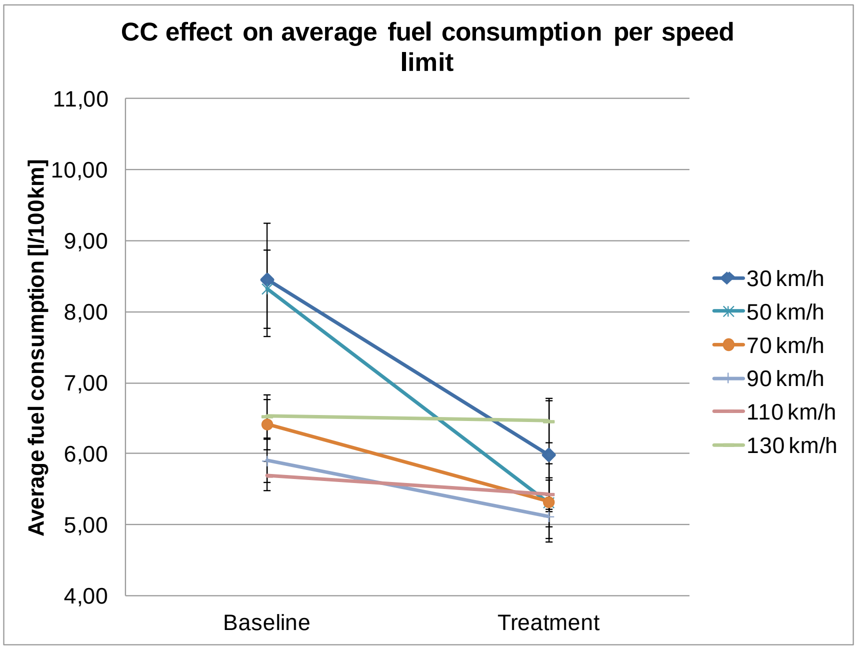


Figure 68: CC effect on average fuel consumption per speed limit

The function SL decreases significantly the average fuel consumption in all driving contexts.

Factor analyses show a similar effect for all the situations, but the decrease is stronger for low speed limits. This is due to thermal engine fuel consumption which is lower for high speeds until 90km/h. After that boundary, fuel consumption start to increase again with speed. The decrease for high speed values is very low although significant, and is certainly a consequence of improving stable speed while using SL.

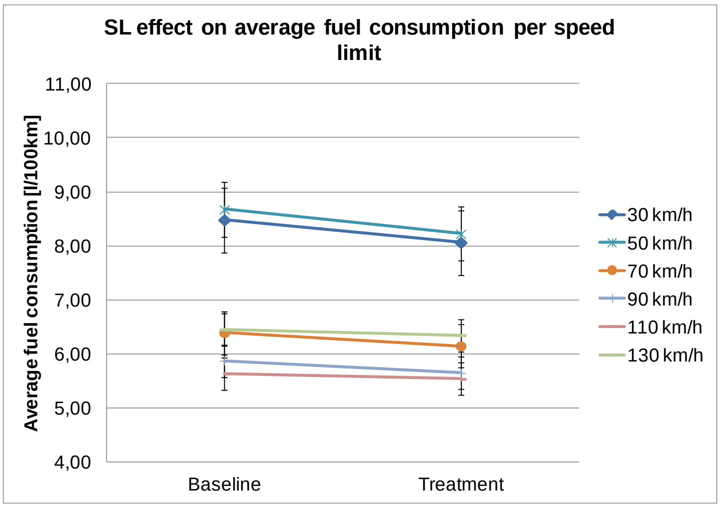


Figure 69: SL effect on average fuel consumption per speed limit

3.3.4 Discussion of results

The French VMC allowed us to study the behaviour of 35 drivers using a system of speed regulation and limitation during 9 months. As expected, the drivers use the cruise control (CC) a lot during free flow conditions and on motorways (40 % and 66 % of the crossed distances). On the other hand the speed limiter (SL) is used a third of the crossed distances on every type of ways (except on motorway: 16 %).

Both systems are less used in curves and the CC is less used where there are intersections. The use of both systems did not change during the experiment. Most of the drivers consider that these systems allow increasing the safety, although both systems do not change the workload, or the number of incidents.

This experiment allowed us to estimate the acceptance of these systems. The a priori acceptance was already very positive and the use of the systems confirmed this tendency. In terms of usefulness, the opinion of the drivers slightly increased for the SL and strongly for the CC whereas the satisfaction slightly decreased for the SL and increased for the CC.

Also, the trust in the system was already positive before its use and during its use, it slightly strengthened for the SL and very strongly for the CC especially in terms of reliability and trust in the system. Both systems were considered very usable by two thirds of the drivers as well in terms of access to visual information, manipulation of the commands and management of the interactions. The only function collecting only half of the positive opinions is the access to on/off button of the system, which is indeed not easily accessible in both vehicle types used for the experiment.

SL

In term of comfort, a third of drivers did not report changes for the SL, half reported an increase and the others a decrease. In terms of pleasure to drive, the proportion of positive change is lower (35 %) and that of negatives is more important (37 %). Overall, the SL does not affect driver behaviour besides speed. But this is not surprising, as the SL intervenes only in order to prevent from exceeding a given speed.

This can lead to inconveniences in certain situations (for example, during insertion on a motorway if the driver forgets to change the speed of the system). The fact that the driver continues to manage the longitudinal control can explain that the influence of the system in term of critical headway, of hard braking and strong jerks is low. On the other hand it allows for considerably reducing the speeding occurrences on freeways and the consumption of fuel, although the average speed slightly increases by 2 km/h.

CC

For the CC, opinions of the drivers are much more positive: 80 % report improved comfort, and 62 % report improved pleasure to drive. This can be explained by the fact that the system allows to unload the driver of a part of the driving task. This automation also has effects in terms of reduction of critical time gaps, strong jerks, and hard braking as well as consumption of fuel although the average speed increases by more than 10 km/h.

The two systems, SL and CC, cannot be active at the same time, and the choice to activate one of them or to change from one system to another largely depends on various parameters of driving conditions that are difficult to control. The previous findings highlight the relationships between systems usage and driving conditions, showing that level of traffic is likely to be an important parameter. Although the congestion level cannot be precisely estimated for the euroFOT data, there are sufficient clues to make the following hypotheses:

- SL is used on all speed limits, but mainly when the likelihood of being caught by a speed enforcement camera is high (road with low speed limits or low congestion level).
- CC is used in high speed roads under free flow conditions that allow to speed without deteriorating too much the safety (drivers use the system to speed, but when it is possible to do so).

The increasing speed observed both when SL or CC were active would lead to a negative impact on safety. But this conclusion does not take into account the fact that SRS usage is stronger for free flow conditions associated with a high safety level.

This kind of behaviour is quite frequent for longitudinal assistance systems: Due to a higher safety level for the use cases of cruise control (or adaptive cruise control), drivers tend to drive faster to maintain constant their own acceptable risk level. It is likely that higher risks due to increased average speed may be compensated for by the absence of congestion, and the ability of the driver to concentrate on other driving tasks. Then, the impact of the average speed increase on the safety cannot be quantified without taking into account the traffic level.

3.4 BLIS

In euroFOT, the impact of Blind Spot Information System (BLIS) on driving was investigated. The results of the FOT on BLIS can be summarised as follows:

- Overall usability and acceptance scores for BLIS are very high (over 90 % positive ratings), and this rating does not change over time.
- Approximately 80 % of drivers feel that BLIS increases safety.
- BLIS is perceived as most useful on urban roads in heavy traffic
- BLIS does not increase workload.

3.4.1 Data used for analysis

Drivers experienced two conditions; 1) driving without the system for about 4 months (baseline condition) and 2) driving with the system available for use during approximately 8 months (treatment condition). While subjective data (i.e. questionnaire responses) are available for the full duration, due to delays in the collection of objective data, the objective data analysis is based on 3 months of baseline and 3 months of treatment.

In total 197 drivers participated in the FOT for BLIS, of which the principal 102 drivers have answered the subjective questionnaire data. Table 13 shows the number of drivers for which complete sets of objective and subjective data was available for the analysis of this particular system.

Table 38: Number of drivers with complete data sets available for the data analysis

Number of drivers questionnaire data	58 - 73
Number of drivers with 6 months of objective data	58 - 73

Table 38 gives an overview over the number of kilometres and hours of driving on which the analysis for BLIS is based. The number of respondents varied between the questions.

Table 39: Description of objective data used for the analysis

	Baseline	Treatment
Mileage overall [km]	347774	492976
Mileage motorway [km]	89028	119003
Mileage rural [km]	87157	111496
Mileage urban [km]	116555	160420

3.4.2 Research questions

Like for all other systems, the focus of the analysis in on usage and acceptance of the system, along with its subjectively experienced impact on driving.

As the evaluated version of BLIS is camera based, and hence at times prone to indicate that there is a vehicle in the blind spot even though there is none, the influence of this behaviour on usage and acceptance is of particular interest. Principally, the question is how drivers relate to a system that reliably indicates when there is a vehicle in the blind spot, but which also gives additional false indications of vehicle presence in the blind spot.

3.4.3 Results

Below are the results of the hypothesis testing on user related aspects. To facilitate reading, not all results are presented. Rather, short summaries are provided for each area, along with some specific examples of interesting data. For a more thorough analysis of each hypothesis, please refer to the Annex.

3.4.3.1 Trust

Confidence in the system is very high which means that the drivers really do trust the system to accurately indicate when there really is a car in the “dead zone”. Reliability and trustworthiness on the other hand were rated low, which is a consequence of the false positives that BLIS sometimes issue, i.e. because the system is camera based and because object identification in image processing in a difficult task, BLIS sometimes reacts to objects other than vehicles which appear in the viewing angle covering the blind spot.

3.4.3.2 Driver Behaviour

In terms of how BLIS influences driver behaviour, 24% of the drivers reported that they occasionally rely on BLIS rather than using visual checks when doing lane changes. 3 % said they did so frequently.

From the objective data how BLIS influences the use of turn indicators was analysed. Usage was expected to decrease, since it can be expected that if the driver has confidence in the system and the system does not indicate any vehicle in the adjacent lane, one can change lanes without using the turn indicator. This analysis of the objective data supported this hypothesis, i.e. there was a 10 % decrease in turn indicator use prior to lane changes when BLIS was in use. Note that to eliminate confounding effects from the LDW system, this analysis was done only on driving during which the LDW system was inactive.

3.4.3.3 Workload

Participants indicated very low effort while driving with the BLIS system in everyday driving and when driving on motorways in normal traffic.

3.4.3.4 User Acceptance

User acceptance is evaluated in accordance with the Van der Laan scale (see chapter 3.1.3.3). Its results are displayed in the figure below:

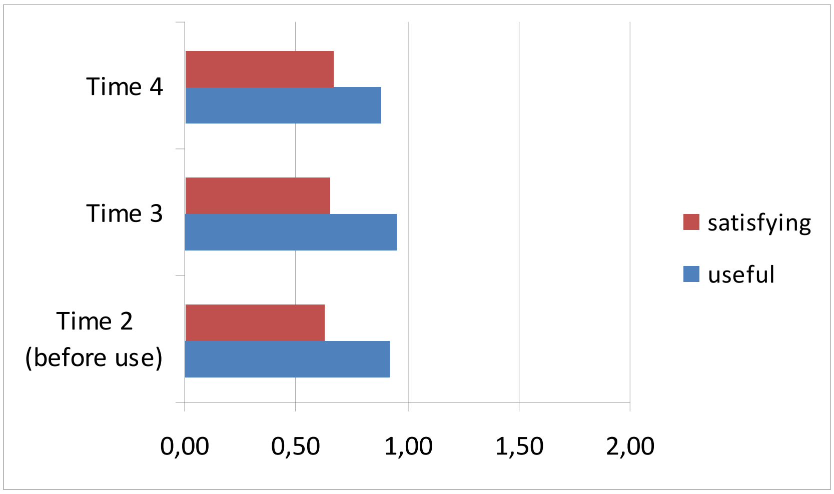


Figure 70: User acceptance, broken down into Usefulness and Satisfaction.

Acceptance, in terms of usefulness and satisfaction is positive at all times and does not change during use of the system. The rating of usefulness is quite high while the satisfaction is lower which could be explained by the fact that the system sometimes gives false positive warnings.

Perceived usefulness was further analysed for the drivers that scored positively on acceptance. These drivers were asked to specify during which driving configuration they found the system most useful.

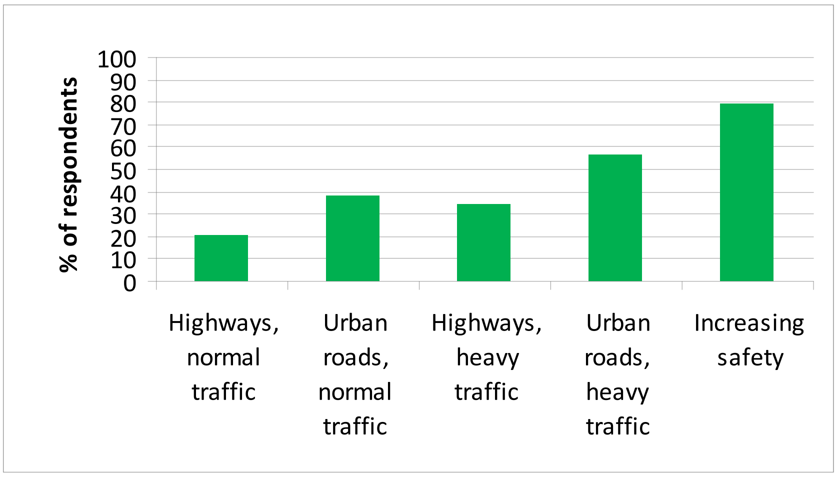


Figure 71: Rating of usefulness by drivers with positive acceptance.

80 % of the drivers perceived increased safety and almost 60% of the drivers found it most useful on urban roads.

To evaluate how certain features of usability influence acceptance, participants were separated into two groups, negative and positive. A "negative" participant is one whose average acceptability score is negative. A positive participant is one whose average acceptability score is positive.

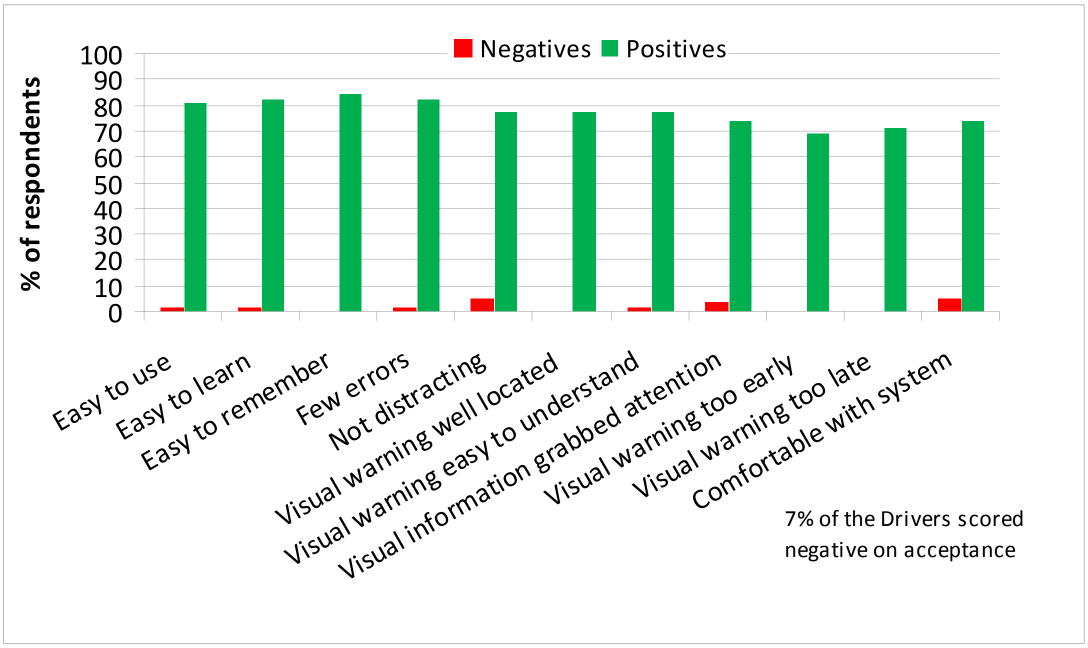


Figure 72: System acceptance

The diagram above shows how certain usability items influence the acceptance of the system. The red bars show where the “negative” drivers rated the system negative. Conversely, the green bars show where the positive rated the system positive.

In general the green bars, which represent the number of positive drivers for each usability item, are very high for all items. The 7 % drivers that scored negative on acceptance did not feel comfortable with the system and experienced the system as distracting.

3.4.3.5 Usage

10 % of the participants believe they have changed user practises over time with system use. The majority of these drivers have increased the usage of the system.

3.4.3.6 Safety & efficiency

Approximately 80 % of drivers feel that BLIS increases safety.

3.4.4 Discussion of results

BLIS gets very good feedback from the drivers who have evaluated the system. The majority of drivers only gave positive responses on all the questionnaire items related to BLIS. Furthermore, acceptance does not change over time, i.e. it stays high with continued use of the system, which indicates that drivers continue to perceive it as useful as they experience interacting with it over an increasingly wide variety of conditions.

BLIS does not increase workload with scores remaining low throughout the treatment phase. This is not very surprising, as the interface is highly intuitive and simple (light indicators are situated on A-pillars; light on means vehicle in blind spot).

From the free text comments, it is clear that many view BLIS as an important complement to visual checks, rather than as a primary source of information. This probably relates to the fact that the system at times gives false positives, i.e. it lights up its indicator even when there is no vehicle in the blind spot.

Drivers seem well aware of this performance limitation in the system, i.e. they score the system low on items related to reliability and trust. Furthermore, while a few drivers stated that they substitute visual checks with BLIS information, a closer reading shows that this is not unconditionally done. Rather they over time seem to learn where and when the BLIS indications are highly accurate, and that's where they feel comfortable relying on BLIS only.

Thus, interestingly, drivers are overall very pleased with a system that gives false positives on a more or less regular basis. This goes to show that as long as the core functionality of the system is perceived as useful, drivers seem willing to learn where the limitations are and/or "forgive" the systems for this type of imperfections. However, it is not known whether this finding can be generalized to other systems.

3.5 LDW (Objective Data)

The results of the FOT on LDW can be summarised the following:

- Participants find the LDW system useful but the satisfaction with the system is low.
- There is no difference in the satisfaction rating before and after use, which indicates that the expectations were low already before drivers started to use LDW.
- Average trust in LDW changes significantly decrease over time, i.e. drivers expected more of the system than it could fulfil.
- Most drivers found LDW very easy to use but many also found the warning irritating and commented on the warning timing.

3.5.1 Data used for analysis

In euroFOT, the impact of Lane Departure Warning (LDW) was investigated. Drivers experienced two conditions; 1) driving without the system for several months (baseline condition) and 2) driving with the system available for use during approximately the remaining months (treatment condition). While subjective data (i.e. questionnaire responses) are available for the full duration, due to delays in the collection of objective data, the objective data analysis is based on 3 months of baseline and 3 months of treatment.

Table below shows the number of drivers for which objective and subjective data is available for the analysis of the LDW.

Table 40: Number of drivers available for the data analysis

Number of drivers questionnaire data	58-66
Number of drivers with 6 months of objective data	58-66

Table below gives an overview over the number of kilometres of driving on which the analysis for LDW is based. The number of respondents varied for the different questions.

Table 41: Description of objective data used for the analysis

	Baseline	Treatment
Mileage overall [km]	347774	492976
Mileage motorway [km]	89028	119003
Mileage rural [km]	87157	111496
Mileage urban [km]	116555	160420

3.5.2 Research questions

Like for all other systems, the focus of the analysis in on usage and acceptance of the system, along with its subjectively experienced impact on driving.

In addition, of particular interest when it comes to LDW is what drivers think of the warnings LDW gives. In comparison to FCW, the coupling between warning and potential threat is much less direct, and the system is not capable of assessing the surrounding traffic state. Hence drivers may perceive some warnings as more of a nuisance rather than as relevant safety information.

3.5.3 Results

Below are the results of the hypothesis testing on user related aspects. To facilitate reading, not all results are presented. Rather, short summaries are provided for each area, along with some specific examples of interesting data. For a more thorough analysis of each hypothesis, refer to the Annex.

3.5.3.1 Trust

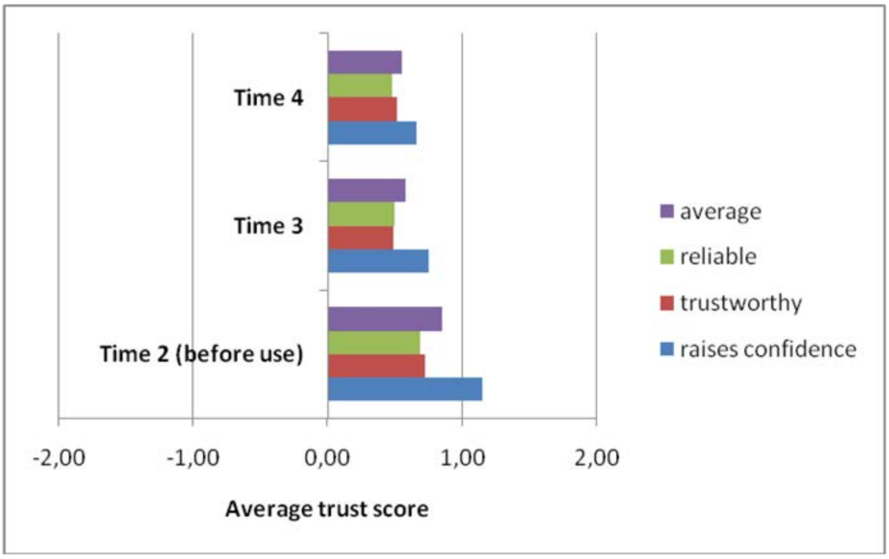


Figure 73: Subjective trust (sub-scales reliable, trustworthy and raises confidence) before, during and after the system usage in the FOT.

Average trust in the LDW system changed significantly over time. This is mainly based on ratings of confidence in the system which clearly decreases when the system is used compared to expectations the drivers had before use. The results show that the driver had much higher trust in the LDW system than it could fulfil when used.

3.5.3.2 Driver Behaviour

Some driving behaviours that can be considered as related to driving with LDW were analysed in terms how frequently they are occurring. The number in parentheses is the frequency of participants that answered that they engage in this particular driver behaviour quite often or frequently.

- Used the turn indicator to turn off the system without checking the lane (7 %).
- Rely on LDW to indicate drifting out of lane when performing other tasks (e.g. eating, changing radio) (6 %).
- Made unnecessary lane changes (5 %).
- Take hands away from the steering wheel while driving with LDW (1 %).
- Drove unsafely to test the system (0 %).

In terms of objective data analysis, there were some indicators that pointed toward an increase in safety when drivers use LDW+IW[2]. The mean steering wheel angle was somewhat reduced and the use of turn indicators increased, both of which indicate improved lateral control.

3.5.3.3 Workload

Drivers experience very little effort in everyday driving with the LDW system. Effort increases when driving at night time and when driving while drowsy but is still only rated as “some effort” by the drivers when rated in accordance with the RSME Mental Workload Scale. There are no significant changes in experienced workload over time of system use.

3.5.3.4 User Acceptance

User acceptance is evaluated in accordance with the Van der Laan scale, as described in chapter 3.1.3.3. Results are displayed in the figure below.

[2] Note that in the analysis of the objective data, LDW was bundled with IW rather than treated as a separate function. This was because the targeted crashes are inseparable in the crash data bases, and also because actual system usage during the FOT overlapped to 97 %. Hence the results presented here are valid for IW as well.

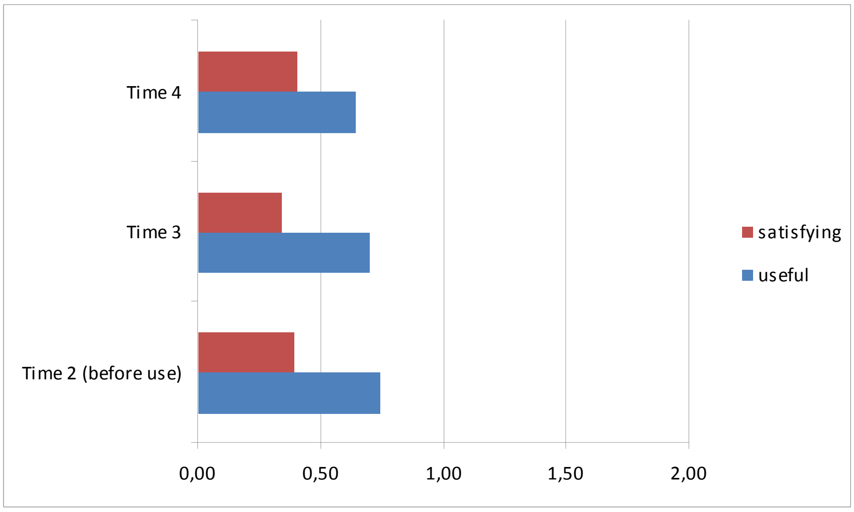


Figure 74: Usefulness under different driving conditions, rated by drivers with positive acceptance.

Drivers overall found LDW useful but satisfaction of the system is very low. There is very little difference in rating before and after use, which indicates that the expectations, especially in terms of satisfaction, was low already before the system was in use. Exposure to the system gives no significant changes of the usefulness and satisfaction scores.

Perceived usefulness was further analysed for the drivers that scored positively on acceptance. These drivers were asked to specify during which driving conditions they found the system most useful.

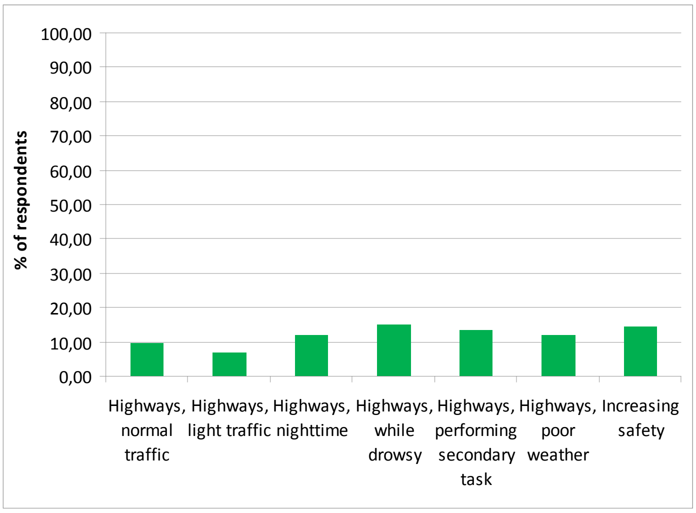


Figure 75: Usefulness under different driving conditions, rated by drivers with positive acceptance.

Overall, the participants rate the usefulness very low under all driving conditions on motorways that were included in the questionnaire. Approximately 10 % of the drivers find the LDW useful on motorway driving regardless of other conditions.

It was also analysed how certain features of usability under the concept of ease of use, influence on the acceptance. 70-80 % of the drivers found the system very easy to use but many drivers found the warning system irritating and had also comments on the timing of the warnings.

3.5.3.5 Usage

The majority of the drivers did not use the LDW system differently at the end of the FOT from the way they did when they first started using the system. It can be stated that user practices of the LDW system didn't change significantly over time during the FOT.

3.5.3.6 Safety & efficiency

For both cars and trucks, the likelihood of experiencing a lateral crash relevant event also decreased when drivers used LDW+IW. However, that decrease was not statistically significant, mainly because the number of annotated events in the end judged relevant for LDW+IW was small. Crash relevant events and near crashes are truly rare events. For cars, over 1200 potential conflicts were video reviewed, and from this dataset, only 133 were judged to be truly relevant events, and hence retained for the analysis. For trucks, over 1000 potential conflicts were selected. From this dataset, only 19 conflicts were judged to be truly relevant lateral conflict events, and hence retained for the analysis.

We also investigated possible negative safety effects of LDW+IW in terms of secondary task engagement and attention to the forward roadway. Results showed some interesting effects. For cars, during normal driving, the likelihood of the driver using a nomadic device almost tripled when using LDW+IW. However, during crash relevant events, no such difference was found. This indicates that drivers are capable of adjusting nomadic device usage to situations where safety is not compromised. This line of reasoning is supported by the fact that there was no difference in visual attention to the forward roadway during critical events in baseline and treatment. For trucks, no side effects were observed. For more details on these topics, the reader is referred to D6.4.

3.5.4 Discussion of results

It is clear that while most participants find LDW useful, they also indicate low levels of satisfaction with the system. That fact is also reflected among the additional items in the questionnaire in which the participants perceive the system as effective and intuitive but not attractive to buy.

This lack of satisfaction seems attributable to the weak coupling that exists between a warning from LDW and potential situational risk. For most drivers, drifting out of lane is only a problem when there are objects and/or places nearby that warrant avoidance (oncoming vehicles, ditches, etc). If no such objects are present or places near, then a leaving lane warning seems unnecessary, even though it is technically correct.

This highlights the need for future LDW systems to be capable of a more sophisticated traffic environment assessment in order to determine when a warning will be perceived as relevant by the driver. Of course, one could also envision a closer coupling to driver state assessments as well (e.g. drowsy drivers might appreciate a lane departure warning even if there is no apparent threat nearby). Regardless of which approach is selected, some method for bringing warning timing closer to perceived relevance in the driver is likely necessary.

3.6 LDW (Subjective data)

The test was carried out collecting subjective data only; the main aspects about acceptance, trust and perceived safety were investigated by questionnaires and the self-reported answers about the perceived impact of the system. According to the particular experimental design, descriptive statistic and derived aggregated values were considered very important for the interpretation of results according to research questions and hypotheses. Moreover inferential statistics were used to test trends and change of perception during test period.

Some of the most important results from Italian test site are briefly listed below.

The majority of the sample found the LDW system effective in increasing the driving and road safety and this perception is stable over time. In particular users perceived the system useful for avoiding dangerous situations and helpful in case of falling asleep at the wheel. The overall driving performance seems not to be affected by the usage of LDW system, but it seems to impact on drivers' ability to keep within the lane. Also users' perceptions of the usage of turn indicators seem to be affected by LDW, as users recognize a positive effect of the system on this behaviour.

The acceptability of the LDW system is high for all the considered features. Drivers found the system very to be useful and satisfying. The acceptance is stable over time. Users also report positive perception for other investigated aspects in relation to users' acceptance such as perceived quality or user-friendliness.

According to results, the LDW usage seems to be perceived as more useful during night and while driving on motorways. In particular drivers indicate an adequate functioning of the system as regards its help in avoiding dangerous situations. Only a low percentage of the drivers experienced situations in which they did not trust the LDW and also misuses of the system seem to be quite rare, except for behaviours performed to test the system (i.e. make unnecessary lane changes).

Several aspects seem to impact on system usability as the ease of use, the ease of learning, the ease of remembrance and the perceived system comfort. Three considered features, level of confidence, trustworthy and reliability of the LDW system are high and stable at all the time points.

Users' workload is higher in some specific driving conditions as driving in poor weather conditions or driving while drowsy. No relevantly different trends (for the LDW and Control groups) emerged during the test period.

3.6.1 Data used for analysis

For the Italian VMC only subjective data are available from questionnaires (see chapter 2).

3.6.2 Research questions

The investigated research questions and hypotheses concern subjective users' related aspects of the function impact. The users' perception about these aspects has been assessed. Driver behaviour, users' workload, acceptance, usability and safety are the areas of impact of the function.

In particular, users' perception of the impact of the LDW on safety (i.e. LDW impact on lateral incidents and chance of accidents and the impact on lateral driving performance) has been investigated. The other areas of interest of the impact of the LDW concern subjective aspects as workload, trust or perceived system usability. Relevant analyses concern users' acceptance of system and the change of this perception during the test.

3.6.3 Results

3.6.3.1 Driver Behaviour

At the end of the test (T4) about 20% of the drivers reported that their travel patterns changed since driving with the LDW. More than 30% of the respondents reported to use always the LDW, while about 30% of them use it more frequently during the night. The perceived usefulness of the system while driving on motorways is the most important features of the LDW system influencing its acceptability.

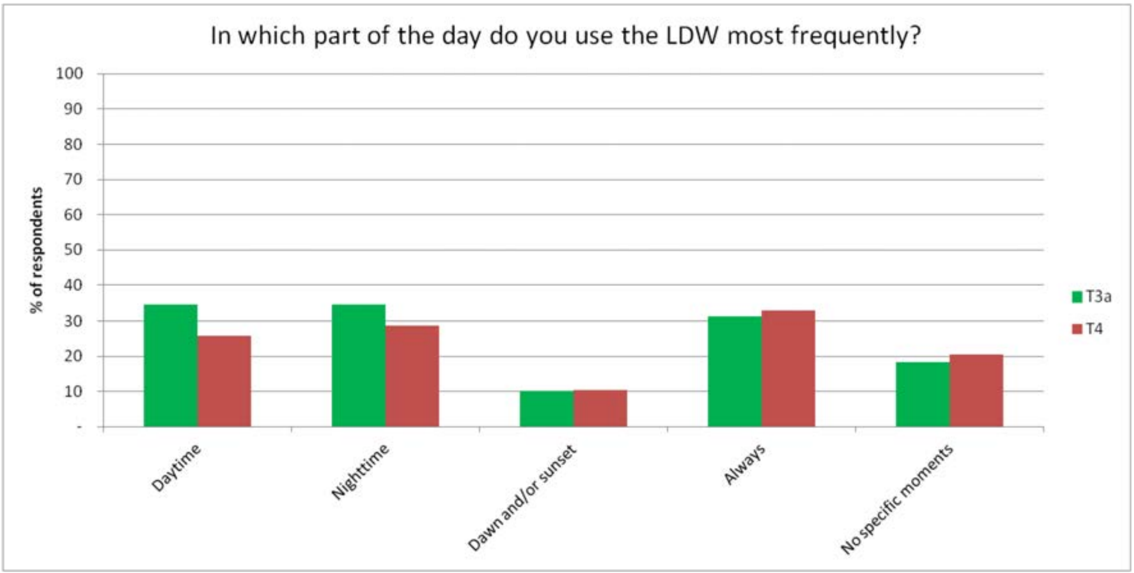


Figure 76: Responses to item "In which part of the day do you use the LDW most frequently?" (%; multiple answers were possible)

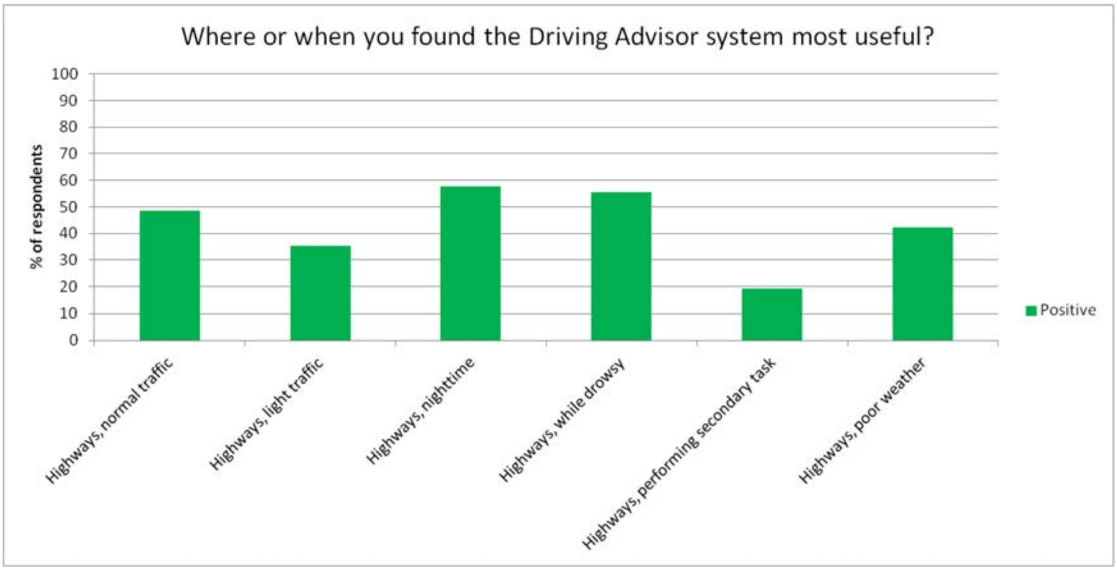


Figure 77: Responses to item "Where or when you found the LDW system most useful?" (%; multiple answers were possible)

The driver evaluations indicate an adequate functioning of the system as regards its help in avoiding Dangerous situations. LDW influence on the driver ability does not change over time. Only a low percentage of the drivers experimented situations in which they did not trust the LDW. About 20% of the drivers from the LDW group at the end of the test had changed the way they use the system. With respect to LDW system misuse, none of the studied behaviours was enacted frequently. The most frequent behaviour is "making unnecessary lane changes" and taking hands off steering wheel". Probably these behaviours are done in order to test the system. The less frequent is "relying on LDW to perform secondary tasks".

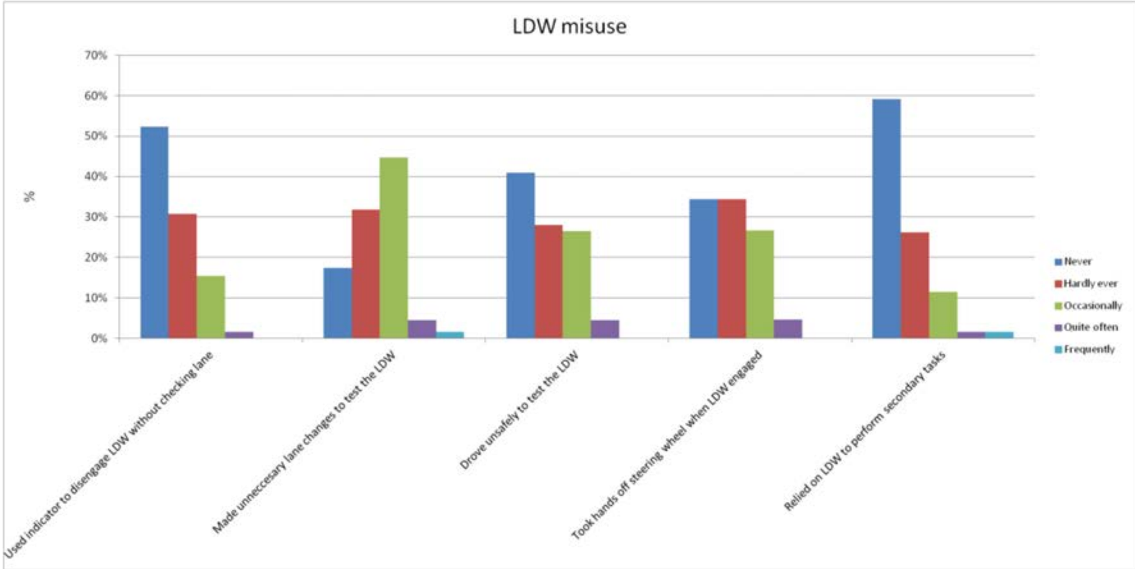


Figure 78: Percentage of answers to the items regarding the misuse of the LDW system at T4.

With respect to obstruction caused by the system we found out that a minority of the sample thinks that the LDW can encumbers or obstruct the driver in some driving situations. This percentage (about 30%) does not vary over time.

3.6.3.2 Workload

The perceived mental workload by test participants from LDW and control group was quite similar for all the considered situations. No different trends (for the LDW and control groups) emerged.

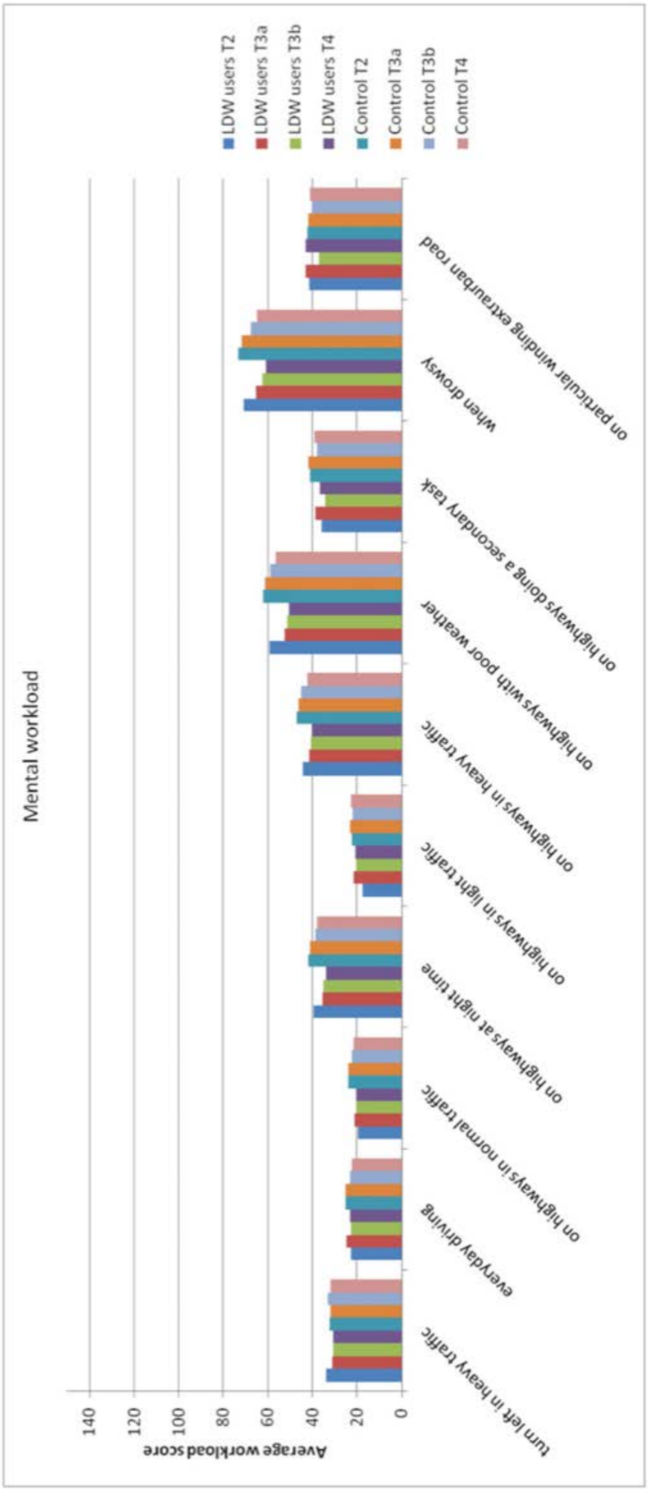


Figure 79: Perceived mental workload in different situations from T2 to T4, in LDW and Control group

3.6.3.3 User Acceptance

The acceptability of the LDW system is high for all the considered features. Drivers found the system very useful and satisfying. This perception does not significantly vary over time. Drivers also reported a positive perception for all the other investigated aspects. The more appealing are the user friendliness, the ease of use ("simple"), the "good quality" and the "reliability", while they have a less positive attitude towards the "attraction to buy", the request by others to use the system and the confidence improvement.

The activation is perceived as adequate by the most part of the sample (about 90%) and this perception is stable over time. With respect to the minimum functioning speed of the system, a large part of the sample (69%) found it to be appropriate. The functioning of the LDW system is not perceived as annoying by the drivers. This perception is stable over time.

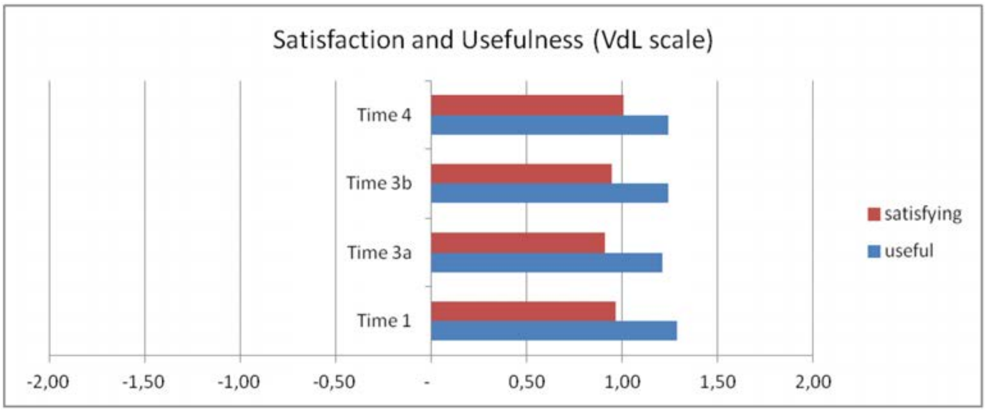


Figure 80: Van der Laan scale – Satisfaction and Usefulness scores from T1 to T4

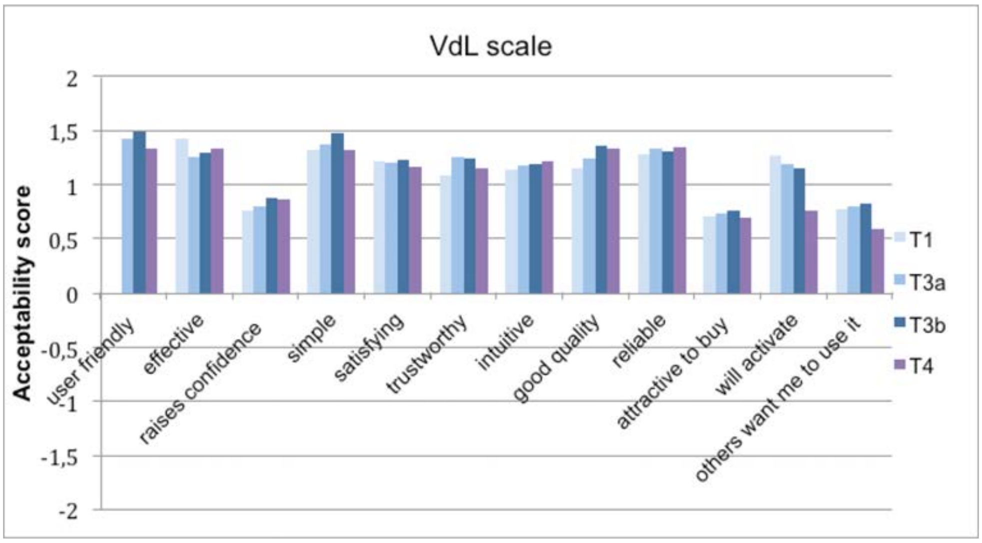


Figure 81: Van der Laan scale - Average acceptability scores from T1 to T4

The most important features of the LDW system influencing acceptability are the perceived usefulness of the system while driving on motorways: in normal traffic, at night time, while drowsy and with poor weather. The less relevant feature is the usefulness perceived driving on motorways performing secondary tasks. With respect to the functioning of the LDW system when drivers are tired, as expected respondents from the experimental group reported that the system warnings increased in those situations. This perception did not change over time. As regards possible problems experienced with the LDW system, drivers reported that they did not find the LDW reporting useless information frequently. This perception of well-functioning was stable over time.

3.6.3.4 Usage

All the investigated features of "Ease of use" seem to positively contribute to the positive perception of the LDW system both in terms of usefulness and satisfaction. There are no relevant differences among the features. About LDW distracting impact on other driving activities, there is a significant difference between perception at Time 3a, Time 3b and Time 4. The system is perceived as less impacting on other driving activities at the end of the test period.

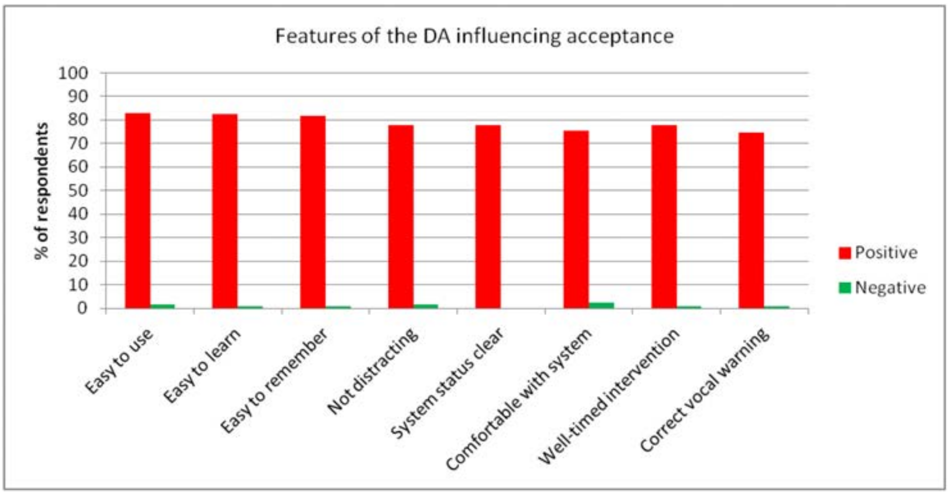


Figure 82: Features of the LDW influencing acceptance of the system (NB: about the last item "Correct vocal warning". LDW system at Italian test site does not provide vocal warning. Acoustic warnings are provided in case of hands-off or automatic system deactivation)

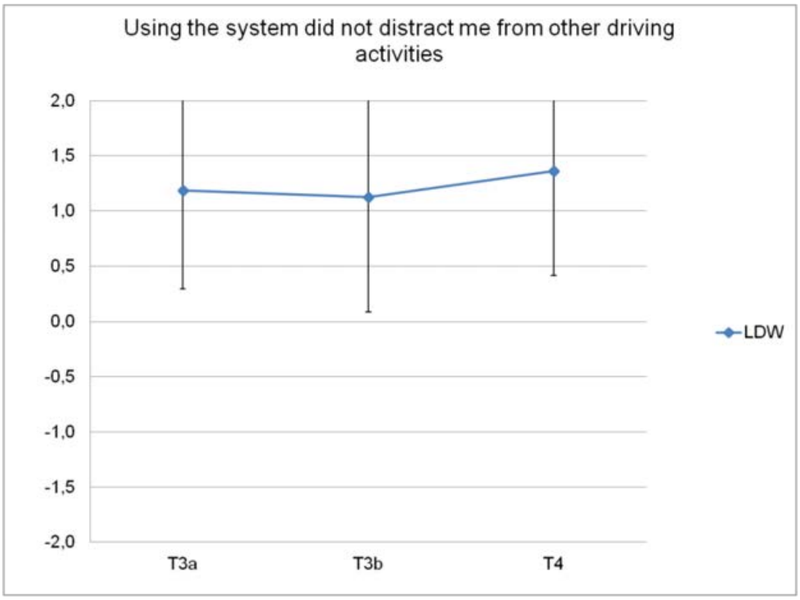


Figure 83: Agreement with the item “Using the system did not distract me from other driving activities” (M and SD)

As the perceptions of three considered features (Raises confidence, Trustworthy, Reliable) of the LDW system are high and stable at all the time points. The “confidence raising” has the lower level, while reliability and trustworthiness have higher levels.

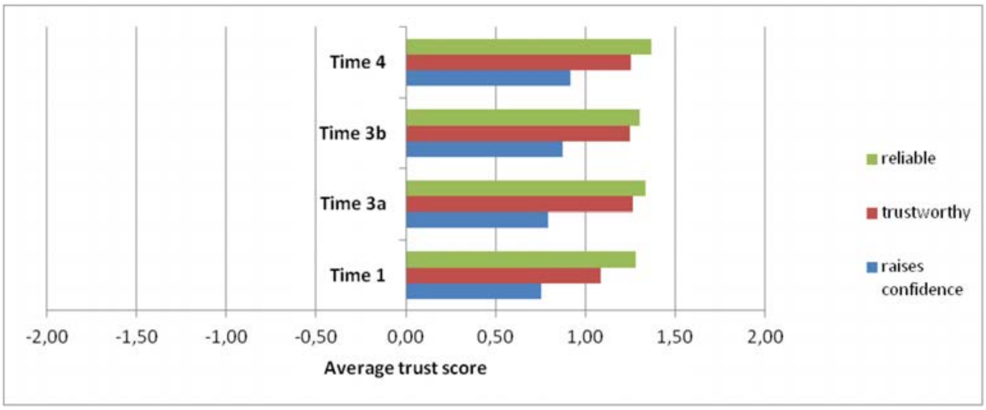


Figure 84: Reliability, trustworthiness, and confidence raise levels from T1 to T4

The level of effectiveness perceived by drivers as regards the LDW is quite high and it did not change from the start to the end of the test. The activation of the system is perceived as adequate by the most part of the sample (about 90%) and this perception is stable over time.

3.6.3.5 Safety & efficiency

The driver evaluations indicate an adequate functioning of the system as regards its help in avoiding Dangerous situations. LDW influence on the driver ability does not change over time. The LDW system does avoid situations that could lead to accidents for a part of the sample and this perception is stable over time. During the experiment, only very few lateral accidents happened.

The biggest part of the sample (more than 90%) found the LDW system effective in increasing the driving safety and this perception is stable over time. Even as regard the perception of road safety, most of the drivers (more than 80% at Time 4) found the LDW system able to improve it significantly. Also this perception is stable over time. As regards distraction, about 90% of the drivers found the LDW helpful in case of distraction and this percentage does not change significantly over time. The LDW system has been perceived as helpful in case of falling asleep at the wheel by the most part of the drivers (94% at Time 3a, 88% at Time 4).

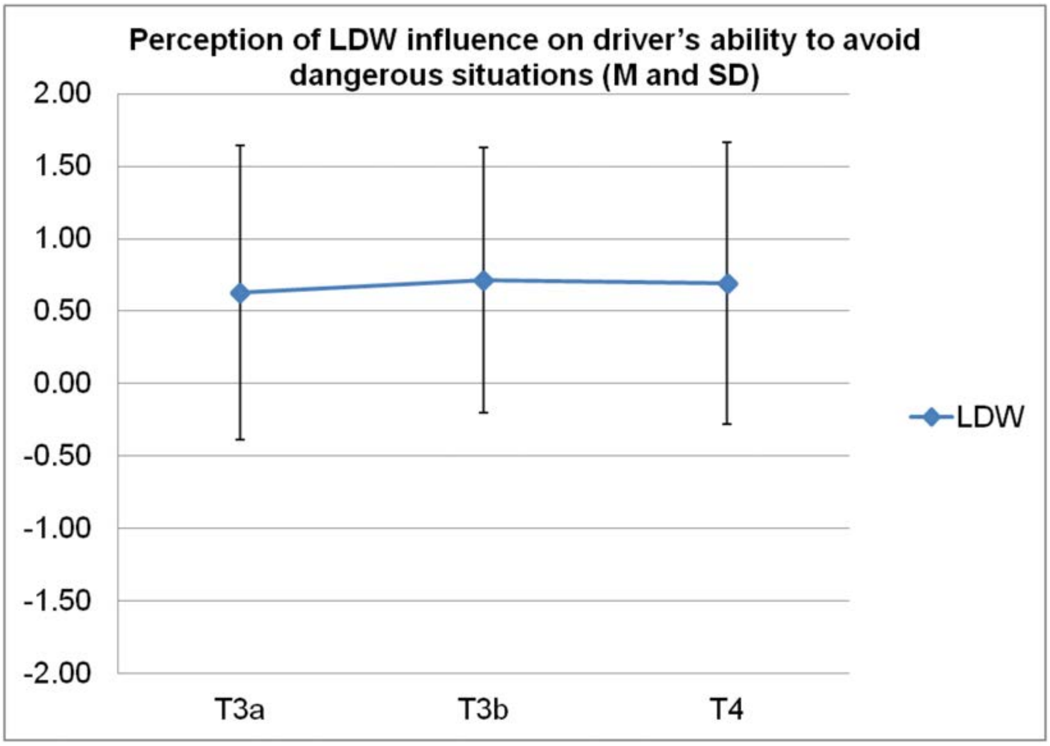


Figure 85: Subjective perception of LDW influence on driver's ability to avoid dangerous situations

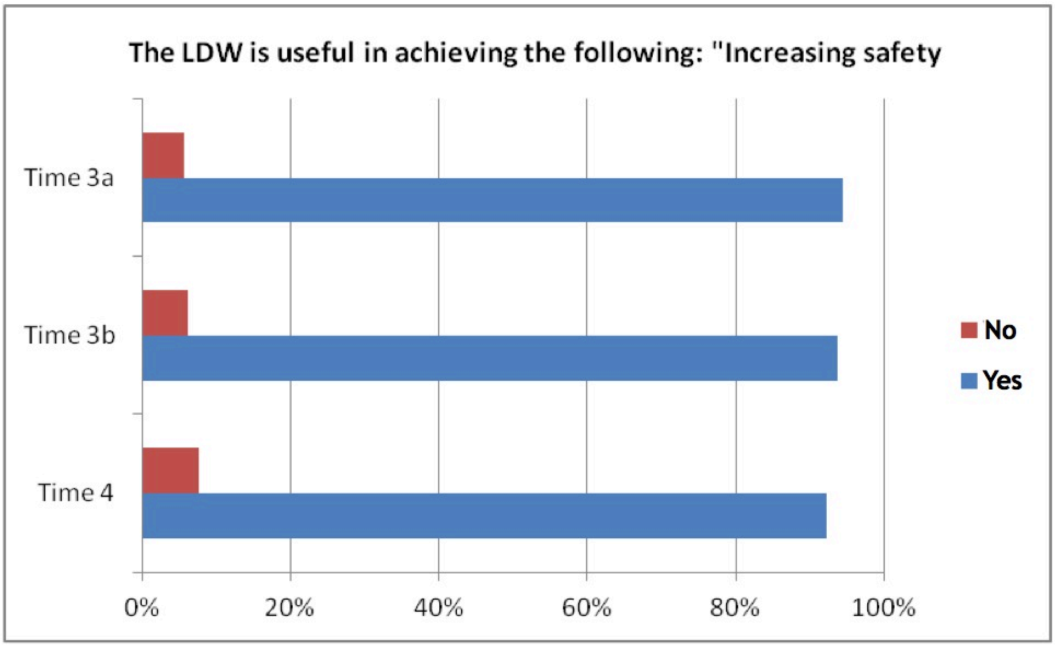


Figure 86: Subjective perception of LDW ability to avoid situations that could lead to accidents

Drivers report that the system positively affected both their ability to keep within the lane and to control the vehicle and these perceptions do not change over time. As regards the overall driving position within the lane, it does not seem that the LDW influences it, even comparing the LDW with the control group.

The driving performance seems not to be significantly affected by the use of LDW system. Both experimental and control groups report improved driving performance during the experimentation time, and that performance improved over time (for both groups).

As regards driving near to the right/left side of the lane, both LDW and control group report a low frequency of this behaviour. This behaviour is slightly more frequent in the LDW group, but it does not change over time, for both the groups.

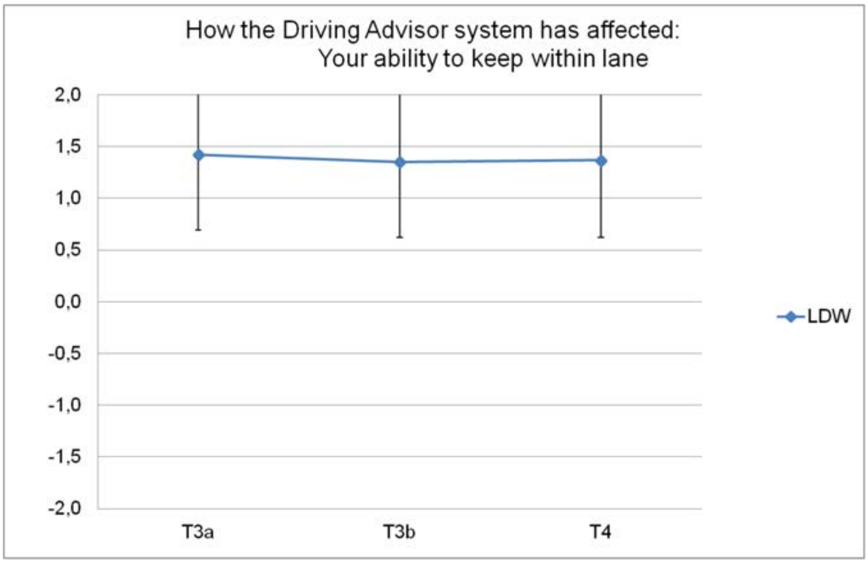


Figure 87: Responses to item "How the system has affected your ability to keep within lane?"

Regarding system effects, data analyses showed that regarding the usage of turn indicators (with the LDW switched on) respondents recognized a positive effect of the LDW on this behaviour and this influence significantly increased over time $F(2.230)=5.24$ $p= 0.006$.

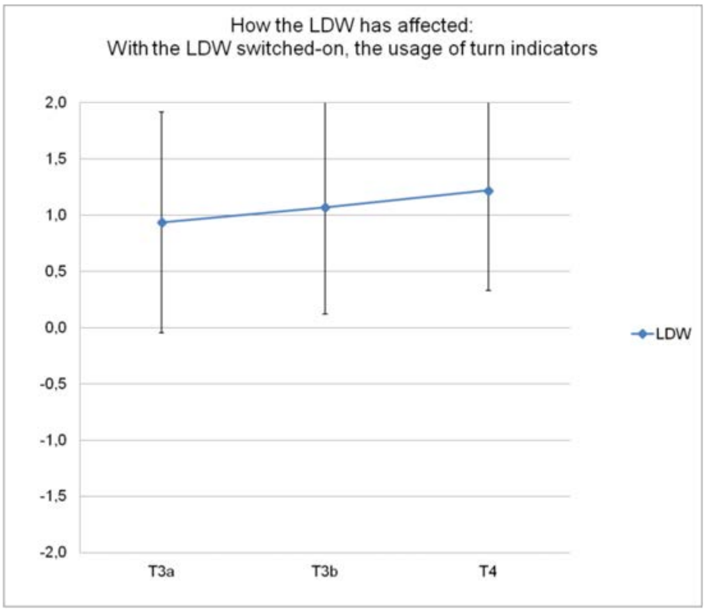


Figure 88: Responses to item "How the system has affected, with the LDW SWITCHED-ON, the usage of turn indicators?"

3.6.4 Discussion of results

Drivers involved in Italian test site of euroFOT project report positive perceptions of the main users' related aspects investigated in the test about LDW system impact. In particular users perceived a good impact of the system on the overall road safety and also on their behaviour of turn indicator activation. The system seems to be well accepted as users recognised the LDW as useful and satisfying. LDW is useful in order to avoid dangerous situations and also driving in critical conditions such as when driver is tired or when there is a high risk to fall asleep at the wheel or at night. According to test results the system seems not to affect drivers' workload in driving conditions. That seems to fit the research expectations as the system provides warning just in specific situational conditions recognized as risky for driver safety. Drivers report some occurrences of system misuses and abuse but they seem to be quite rare. They performed some tests in order to assess their confidence with system usage and intervention. Users report very rare occurrences in which the system is misused in order to improve performances of secondary tasks while driving with potential impact on safety.

3.7 CSW

The results of the FOT on CSW can be summarised as follows:

- Overall usability and acceptance scores for CSW are high.
- Approximately 75% of drivers feels that CSW increases safety
- CSW is perceived as most useful on rural roads.

3.7.1 Data used for analysis

The data used for CSW analysis is depicted in Chapter 2, section 2.2 “CSW data”.

3.7.2 Research questions

Research Questions for CSW are basically focused on usage and acceptance.

3.7.3 Results

In the case of CSW, no hypotheses were selected for some group of results (e.g., driver behaviour or workload). The following subchapters include a summary on the results, being the complete list of analysed hypothesis on the Annex.

3.7.3.1 Trust

Average trust scores in the CSW system are all positive (reliable, trustworthy and raises confidence). Drivers trusted more in the system after the system usage in the FOT. For trustworthy and reliable differences are statistically significant.

3.7.3.2 User Acceptance

User acceptance is evaluated according the Van der Laan scale as described on chapter 3.1.3.3. Results are displayed on the figure below.

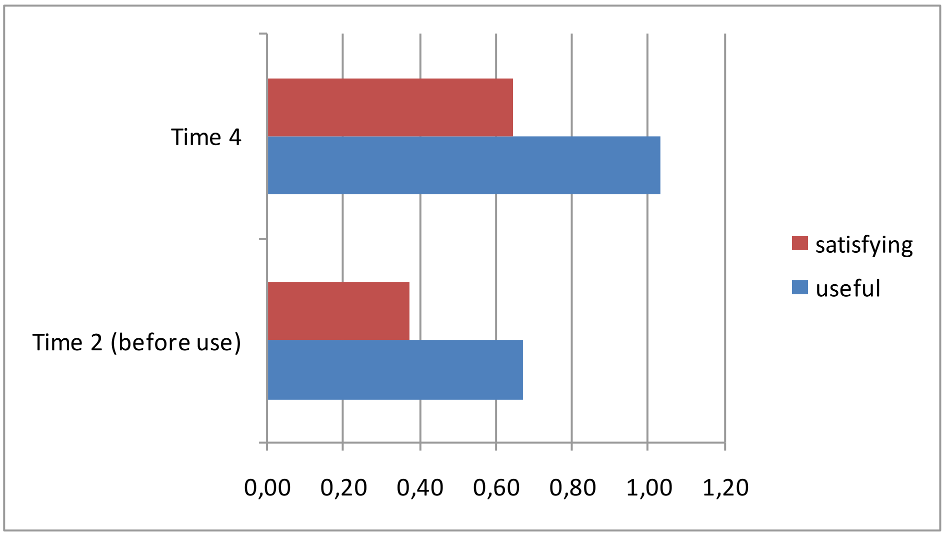


Figure 89: Acceptance rating in terms of usefulness and satisfaction.

Acceptance level of the CSW systems is high. It was observed that values for satisfying and useful categories increase from Time 2 to Time 4. Both differences are statistically significant.

Perceived usefulness was further analysed for the drivers that scored positively on acceptance. These drivers were asked to specific during which driving conditions they found the system most useful.

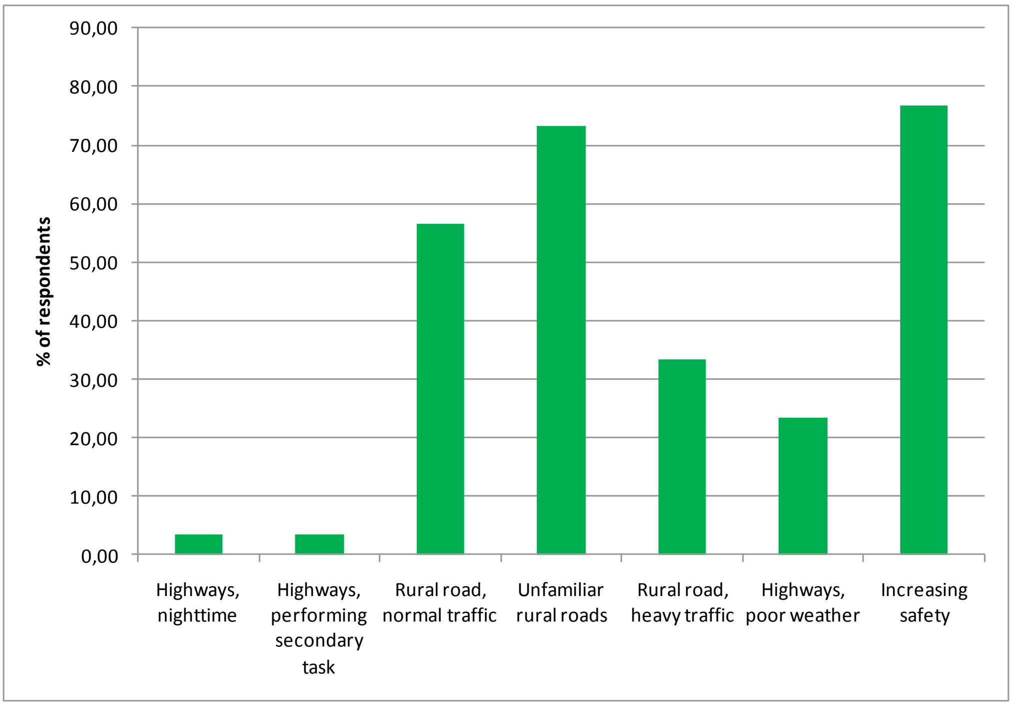


Figure 90: Usefulness of CSW according to interviewed drivers

75% of the drivers felt that the system increased driving safety. Moreover, they found CSW is most useful in rural road driving, mainly in unfamiliar rural roads and in normal traffic conditions.

It was also analysed how certain features of usability under the concept of ease of use, influence on the acceptance. In general the drivers found the visual information is easy to read, easy to understand and grabbed their attention.

3.7.3.3 Usage

Around a quarter or the sample who tried CSW answered that they have changed their usage of the system during the time using the system within FOT. A couple of drivers expressed that they used it as indicator or for practising more defensive driving.

3.7.4 Discussion of results

Altogether, CSW is a system where driver's expectations were fulfilled, i.e. the scores on satisfaction and usefulness gave before gaining access to the systems matched those given during and after the trial.

In terms of usage, it seems that drivers make most use of the CSW on rural roads.

3.8 Navigation System

The results of the FOT on navigation system can be summarised the following:

- Navigation systems are used in about 40% of driving time. Usage is higher on unfamiliar and long trips.
- The built-in navigation system is evaluated more positively than the mobile device. This difference in subjective evaluation is reflected in system usage.
- When driving with a navigation system activated, driving behaviour is safer.
- While driving with a navigation system activated, travel time is significantly reduced.
- Depending on the routing algorithm used by the system, there is also the potential to reduce travel distance and fuel consumption by using a navigation system.
- Navigation systems do not reduce the time spent in congestion.
- Handling of navigation systems occurs more often in low demanding situations.
- Handling of navigation systems leads to a decrease of speed and to an increase of distance to the lead vehicle. There is no indication that handling of navigation systems is related to an increase of safety critical situation.

3.8.1 Data used for analysis

For analysing the impact of navigation systems on driving, data collected in the German 2 VMC has been used (see chapter 2).

3.8.2 Research questions

As for all other systems, usage and acceptance of the systems as well as their impact on driving is the focus of the analysis. Since the aim of a navigation system is to support the driver in choosing a short and fast route, the main focus is on the impact of navigation systems on efficiency and environment. Besides that, also the impact on driving safety is investigated.

Especially for usage and acceptance of the system, the influence of the HMI-solution (built-in vs. mobile navigation system) is of interest. Furthermore, two areas of interest were investigated which are specific for navigation systems:

- Handling of the navigation system: in the literature experiments report a negative impact of the handling of a navigation system (e.g. entering destination) on driving performance and safety. To evaluate the overall impact of navigation systems on driving, the impact of system handling has to be taken into account. Therefore, three hypotheses are directly related to assessing the handling of a navigation system and its influence on driving in detail.
- Influence of navigation systems on driving at intersections: Regarding changes of driving behaviour or driving style, the main influence of navigation systems is expected on or directly prior to intersections. Therefore, for some hypotheses parameters describing driving behaviour at intersections are analysed.

3.8.3 Results

The following results have been extracted from the analysis of the Navigation System data.

3.8.3.1 Workload

Drivers report that subjective workload on intersections is lower when driving with a navigation system. For the built-in navigation systems, there is a significant decrease of load on different types of intersections on unfamiliar roads. With the mobile device, the decrease of workload is only significant for complex intersections on unfamiliar roads. For both systems there is no systematic change of subjective workload over time.

3.8.3.2 Driver behaviour

Regarding driver behaviour, the focus of the analysis is on driving behaviour at intersections and the impact of the handling of the navigation systems on driving.

Several indicators describing driving behaviour while turning at intersections are analysed.

- In urban areas there is a tendency for both left and right turns that drivers use the indicator more often while turning if the navigation system is activated.
- In urban areas, drivers are faster during turning manoeuvres while driving with the built-in navigation system. There is also a tendency for higher speeds when driving with the mobile device.
- In urban areas, the proportion of time driving very slowly while approaching an intersection is lower when driving with a navigation system.

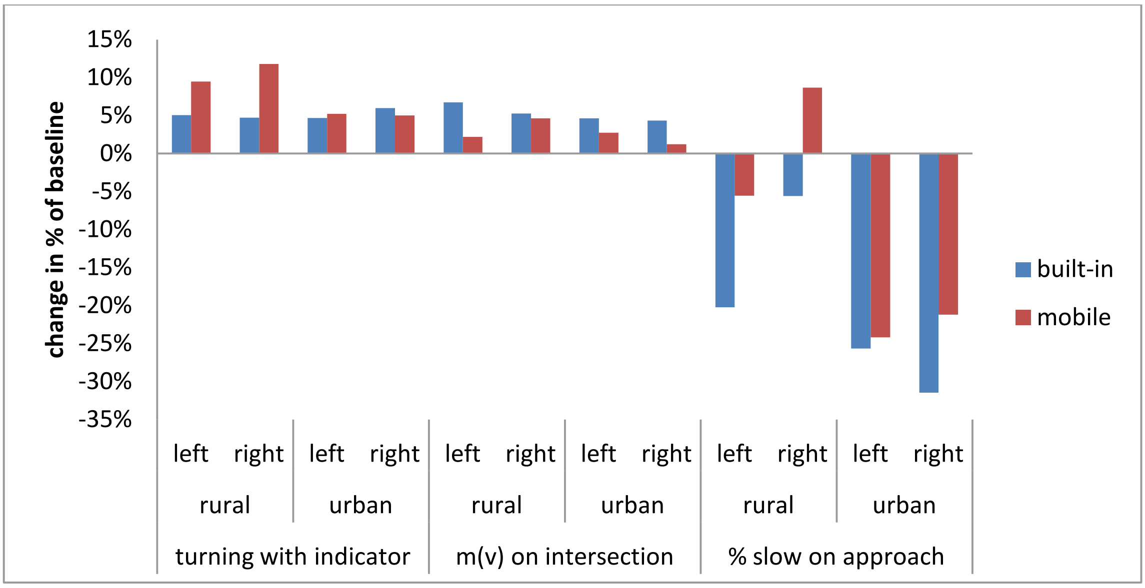


Figure 91: Change in percent of baseline values for different parameters describing driving while turning at intersections.

To analyse the handling of navigation systems, single system inputs are merged into longer periods of system handling as soon as the timely distance between two system inputs is below five seconds. All analyses relate to system handlings that endure for at least five seconds.

First, it is tested whether low demanding driving situations are preferred for handling of the navigation system. Handling of navigation systems is preferred in standstill and at speeds below 10 km/h. On motorways and rural roads, handling of a navigation system is avoided. The only difference between the two HMI-solutions can be found on urban roads: Here, handling of a navigation system is avoided for the mobile device and preferred for the built-in navigation system.

In a next step, the influence of system handling on driving is investigated. To do so, the driving during system handling is compared to the driving behaviour directly before starting the system handling and directly after ending the system handling. To evaluate the impact of system handling on driving, parameters directly related to driving safety (e.g. proportion of time with critical time-head-way) and parameters describing changes in overall driving behaviour are used. The later parameters are useful to evaluate whether drivers compensate the distraction through system handling by adapting their driving behaviour appropriately. The following parameters are used:

- Descriptive:
  - Change in speed
  - Mean time-head-way
  - Standard deviation of lane position (sdlp)
- Related to safety:
  - Proportion of time with critical time-head-way (< 0.5 seconds)
  - Proportion of time with critical time-to-collision (< 1.75 seconds)
  - Proportion of time with critical time-to-line-crossing (< 1.0 seconds)
  - Frequency of lane exceedences

Table below gives an overview of the results for the impact of system handling on driving.

Table 42: Summary of results regarding the impact of system handling on driving

		Built-in			Mobile		
		Motorway	Rural	Urban	Motorway	Rural	Urban
Descriptive	v		<<	<<		<<	
	THW		>	>>		>	>>
	sdlp				>>		>>
Safety	Crit. THW	<<			<<		
	Crit. TTC	<<		<<	<<		<<
	Crit. TLC	<<					
	Lane exceed.						

>> indicates a significant increase (p<0.05), > a tendency for an increase (p<0.1), << indicates a significant decrease (p<0.05), < a tendency for a decrease (p<1). Green symbolizes a positive change of driving behaviour, red symbolizes a negative change. Empty cells show that there was no statistically significant effect.

Results indicate that drivers compensate during system handling by decreasing speed and by increasing the distance to the lead vehicle. Compensatory behaviour can be found on urban and rural roads as well as for both HMI-solutions. For none of the safety related parameters an increase of safety critical situations can be found. On urban roads and on motorways, system handling is even related to a decrease of very small distances to the lead vehicle for both HMI-solutions.

That the handling of the mobile device is more demanding can be seen in the descriptive parameter for lane keeping performance. Here, a significant increase of sdlp and that is a significant impairment of lane keeping can be found. This is in-line with the subjective evaluation of the usability of the mobile device. For both HMI-solutions, there is no increase of critical lane keeping events. Therefore, handling of both HMI-solutions does not lead to an increase of safety critical events.

3.8.3.3 User acceptance & usability

On nearly all questionnaire items assessing the subjective evaluation of the navigation system, a significant preference can be found for the built-in navigation system compared to the mobile device. Drivers report a more positive evaluation of the built in navigation system regarding:

- Its usefulness in system relevant situations (e.g. driving on unfamiliar routes),
- Its learnability
- Its usability (input to the system as well as system outputs)
- Its impact on driving comfort

The difference in subjective usability between the two HMI-solutions does probably influence the reported misuse. The behaviours considered as misuse are more complex types of system input that might be safety critical while driving For both considered types behaviour (‘surfing maps while driving’ and ‘entering destination while driving’) drivers state that they do at least occasionally engage in that type of behaviour for the built-in navigation system but not for the mobile device.

A more detailed analysis of items relating to subjective acceptance and trust shows that before testing the system, expectation on both HMI-solutions is positive. For the built-in device, the expectation is fulfilled and the evaluation of the system does not systematically change over time. For the mobile device, the positive expectation is not fulfilled by the system and subjective evaluation gets more negative over time.

3.8.3.4 Usage

The reported change of subjective acceptance and trust over time is reflected in objectively measured usage of the system. The mobile device is used for a lower proportion of total driving time in the second half of the FOT condition compared to the first half. For the built-in device there is no change of objective usage over time.

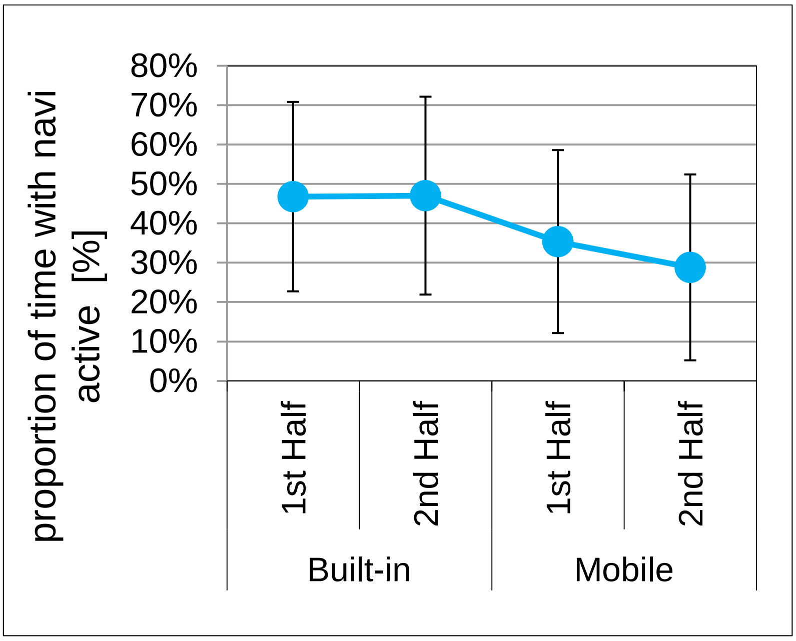


Figure 92: Proportion of driving time with activated navigation system.

Further analysis of objective system usage shows that the usage of a navigation system depends on the familiarity of a trip and trip length. The navigation system is activated more often on long and on unfamiliar trips. The mobile device is used less often than the built-in device especially in situations where overall system usage is less likely (short trips, unfamiliar trips).

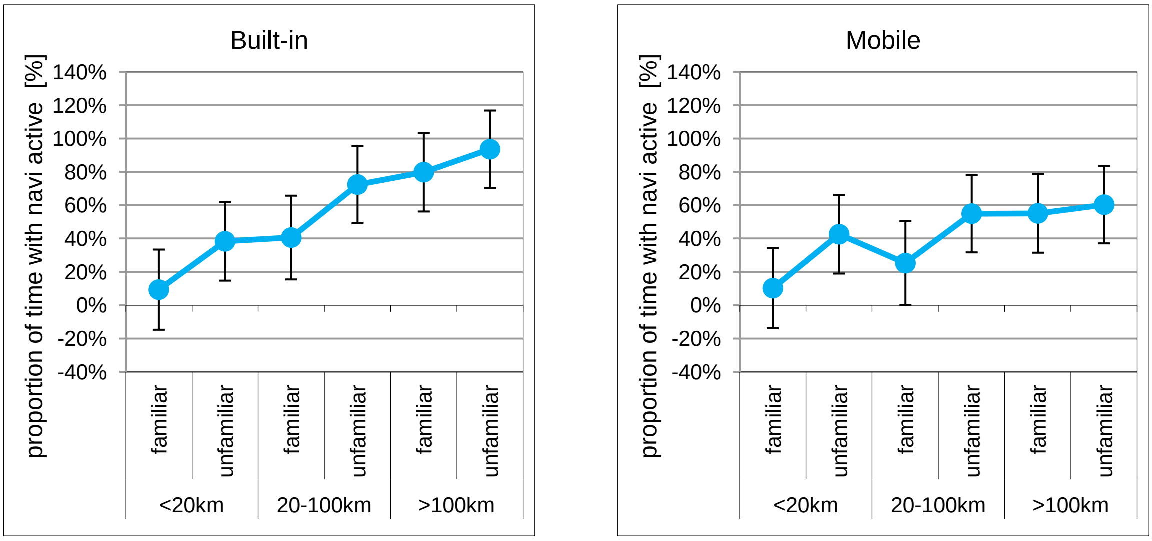


Figure 93: Proportion of trips with active navigation system separate for familiarity of route and trip length.

In the questionnaires, drivers indicate that they do not only use a navigation system because of its routing function but also to know about and if possible to avoid traffic jams and to estimate the arrival time.

3.8.3.5 Safety & efficiency

For both HMI-solutions, a decrease of safety critical events can be found in urban areas while driving with the navigation system active. For the built-in navigation system, this effect is more global and is based on parameters related to distance to the lead vehicle, to lane keeping performance and to adaptation of speed. For the mobile device, there is only a decrease of critical distances to the lead vehicle while driving with the system active. A more detailed description and discussion of the results related to driving safety can be found in D6.4.

Since the main goal of a navigation system is to support the driver to choose short and time efficient routes, the impact of the system on efficiency is analysed by using a variety of different indicators.

- For each trip, the measured travel time and travel distance are set in relation to the estimates provided by a reference route planner. For both HMI-solutions a significant decrease of travel time can be found if drivers use a navigation system. For the built-in system, also travel distance is significantly reduced.
- For motorways, the proportion of time spent in congestion is calculated. There is no influence of navigation system usage on the time drivers spent in congestion.
- For urban and rural roads, fuel consumption is significantly reduced when having the built-in navigation system activated.

Further analysis indicates that difference between the two HMI-solutions especially regarding fuel consumption is not caused by the HMI-design but by differing routing algorithms used by the systems. The routing algorithm from the built-in device prefers staying on larger roads and avoids using smaller roads e.g. side roads through residential areas. Compared to that, driver spent a larger proportion of time on smaller side roads then driving with the mobile device. These differences in route choice are possibly the reason for the differing impacts of the mobile and the built-in navigation system on fuel consumption and on relative travel distance. A more detailed description and discussion of the results related to efficiency and environment can be found in D6.5.

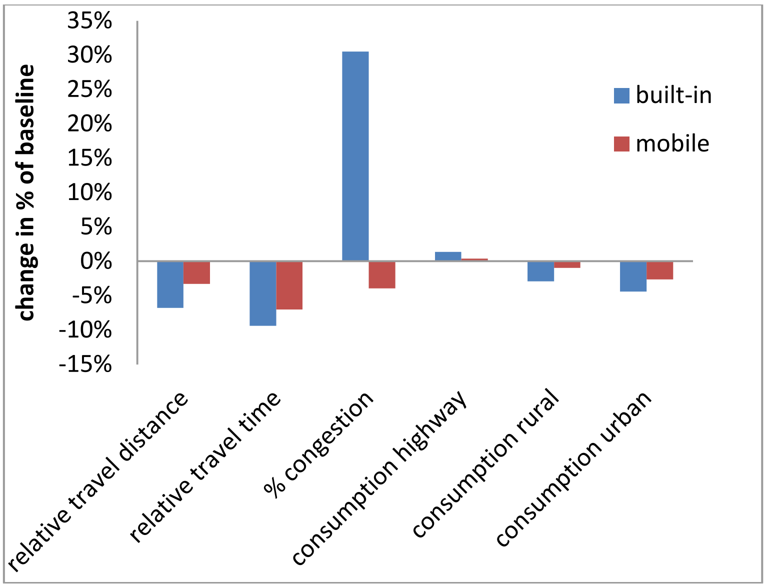


Figure 94: Change in percent of baseline values for different parameters related to efficiency and environment.

3.8.4 Discussion of results

The built-in navigation is evaluated positive at all times during the FOT and is used between 75% of mileage on motorways and 31% of mileage in urban areas. Compared to that, the mobile device doesn't fulfil the positive expectations of the driver and its usage decreases over time. The difference between the two HMI-solutions regarding acceptance and usage is surprising. Especially because in a survey on navigation systems conducted early in the euroFOT-project, drivers (in total N=134; 48 with built-in device) in general evaluated their navigation system positively. In the survey, the evaluation of the systems did not differ between built-in and mobile navigation systems. The negative evaluation of the mobile device in euroFOT can either be caused by specific characteristics of the mobile navigation system used in the FOT or it can be caused by the design of the FOT. The following aspects might have influenced the evaluation of the mobile device:

- Most drivers participating in the FOT are used to having a built-in navigation system. These prior experiences might influence the expectation on navigation systems. As a consequence, the drawbacks of a mobile device might be subjectively of higher relevance than for a sample with no larger experience with a built-in navigation system.
- In general, mobile navigation systems have larger problems with GPS-positioning than built-in devices. It depends on the algorithms used by a specific system how it deals with problems of positioning and how long finding the correct position at the beginning of a trip takes especially in urban areas. Comments of the drivers e.g. in the open questions indicate that the system used in the FOT took very long (sometimes up to 10 minutes) to find the correct GPS-position at the beginning of a trip.
- Answers to the open questions indicate that the mobile device sometimes proposed routes that in the opinion of the drivers' were wrong or inefficient (e.g. because traffic signs showed a different direction). This might be caused by actual errors of the routing algorithm or it might be a consequence of the routing algorithm of the mobile

device. Analyses reported in more detail in D6.5 indicate that compared to the built-in navigation system the routing algorithm of the mobile device chooses more often smaller routes and avoids staying on main roads. It might be that the drivers need longer to learn to trust a navigation system that uses such an algorithm.

Based on the available data it cannot be decided which of the named reasons is the actual cause for the negative evaluation of the mobile device. Nevertheless, it is assumed that the extremely negative evaluation of the mobile device is caused by a combination of specific characteristics of the system tested and of the experimental designs used (e.g. selection of study sample). Therefore, it cannot be transferred to mobile navigation systems in general.

The routing function of the tested navigation systems reaches its main goal that is to support the driver in choosing an efficient route. Contrary to that, the data does not show the effectiveness of the second function of most navigation systems that is to guide the driver dynamically around congestion. The proportion of time spent in congestion does not change with navigation system usage.

Driving is safer if a navigation system is activated. This result is new because safety effects of navigation systems are normally not studied in experiments. One reason for the safety effect might be that the routing function supports an anticipating and less abrupt driving style by providing the driver with the routing information when needed. This is also in line with the results on driving behaviour at intersections. Here, drivers use the turn indicator more often and also spent less time driving extremely slowly when using a navigation system. Both parameters can be seen as indicators for a smoother and more anticipating driving through intersections. Since safety benefits of navigation systems are not reported in the literature it is difficult to judge how global that effect is.

Although an overall safety benefit of navigation systems is not reported in the literature, the impact of system handling in widely investigated. The results from the FOT-data indicate that system handling mainly occurs in low demanding situations like standstill or at very low speeds. The difference between the two HMI-solutions on urban roads indicates that the effect is at least partly due to active compensation by the driver since it is unlikely that the two systems have largely differing demands of when longer system inputs (e.g. entering destinations) are needed. Therefore, that handling of the mobile device is avoided more in urban driving can be interpreted as a more pronounced active compensation by the drivers. This compensation is necessary because it is more demanding to make system inputs to the mobile device. If navigation systems are handled during driving, results show an adaptation of driving behaviour on urban and rural roads by slowing down and enlarging distance to the lead vehicle. There is no indication that there is an enhanced risk for driving safety during system inputs. In summary, the overall effect of the investigated navigation systems on driving safety is positive.

3.9 IW

The results of the FOT on IW can be summarised the following:

- IW rates highly positive in terms of acceptance, satisfaction and usefulness.
- The IW ratings are stable, i.e. they do not change over time.
- Many respondents feel that IW increases safety.
- IW is perceived as most useful on motorway in normal traffic
- Trust in IW is overall high and does not change with time. This indicates that drivers agree with IW's assessment of their level of attention/drowsiness.

3.9.1 Data used for analysis

In euroFOT, the impact of Impairment Warning (IW) was investigated. Drivers experienced two conditions; 1) driving without the system for about 4 months (baseline condition) and 2) driving with the system available for use during approximately 8 months (treatment condition). While subjective data (i.e. questionnaire responses) are available for the full duration, due to delays in the collection of objective data, the objective data analysis is based on 3 months of baseline and 3 months of treatment.

In total 197 drivers participated in the FOT, of which the principal 102 drivers have answered the subjective questionnaire data. Table 13 shows the number of drivers for which objective and subjective data is available for the analysis of this particular system.

Table 43: Number of drivers available for the data analysis

Number of drivers questionnaire data	58-66
Number of drivers with 6 months of objective data	58-66

Table below gives an overview over the number of kilometres and hours of driving on which the analysis for IW is based. The number of respondents varied for the different questions.

Table 44: Description of objective data used for the analysis

	Baseline	Treatment
Mileage overall [km]	347774	492976
Mileage motorway [km]	89028	119003
Mileage rural [km]	87157	111496
Mileage urban [km]	116555	160420

3.9.2 Research questions

Like for all other systems, the focus of the analysis in on usage and acceptance of the system, along with its subjectively experienced impact on driving.

As IW makes an assessment of how drowsy/attentive the driver is based on his/her lane keeping performance, it was of particular interest to study the extent to which drivers agree with the assessment that IW gives. Principally, are drivers as drowsy/inattentive as the system suggests when giving an impairment warning, or do drivers disagree with the systems assessment?

3.9.3 Results

Below are the results of the hypothesis testing on user related aspects. To facilitate reading, not all results are presented. Rather, short summaries are provided for each area, along with some specific examples of interesting data. For a more thorough analysis of each hypothesis, refer to the Annex.

3.9.3.1 Trust

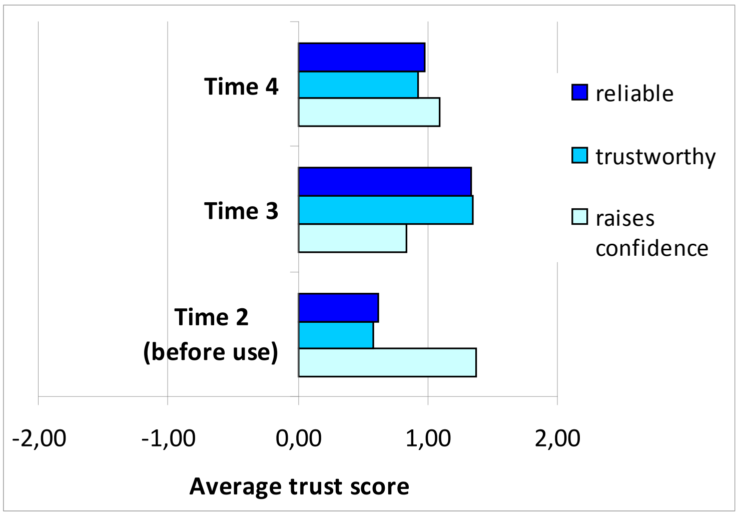


Figure 95: Trust in the IW system

Participants found the system more reliable and trustworthy than expected. Confidence, however, decreased after use. Over time with system use the trust in the system stays high and the decrease that can be seen in Fig 95 is not significant for any of the items.

3.9.3.2 Driver Behaviour

17 % of the drivers have driven at least occasionally whilst tired and relied on the IW system. 2% did so frequently.

In terms of analysis of the objective data, it is important to point out that LDW and IW here were treated as a bundled system rather than as separate functions. Bundling these functions was based on both an inseparable overlap in target crash populations and in the empirical data (usage overlapped to 97%). Hence, the results described in section 3.5.3.2 are valid for IW as well, and the reader is referred there for a detailed description.

3.9.3.3 Workload

Participants indicated very low effort experienced when driving with the IW system at everyday driving and when driving on motorways in light traffic and does not change over time in use.

3.9.3.4 User Acceptance

User acceptance is evaluated in accordance with the Van der Laan scale, as described in chapter 3.1.3.3. Results are described in the figure below.

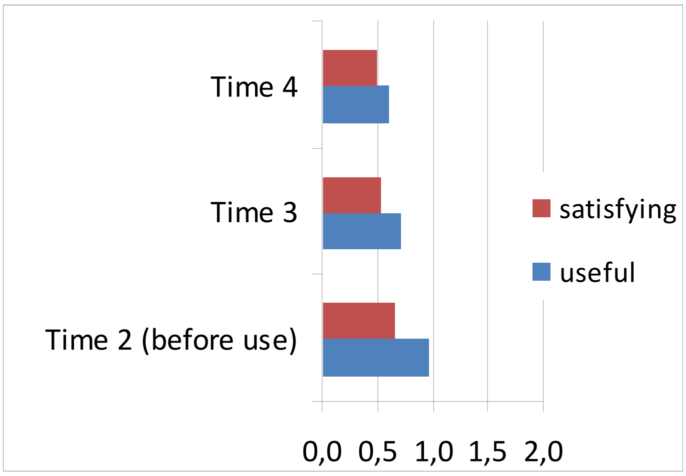


Figure 96: User acceptance, broken down into Usefulness and Satisfaction at different timesshows no significant change over time.

Perceived usefulness was further analysed for the drivers that scored positively on acceptance. These drivers were asked to specify during which driving configuration they found the system most useful.

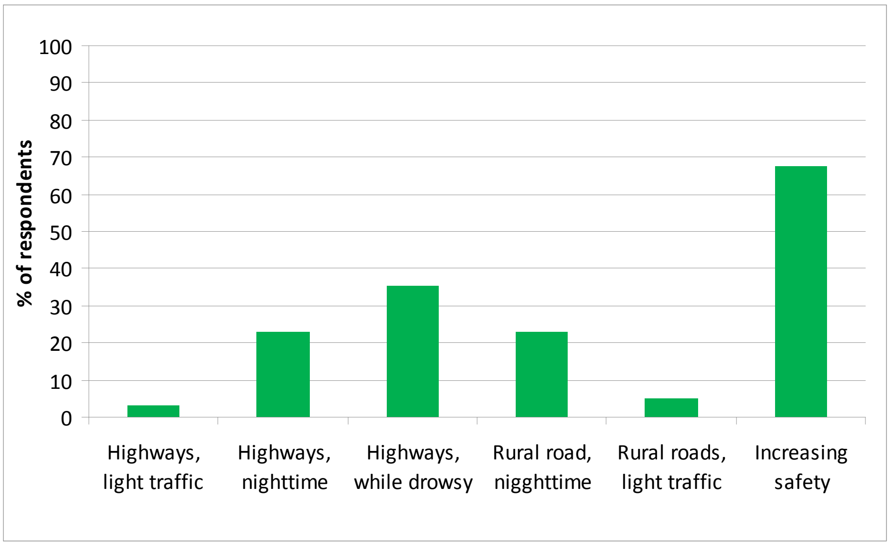


Figure 97: Rating of usefulness by drivers with positive acceptance.

Almost 70 % of driver's perceived increased safety and drivers found it most useful on motorways and at night time driving.

To evaluate how certain features of usability influence acceptance, participants were separated into two groups, negative and positive. A "negative" participant is one whose average acceptability score is negative. A positive participant is one whose average acceptability score is positive

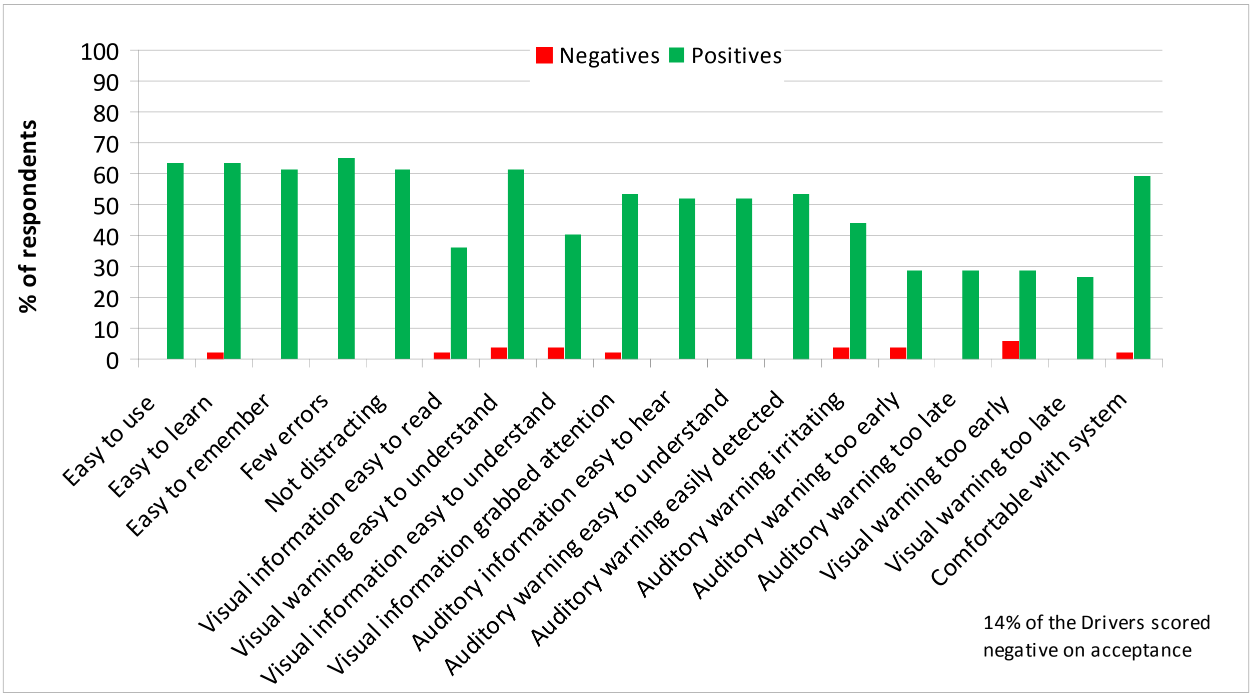


Figure 98: Acceptance influence through different items

Figure above diagram shows how certain usability items influence the acceptance of the system. The red bars show where the “negative” drivers rated the system negative. Conversely, the green bars show where the positive rated the system positive.

In general the green bars, which represent the number of positive drivers for each usability item, are relatively high for the majority of the items. The 14 % drivers that scored negative on acceptance were not satisfied with the timing of the warnings including the warning sound and the visual information on the instrument panel provided by the system which they found hard to understand. Also the positive drivers scored low on these items.

3.9.3.5 Usage

Only 2 % of the participants (corresponds to one driver only in this survey) believe they have changed user practises over time with system use.

3.9.3.6 Safety & efficiency

Possible negative side effects of LDW+IW in terms of secondary task engagement, attention to forward roadway and drowsy trip frequency were also investigated (see D6.4 for more detailed results). Results showed an interesting effect of LDW+IW in the first two measures. During normal driving, the likelihood of the driver using a nomadic device almost tripled when drivers used LDW+IW. However, during crash relevant events, no such difference was found. This indicates that drivers are capable of adjusting nomadic device usage to situations where safety is not compromised. This line of reasoning is supported by the fact that there was no difference in visual attention to the forward roadway during critical events in baseline and treatment.

3.9.4 Discussion of results

Impairment Warning scores very high on usability. This is perhaps not surprising, given the usage is extremely simple (i.e. turn the system on) and its intuitive interface (the coffee cup and the text "time for a break"). In other words, there is little to do and little to misread in terms of interpreting system output. This is also reflected in the low workload score.

Of greater interest is the topic of whether drivers agree with IW's assessment of drowsiness/inattention. Here, drivers report a high level of trust in the system, and this rating does not change with time. Drivers thus seem to agree with the system's assessment of their level of attention/drowsiness, which is both good in terms of showing that the system is accurately tuned, and a necessary prerequisite for drivers to act on the information given. Regarding the latter, many comments indicate that the real obstacle to efficient impairment warning may not be detection of impairment per se, but rather finding ways and means for the driver to do something about it. The number of places to stop and take a break on the motorway is limited, and other factors such as a desire to get home (also referred to as extra motives, by e.g. Summala) may amount a type of social pressure that forces the driver to disregard the impairment warning.

As for potential misuse of the system, only one driver reported driving while drowsy and relying on IW to indicate when to take a break. On the other hand, as the indication IW gives seems to match the drivers' own state assessment, it is unclear whether this is to be viewed as misuse or simply efficient use of the system.

4 Conclusions

This document has presented the main outlines of the assessment of the hypotheses defined in euroFOT for all tested functions. However, this assessment has been conducted partially, focusing on the User related aspects, and is complementary to those conducted in Deliverables D6.4 – Final results: impacts on traffic safety, D6.5 – Final results: impacts on traffic efficiency and D6.6 – Final results: impacts on environment.

In the main body of the deliverable the presented results are summarised based on the tested hypotheses. To get an overall comprehensive picture, reference to the Annex where all tested hypotheses are presented separately is requested.

Based on the analysis of user acceptance and user related (objective as well as subjective data) the following conclusions can be extracted:

- ACC
    - Overall acceptance is very high.
    - Acceptance is also stable (no significant changes between the time based questionnaires).
    - Almost 80 % of drivers state that driving comfort increases while driving with ACC.
    - Most drivers feel that ACC increases safety.
    - ACC is perceived as most useful on motorways in normal traffic.
    - ACC influences driver behaviour in a way that increases safety.
    - Average THW is increased by about 15%.
    - As a consequence of increased average THW also high reduction of harsh braking events, incidents and number of critical THW 0.5 seconds.
    - Driving with ACC reduces fuel consumption in all driving context (2% to 3% on motorways)
    - Driver expectations were fulfilled, i.e. the scores on satisfaction and usefulness that drivers gave before gaining access to the systems matched those given during and after the trial.
    - Most usage of ACC was on motorways.
    - Engagement in secondary tasks increased (during actual non-critical situations).
- FCW
    - Close to 70 % of drivers feel that FCW increases safety.
    - Before trying FCW, participants had very high expectations of the system. These were later somewhat devaluated based on their experience with the system.
    - However, the perceived usefulness and driver satisfaction are both very high and also stable.
- CC / SL
    - SL or CC is used in about 35% to 85% of driving distance according to road types. Usage is higher on motorways (130 km/h).
    - No change in SL and CC usage was observed during the FOT.

  - For both systems there is no systematic change of workload over the period of system usage
  - For both systems, drivers have positive expectations at the beginning of the FOT and expectations are confirmed.
  - The SL is perceived as increasing the driver comfort for 46 % of the drivers and the CC for 80 %.
  - The SL is perceived as increasing the pleasure to drive for 35 % of the drivers and the CC for 63 %.
  - The SL and CC decrease the average fuel consumption in all driving contexts.
  - The function CC increases the average speed in all driving contexts (more than 10 km/h).
  - The function SL increases the average speed for 2km/h in all driving contexts except for motorways (130km/h limited roads).
  - The ability of the CC system to reduce critical time gap occurrences probability is significant for all the speed limits.
  - The ability of the SL system to reduce hard braking occurrences probability is only significant for 50, 70, and 90 km/h roads. The ability of the CC system to reduce hard braking occurrences probability is significant for all roads except 30km/h roads.
  - CC has a clear positive influence by reducing the probability of observing a strong jerk event while driving.
  - CC increases the probability of exceeding the speed on most roads, but the effect is opposite on motorways. SL succeeds in reducing over speeding events, especially for high speed limits, where a reduction of up to 50% can be observed when using the system
- BLIS
  - Overall usability and acceptance scores for BLIS are very high (over 90 % positive ratings), and this rating does not change over time.
  - Approximately 80 % of drivers feel that BLIS increases safety.
  - BLIS is perceived as most useful on motorways in normal traffic.
  - BLIS does not increase workload.
- LDW
  - Participants find the LDW system useful and effective in increasing driving safety.
  - Drivers recognize a higher usage of turn indicators.
  - The satisfaction with the system is relatively low.
  - The expectations of the drivers were low already before using LDW
  - Average trust in LDW changes significantly decrease over time, i.e. drivers expected more of the system than it could fulfil. This is slightly different in the Italian case, where only a few drivers did not trust the system.
  - Additionally, some drivers experienced a higher workload especially in some driving conditions (e.g., poor weather conditions).

  - Most drivers found LDW very easy to use but many also found the warning irritating and commented on the warning timing.
  - Drivers tend to identify LDW as more useful during night and motorway driving.
  - However, acceptance of the system is high in Italy, where only subjective questionnaires were distributed.
- CSW
  - Overall usability and acceptance scores for CSW are high.
  - Approximately 75% of drivers feel that CSW increases safety.
  - CSW is perceived as most useful on rural roads.
- Navigation System
  - Navigation systems are used in about 40% of driving time. Usage is higher on unfamiliar and long trips.
  - The built-in navigation system is evaluated more positively than the mobile device. This difference in subjective evaluation is reflected in system usage.
  - When driving with a navigation system activated, driving behaviour is safer.
  - While driving with a navigation system activated, travel time is significantly reduced.
  - There is a potential to reduce travel distance and fuel consumption by using a navigation system.
  - Navigation systems do not reduce the time spent in congestions.
  - Handling of navigation systems occurs more often in low demanding situations.
  - Handling of navigation systems leads to a decrease of speed and to an increase of distance to the lead vehicle.
  - There is no indication that handling of navigation systems is related to an increase of safety critical situation.
- IW
  - IW rates highly positive in terms of acceptance, satisfaction and usefulness.
  - The IW ratings are stable, i.e. they do not change over time.
  - Many respondents feel that IW increases safety.
  - IW is perceived as most useful on motorway in normal traffic
  - Trust in IW is overall high and does not change with time.

In order to achieve these results, up to 151 hypotheses were analysed overall, having used the data described in chapter 2.

Total number of drivers was 1030, with the following distributions:

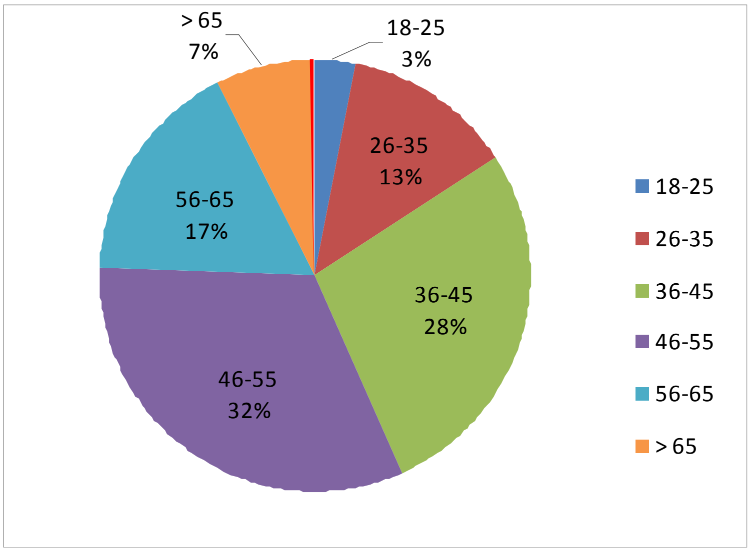


Figure 99: Driver distribution (per age)

As main conclusion, it can be outlined that most of the analysed systems are perceived as useful and trustworthy, with a good capability to improve safety. Some functions ranked better than others (e.g., FCW in front of LDW), but overall conclusion was quite positive. These results have to be additionally upgraded with deliverables D6.4, D6.5 and D6.6 to get an overall picture.

In any case, further research on the influence of Advanced Driver Assistance Systems on the driver behaviour is conceivable. A deeper understanding on the links in between objective and subjective (questionnaires and interviews) data should be made, to cross-check the reliability of both studies and to analyse how objective data can be validated with the collected subjective data. This can also be of value when analyzing the results of certain hypothesis with only one type of data (objective or subjective), as the model would have been validated first. Moreover, additional data can be used to support this validation and to provide further information. Especially, detailed video analysis can give more insights on how drivers behave during certain situations.

Annex 1 Adaptive Cruise Control (ACC)

List of selected hypothesis

The list of selected hypothesis for ACC is the following one:

Table 1: List of hypothesis for ACC

ACC decreases the number of critical Time-headway to the lead vehicle (passenger cars)
ACC decreases the number of critical Time-headway to the lead vehicle (trucks)
ACC increases the average THW (passenger cars)
ACC increases the average THW (trucks)
ACC reduces the average fuel consumption (passenger cars)
ACC reduces the average fuel consumption (trucks)
ACC reduces the number of hard braking (passenger cars)
ACC reduces the number of hard braking (trucks)
ACC reduces the number of incidents (passenger cars)
ACC reduces the number of incidents (trucks)
ACC reduces the average speed (passenger cars)
ACC reduces the average speed (trucks)
ACC+FCW use increases over time
The driver changes the use of ACC over time by increasing the occurrence of overriding the ACC function by using the accelerator pedal (passenger cars)
The driver changes the use of ACC over time by increasing occurrence of overriding the ACC system by using the accelerator pedal (trucks)
The acceptance of ACC will be positive
ACC increases driving perceived safety and comfort
Certain features of the systems, in terms of usability, influence acceptance
Certain features of the systems, in terms of usefulness, influence acceptance
Trust in system changes over time with system use
User practices (heuristics/rules) will change over time during the FOT
Drivers will not abuse or misuse ACC
Acceptance changes over time with system use
Using ACC, focus and level of engagement on secondary tasks will increase
Driver workload decreases over time with the system

ACC decreases the number of critical Time-headway to the lead vehicle (passenger cars)

Comparison situations

1. Baseline: All baseline with ACC state off
2. Treatment: All treatment with ACC state active (plus 5 sec after ACC shut off)

Filtering criteria

1. Travelled time with vehicle speed not null > 5 min.
2. Vehicle speed >=50 km/h
3. THW>0 (car following)
4. Expected speed >60 km/h
5. Minimum mileage for each driver in baseline/treatment conditions (100km)

Factors

1. Road type
2. Weather (only motorway)
3. Lighting (only motorway)

Performance indicators (PIs)

1. Number of Time-headway under 0.5s per 100km
2. Percentage of Time-headway under 0.5s

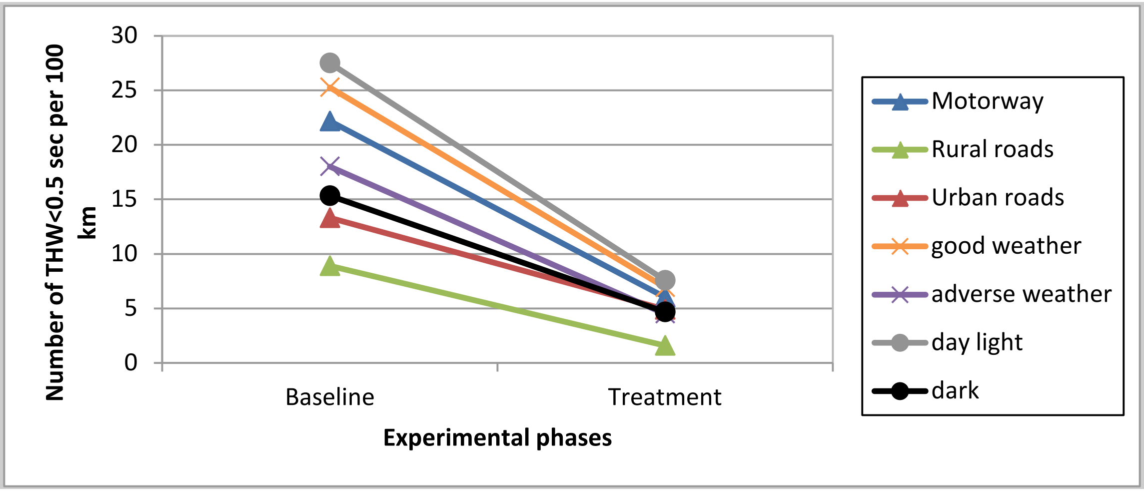
Data

All drivers (N), which have sufficient number of accumulated kilometres (>100 km) in Baseline and Treatment: N=174 for motorway (709607 km), N=64 for rural (37211 km) and urban (33728 km) roads, N=80 for lighting conditions (557663 km) and N=77 for weather conditions (555412 km).

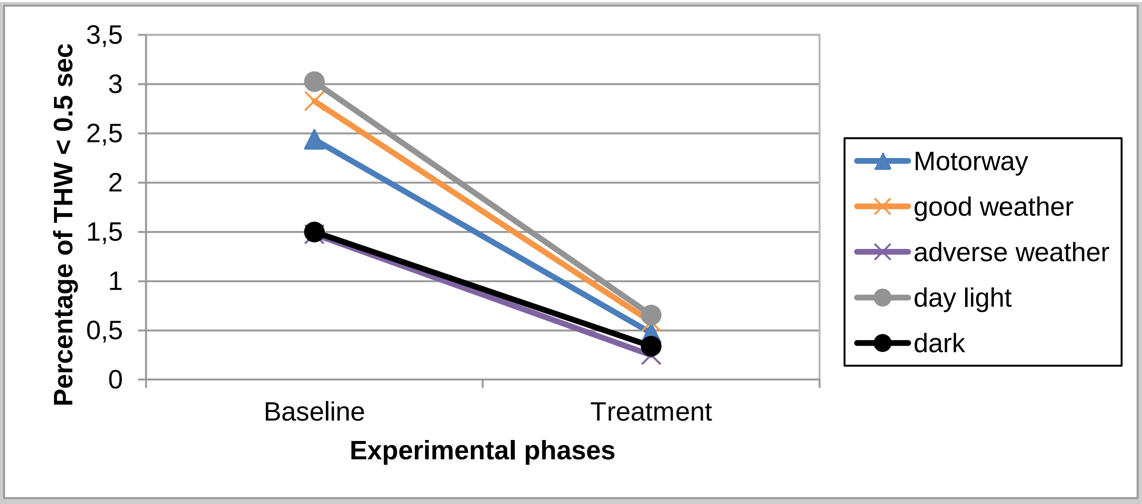
Statistical Methods

Wilcoxon signed-rank test and 2 sample T-test.

Results



Conditions	Baseline	Treatment	% Increase/ Reduction	N	Mileage [km]
	Mean	Mean			
motorway	22.22	6.02	-72.86	174	709607
rural	8.9	1.6	-82.02	64	37.211
urban	13.3	4.9	-63.16	64	33728
good	25.66	7.07	-72.58	77	489399
adverse	18.32	4.63	-74.95	77	66013
day light	27.86	7.75	-72.47	80	413223
dark	15.51	4.7	-69.5	80	144440



Conditions	Baseline	Treatment	% Increase/ Reduction	N	Mileage [km]
	Mean	Mean			
motorway	2.16	0.41	-80.65	110	651099
rural	no significant results				
urban	no significant results				
good	2.82	0.57	-79.27	77	489399
adverse	1.48	0.25	-83.06	77	66013

day light	1.48	0.32	-78.35	80	413223
dark	3.01	0.63	-77.4	80	144440

Conclusions

The number of critical time gaps (THW<0.5 sec) to the lead vehicle was reduced by 72.86% for motorway driving which is lower than the decrease on rural roads (82.02%) but higher than that on urban roads (63.16%).The results within the different weather and lighting conditions vary between 69.5% and 74.95%.

The analysis of the percentage of THW under 0.5 seconds revealed no significant results could be found on rural and urban roads. The assessment on motorways shows a reduction of 80.65% which is also reflected in the number of the different weather and lighting conditions (between 77.4% and 83.06%) which were also analysed on motorways.

ACC decreases the number of critical Time-headway to the lead vehicle (trucks)

Comparison situations

1. Baseline: All baseline with ACC state off
2. Treatment: All treatment with ACC state active (plus 5 sec after ACC shut off)

Filtering criteria

1. Travelled time with vehicle speed not null > 5 min.
2. Vehicle speed >=50 km/h
3. THW>0 (car following)
4. Posted speed > 100 km/h
5. Minimum mileage for each driver in baseline/treatment conditions (100km)

Factors

- Weight

Performance indicators (PIs)

Relative risk of Time-headway under 0.5s per 100km

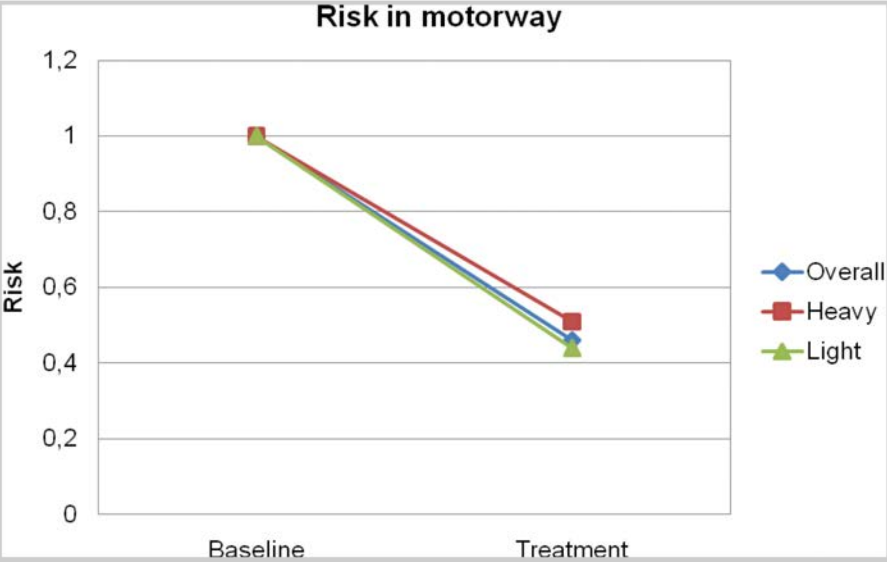
Data

All drivers (N), which have sufficient number of accumulated kilometres (>100 km) in Baseline and Treatment, were used for the analyses. N=36 for motorway (501069 km).

Statistical Methods

Wilcoxon signed-rank test and 2 Proportion test and 2 sample T-test

Results



Conditions	Relative risk (risk treatment / risk baseline)	% Increase/ Reduction	N	Mileage [km]
motorway	0.46	-54.0	36	501069
motorway, heavy	0.51	-49.0	36	501069
motorway, light	0.43	-57.0	36	501069

Conclusions

The number of critical time gaps (THW<0.5 sec) to the lead vehicle was reduced by 54.0% in the overall evaluation on motorway driving. When the truck was light (weight < 30 tons), the benefit was the highest. When the truck is heavy, drivers tend to keep longer time-gaps and therefore, better safety margins in baseline as well. This reduces the benefit in the treatment phase for this condition.

ACC increases the average THW (passenger cars)

Comparison situations

- Baseline: All baseline with ACC state off
- Treatment: All treatment with ACC state active

Filtering criteria

1. Travelled time with vehicle speed not null > 5 min.
2. Vehicle speed >=50 km/h
3. THW>0
4. Expected speed >60 km/h
5. Minimum mileage for each driver in baseline/treatment conditions (100km)

Factors

1. Road type
2. Weather (only motorway)
3. Lighting (only motorway)

Performance indicators (PIs)

Average time headway (THW)

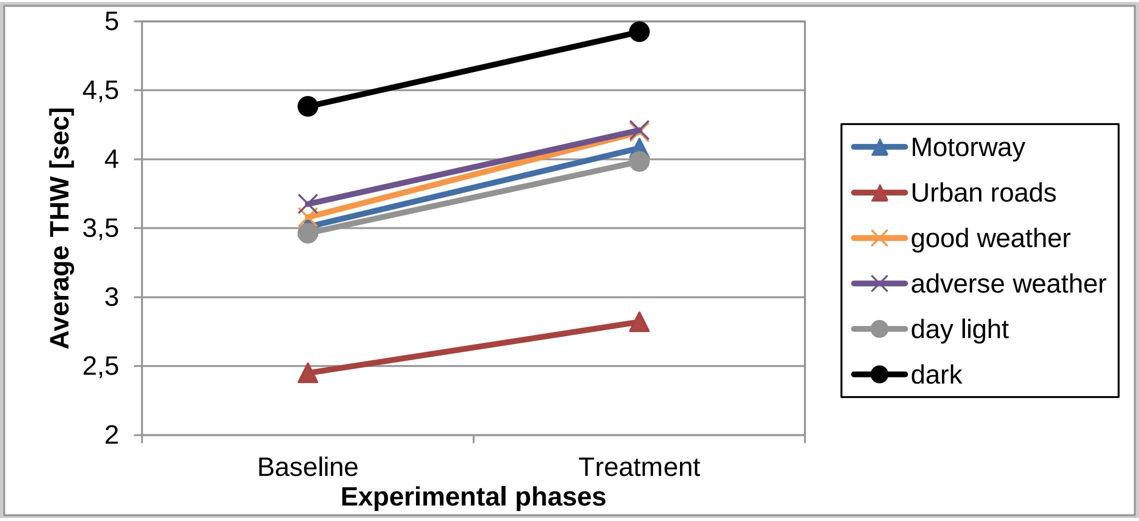
Data

All drivers (N), which have sufficient number of accumulated kilometres (>100 km) in Baseline and Treatment. N=174 for motorway (709607 km), N=64 for rural (37211 km) and urban roads (33728 km), N=80 for lighting conditions (557663 km) and N=77 for weather conditions (555412 km).

Statistical Methods

Repeated measures ANOVA

Results



Conditions	Baseline	Treatment	% Increase/ Reduction	N	Mileage [km]
	Mean	Mean			
motorway	3.51	4.08	16.21	173	709607
rural	no significant results			64	37211
urban	2.45	2.82	15.1	64	33728
good	3.57	4.18	17.27	77	489399
adverse	3.66	4.19	14.55	77	66013
day light	3.45	3.97	15.03	80	413223
dark	4.38	4.92	12.36	80	144440

Conclusions

The average THW increases by 16.21% on motorways and 15.1% on urban roads. On rural roads no significant changes could be found. Within the analyses of weather and lighting conditions the results vary between 12.36% and 17.27%.

ACC increases the average THW (trucks)

Comparison situations

1. Baseline: All baseline with ACC state off
2. Treatment: All treatment with ACC state active

Filtering criteria

1. Travelled time with vehicle speed not null > 5 min.
2. Vehicle speed >=50 km/h
3. THW>0
4. Posted speed > 100 km/h
5. Minimum mileage for each driver in baseline/treatment conditions (100km)

Factors

- Weight (heavy >30 tons, light < 30 tons)

Performance indicators (PIs)

- Average time headway (THW)

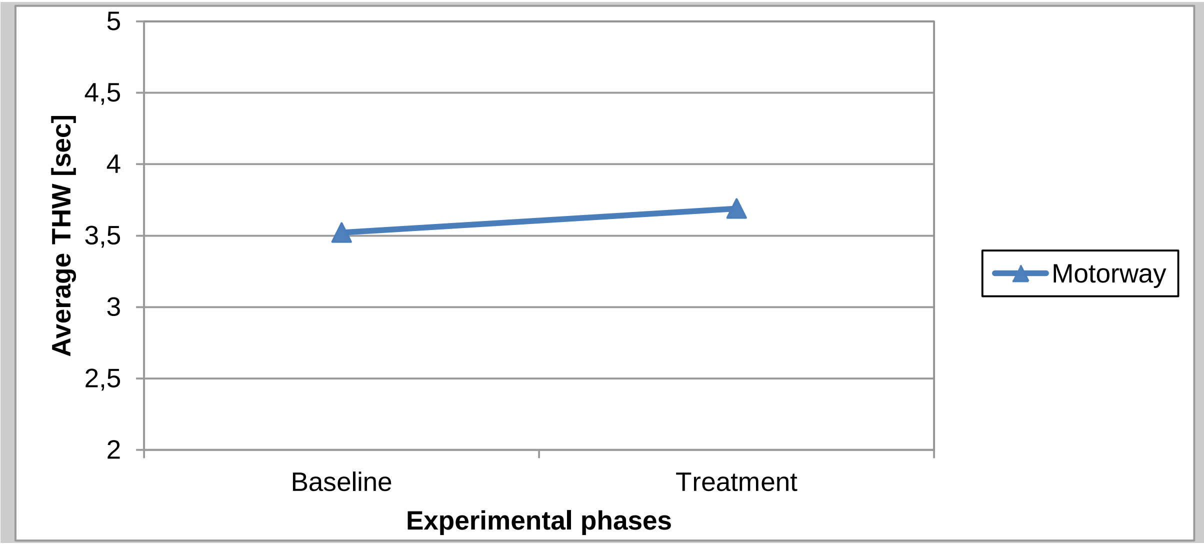
Data

All drivers (N), which have sufficient number of accumulated kilometres (>100 km) in Baseline and Treatment, were used for the analyses. N=53 for motorway (570183 km).

Statistical Methods

Repeated measures ANOVA

Results



Conditions	Baseline	Treatment	% Increase/ Reduction	N	Mileage [km]
	Mean	Mean			
motorway	3.52	3.69	4.78	53	570183

Conclusions

The average THW increases by 4.78% on motorways.

ACC reduces the average fuel consumption (passenger cars)

Comparison situations

1. Baseline: All baseline with ACC state off
2. Treatment: All treatment with ACC state active

Filtering criteria

1. Travelled time with vehicle speed not null > 5 min.
2. Vehicle speed >=50 km/h
3. THW>0 (car following)
4. Expected speed >60 km/h
5. Minimum mileage for each driver in baseline/treatment conditions (100km)

Factors

1. Road type
2. Weather (only motorway)
3. Lighting (only motorway)

Performance indicators (PIs)

- Average fuel consumption per 100 driven km

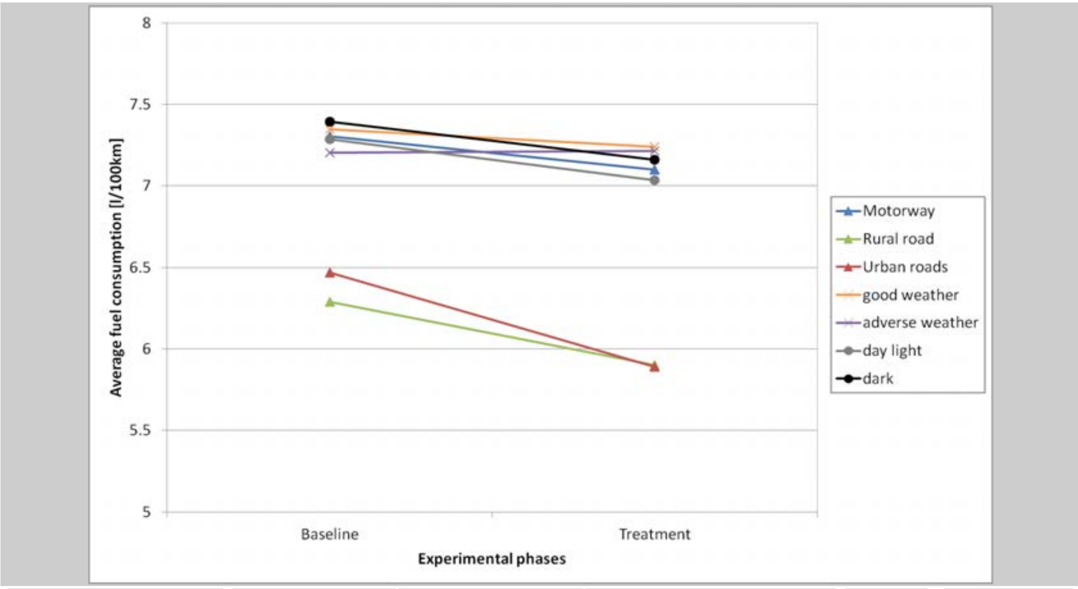
Data

All drivers (N), which have sufficient number of accumulated kilometres (>100 km) in Baseline and Treatment, were used for the analyses. N=163 samples for motorway (698695 km), N=53 for rural (30189 km) and urban roads (27944 km), N=80 for lighting conditions (557663 km) and N=77 for weather conditions (555412 km).

Statistical Methods

Repeated measures ANOVA

Results



Conditions	Baseline	Treatment	% Increase/ Reduction	N	Mileage [km]
	Mean	Mean			
motorway	7.30	7.1	-2.77	163	698695
rural	6.29*	5.9	-6.2	53	30189
urban	6.47*	5.89	-8.96	53	27944
good	7.37	7.26	-1.46	77	489399
adverse	7.16	7.24	0.11	77	66013
day light	7.29	7.04	-3.44	80	413223
dark	7.39	7.11	-3.17	80	144440

* Only diesel-powered vehicles

Conclusions

Using ACC decreases the average fuel consumption by 2.77% while driving on motorway. A higher reduction could be found on rural and urban roads (6.2% and 8.96%). The reduction on rural and urban roads might overestimate the fuel saving potential because of the differences in driving patterns in both experimental phases caused by the driver's choice when to use the system. The evaluation of weather and lighting conditions (while driving on motorways) reveals reductions between 1.46% and 3.44% with an increase of 0.11% during adverse weather conditions.

ACC reduces the average fuel consumption (trucks)

Comparison situations

1. Baseline: All baseline with ACC state off
2. Treatment: All treatment with ACC state active

Filtering criteria

1. Travelled time with vehicle speed not null > 5 min.
2. Vehicle speed >=50 km/h
3. THW>0 (car following)
4. Expected speed > x (x = 95km/h for fleet1 and x = 115km/h for fleet2)
5. Minimum mileage for each driver in baseline/treatment conditions (100km)

Factors

- Motorway

Performance indicators (PIs)

- Average fuel consumption per 100 driven km

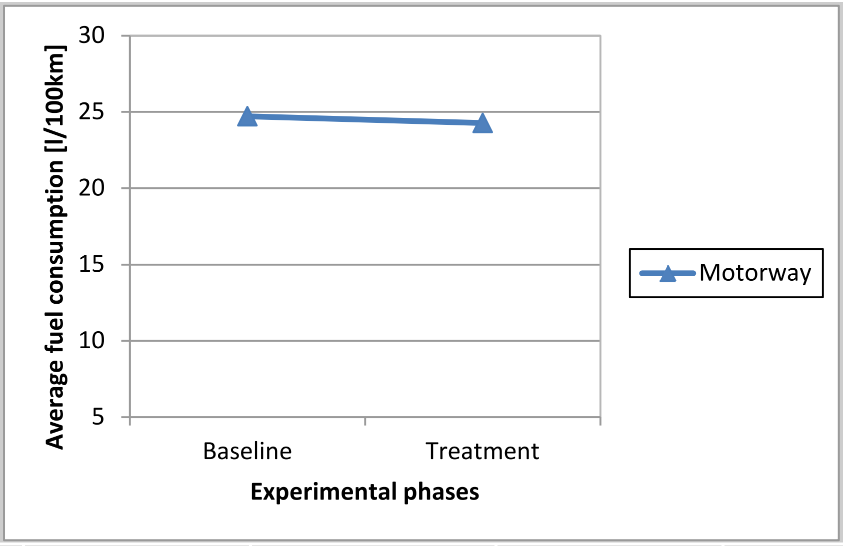
Data

All drivers (N), which have sufficient number of accumulated kilometres (>100 km) in Baseline and Treatment, were used for the analyses. N=23 driver for motorway (327295 km).

Statistical Methods

Repeated measures ANOVA

Results



Conditions	Baseline	Treatment	% Increase/ Reduction	N	Mileage [km]
	Mean	Mean			
motorway	24.71	24.28	-1.78	23	327295

Conclusions

Using ACC decreases the average fuel consumption by 1.78% while driving on motorway.

ACC reduces the number of hard braking (passenger cars)

Comparison situations

1. Baseline: All baseline with ACC state off
2. Treatment: All treatment with ACC state active (plus 5 sec after ACC shut off)

Filtering criteria

1. Travelled time with vehicle speed not null > 5 min.
2. Vehicle speed >=50 km/h
3. THW>0 (car following)
4. Expected speed >60 km/h
5. Minimum mileage for each driver in baseline/treatment conditions (100km)

Factors

1. Road type
2. Weather (only motorway)
3. Lighting (only motorway)

Performance indicators (PIs)

1. Number of high decelerations per 100 driven km
2. Number of strong braking reactions

Data

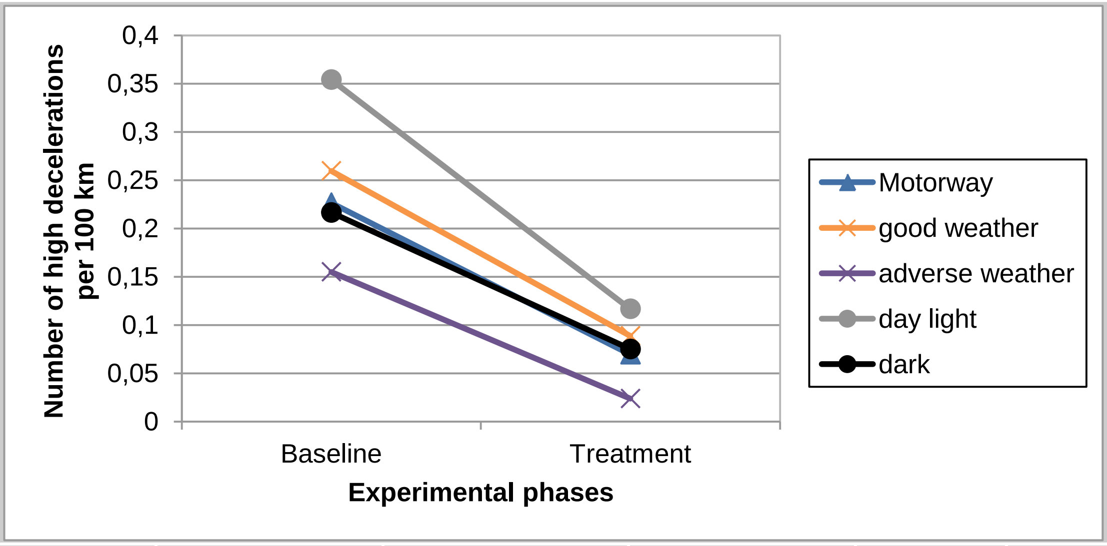
All drivers (N), which have sufficient number of accumulated kilometres (>100 km) in Baseline and Treatment, were used for the analyses.

1. Number of high decelerations per 100 driven km :
   N=110 for motorway (651099 km), N=80 (557663 km) for lighting conditions and N=77 (555412 km) for weather conditions.
2. Number of strong braking reactions:
   N=64 for motorway (58508 km), rural (37211 km) and urban roads (33728 km).

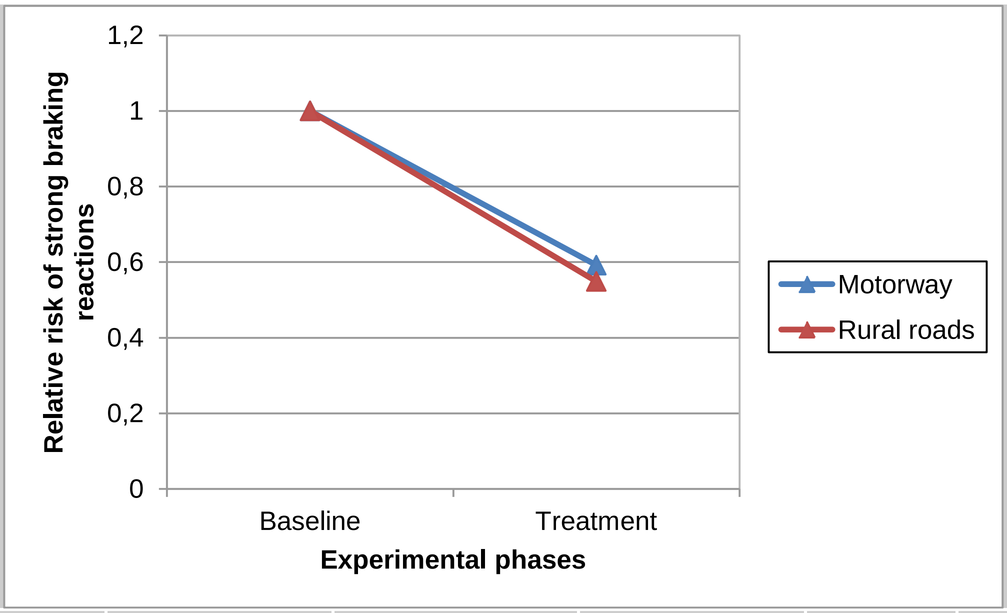
Statistical Methods

Wilcoxon signed-rank test and 2 sample T-test.

Results



Conditions	Baseline	Treatment	% Increase/ Reduction	N	Mileage [km]
	Mean	Mean			
motorway	0.23	0.07	-69.23	110	651099
good	0.25	0.09	-65.78	77	489399
adverse	0.15	0.02	-84.6	77	66013
day light	0.33	0.11	-67.02	80	413223
dark	0.21	0.07	-65.29	80	144440



Conditions	Baseline	Treatment	% Increase/ Reduction	N	Mileage [km]
	Relative risk	Relative risk			
motorway	1	0.59	-40.81	64	58832
rural	1	0.55	-45.12	64	37728
urban	no significant results			64	34436

Conclusions

The number of high decelerations was reduced by 69.23% within the assessment on motorways. For the weather and lighting conditions the reduction varies between 65.29% and 67.02% with an outlier for adverse weather and 84.6%.
In the treatment phase the strong braking reactions on motorways were reduced by 40.81% compared to Baseline. On rural roads the reduction is 45.12%. No significant results were found on urban roads.

ACC reduces the number of hard braking (trucks)

Comparison situations

1. Baseline: All baseline with ACC state off
2. Treatment: All treatment with ACC state active (plus 5 sec after ACC shut off)

Filtering criteria

1. Travelled time with vehicle speed not null > 5 min.
2. Vehicle speed >=50 km/h
3. THW>0 (car following)
4. Expected speed > x (x = 95km/h for fleet1 and x = 115km/h for fleet2)
5. Minimum mileage for each driver in baseline/treatment conditions (100km)

Factors

- Motorway

Performance indicators (PIs)

1. Number of high decelerations per 100 driven km
2. Relative risk of strong braking reactions

Data

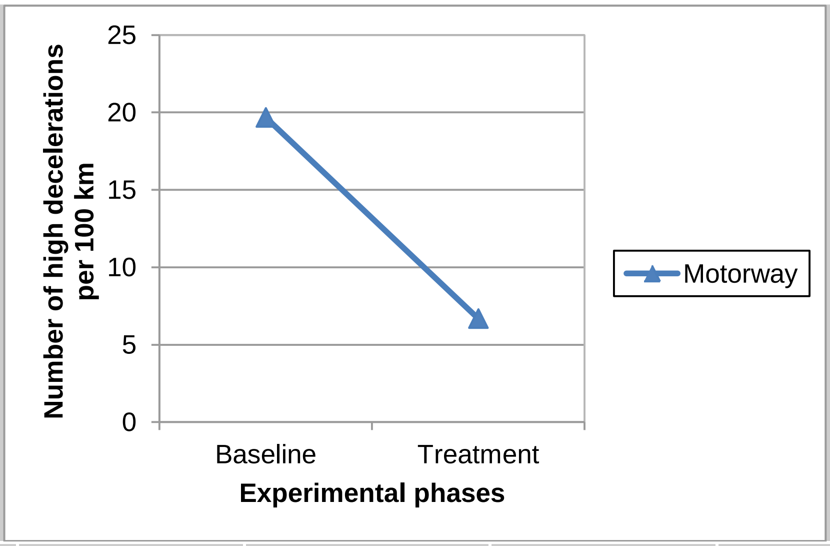
All drivers (N), which have sufficient number of accumulated kilometres (>100 km) in Baseline and Treatment, were used for the analyses.

1. Number of high decelerations per 100 driven km :
   N=6 for motorway (71854 km)
2. Number of strong braking reactions:
   N=30 for motorway (429215 km)

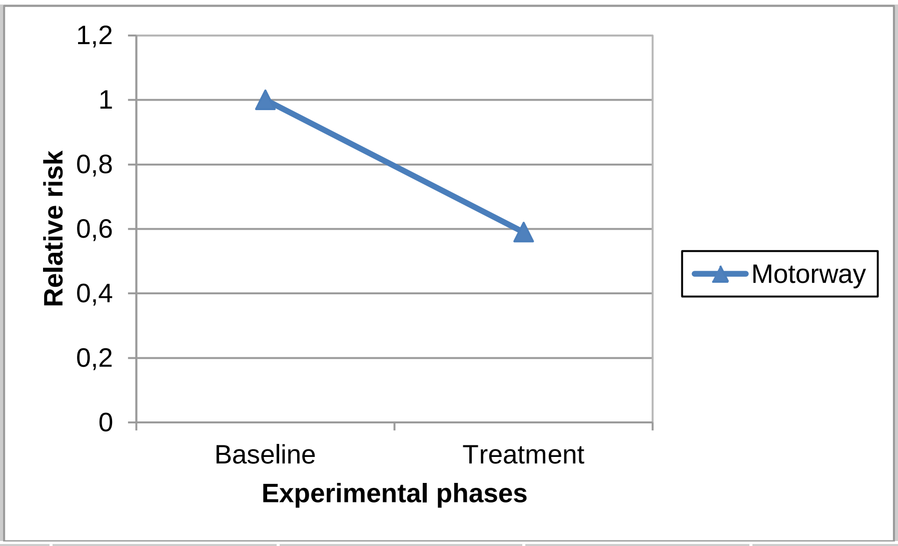
Statistical Methods

Wilcoxon signed-rank test and 2 sample T-test

Results



Conditions	Baseline	Treatment	% Increase/ Reduction	N	Mileage [km]
	Mean	Mean			
motorway	19.68	6.69	-66.01	6	71854



Conditions	Baseline	Treatment	% Increase/ Reduction	N	Mileage [km]
	Relative risk	Relative risk			
motorway	1	0.59	-40.81	30	429215

Conclusions

The number of high decelerations was reduced by 66.01% within the assessment on motorways. In the treatment phase the strong braking reactions on motorways were reduced by 40.81% compared to Baseline.

ACC reduces the number of incidents (passenger cars)

Comparison situations

1. Baseline: All baseline with ACC state off
2. Treatment: All treatment with ACC state active (plus 5 sec after ACC shut off)

Filtering criteria

1. Travelled time with vehicle speed not null > 5 min.
2. Vehicle speed >=50 km/h
3. THW>0 (car following)
4. Expected speed >60 km/h
5. Minimum mileage for each driver in baseline/treatment conditions (100km)

Factors

1. Road type
2. Weather (only motorway)
3. Lighting (only motorway)

Performance indicators (PIs)

1. Number of incidents per 100 driven km based on vehicle kinematics
2. Number of incidents per 100 driven km based on subjective video analysis

Data

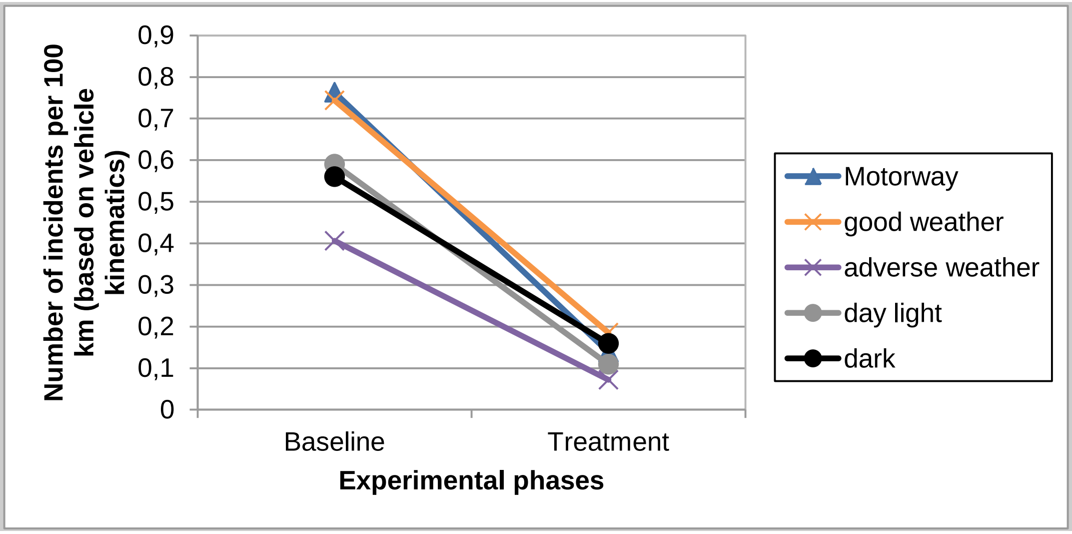
All drivers (N), which have sufficient number of accumulated kilometres (>100 km) in Baseline and Treatment, were used for the analyses.

1. Number of incidents based on vehicle kinematics:
   N=110 for motorway (651099 km), N=80 (557663 km) for lighting conditions and N=77 (555412 km) for weather conditions.
2. Number of incidents based on subjective video analysis:
   N=92 (60471 km) independent on the road type.

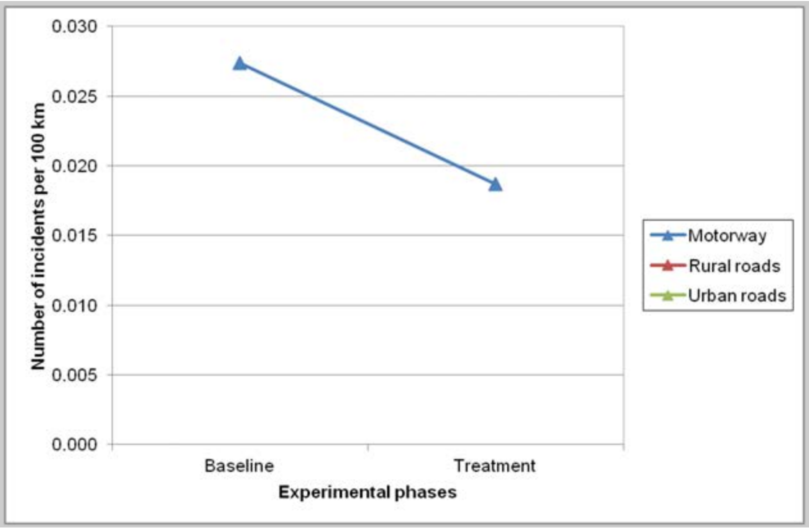
Statistical Methods

Wilcoxon signed-rank test and 2 sample T-test.

Results



Conditions	Baseline	Treatment	% Increase/ Reduction	N	Mileage [km]
	Mean	Mean			
motorway	0.76	0.14	-81.9	110	651099
good	0.74	0.18	-75.13	77	489399
adverse	0.41	0.07	-82.33	77	66013
day light	0.59	0.11	-81.54	80	413223
dark	0.56	0.16	-71.6	80	144440



Conditions	Baseline	Treatment	% Increase/ Reduction	N	Mileage [km]
	Relative risk	Relative risk			
motorway	0.027	0.019	-31.75*	92	60471

*Not statistically significant

Conclusions

The number of incidents based on kinematics was reduced by 81.9% within the assessment on motorways. For the weather and lighting conditions the reduction varies between 71.6% and 82.33%.

In treatment the number of incidents based on video analyses was reduced by 31.75%. Notice that this not significant change was found without considering road types because of low event frequency.

ACC reduces the number of incidents (trucks)

Comparison situations

1. **Baseline**: All baseline with ACC state off
2. **Treatment**: All treatment with ACC state active (plus 5 sec after ACC shut off)

Filtering criteria

1. Travelled time with vehicle speed not null > 5 min.
2. Vehicle speed >=50 km/h
3. THW>0 (car following)
4. Expected speed >60 km/h
5. Minimum mileage for each driver in baseline/treatment conditions (100km)

Factors

None

Performance indicators (PIs)

1. Number of incidents per 100 driven km based on vehicle kinematics
2. Number of incidents per 100 driven km based on subjective video analysis

Data

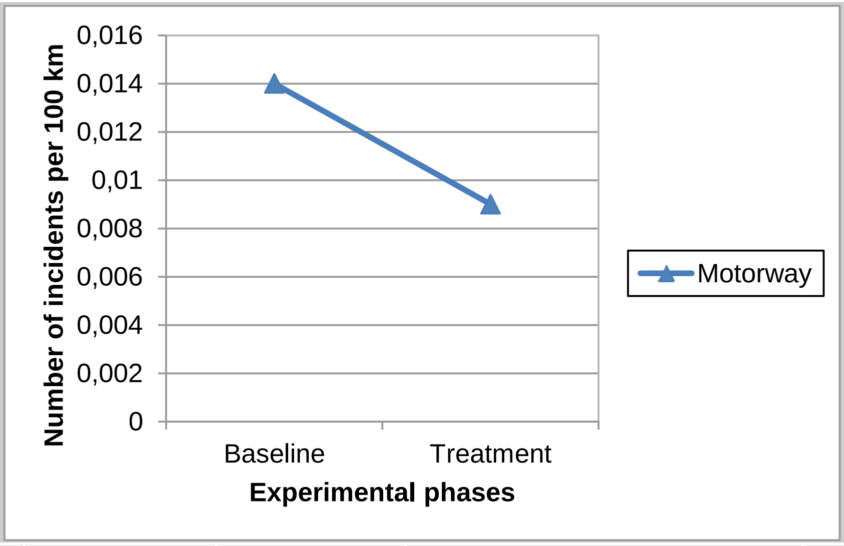
All drivers (N), which have sufficient number of accumulated kilometres (>100 km) in Baseline and Treatment, were used for the analyses.

1. Number of incidents based on vehicle kinematics: N=6 for motorway (71854 km).
2. Number of incidents based on subjective video analysis: N=30 for overall (429215 km).

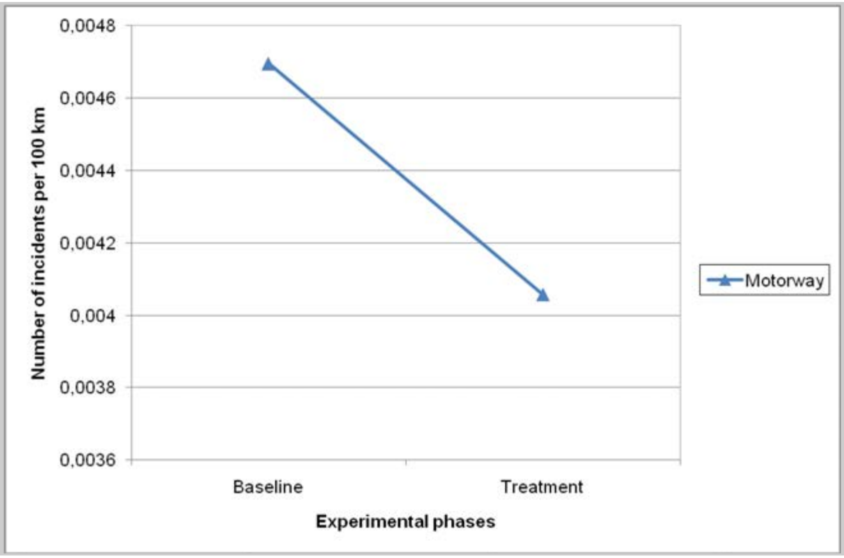
Statistical Methods

Wilcoxon signed-rank test and 2 Proportion test and 2 sample T-test

Results



Conditions	Baseline	Treatment	% Increase/ Reduction	N	Mileage [km]
	Mean	Mean			
motorway	0.014	0.009	-35.71 (CI* = 90%, sig p = 0.086)	6	71854



Conditions	Baseline	Treatment	% Increase/ Reduction	N	Mileage [km]
	events/100km	events/100km			
motorway	0.0047	0.00406	-13.6*	30	429215

*Not statistically significant

Conclusions

The number of incidents based of vehicle kinematics was reduced by 35.71% within the assessment on motorways. Those evaluated by video analyses showed a reduction of 13.6%. The lack of significance for the video annotated critical events is likely due to the fact that the final number of events judged relevant for ACC+FCW was very small.

ACC reduces the average speed (passenger cars)

Comparison situations

1. Baseline: All baseline with ACC state off
2. Treatment: All treatment with ACC state active

Filtering criteria

1. Travelled time with vehicle speed not null > 5 min.
2. Vehicle speed >=50 km/h
3. THW>0 (car following)
4. Expected speed >60 km/h
5. Minimum mileage for each driver in baseline/treatment conditions (100km)

Factors

1. Road type
2. Weather (only motorway)
3. Lighting (only motorway)

Performance indicators (PIs)

1. Average speed

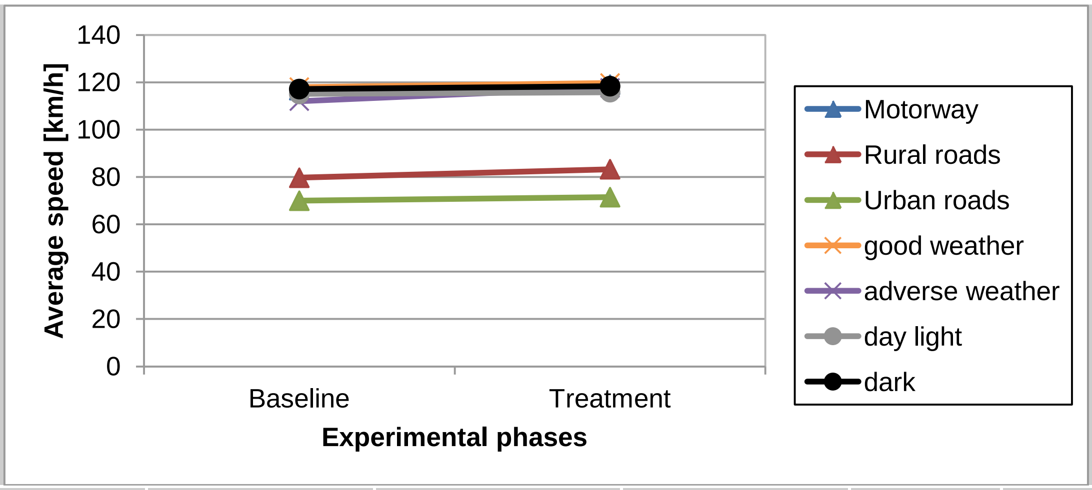
Data

All drivers (N), which have sufficient number of accumulated kilometres (>100 km) in Baseline and Treatment. N=174 for motorway (709607 km), N=64 for rural (37211 km) and urban roads (33728 km), N=80 for lighting conditions (557663 km) and N=77 for weather conditions (555412 km).

Statistical Methods

Repeated measures ANOVA

Results



Conditions	Baseline	Treatment	% Increase/ Reduction	N	Mileage [km]
	Mean	Mean			
motorway	116.7	119.02	1.99	174	709607
rural	79.7	83.3	4.52	64	37211
urban	70*	71.5*	2.14	64	33728
good	118.02	119.63	1.46	77	489399
adverse	112.22	117.4	4.99	77	66013
day light	115.11	115.85	0.65	80	413223
dark	117.15	118.38	1.05	80	144440

* only where expected speed >60 km/h

Conclusions

The average speed increases by 1.99% when driving with ACC on motorways. Additionally, an increase of 2.14% on urban roads and 4.52% on rural roads was found. The increases in different lighting conditions are 0.65% in day light conditions and 1.05% in the dark. The difference between good and adverse weather conditions is higher (1.46% in good weather conditions and 4.99% in adverse weather conditions) but might be influenced by the low mileage in adverse weather conditions.

ACC reduces the average speed (trucks)

Comparison situations

1. **Baseline**: All baseline with ACC state off
2. **Treatment**: All treatment with ACC state active

Filtering criteria

1. Travelled time with vehicle speed not null > 5 min.
2. Vehicle speed >=50 km/h
3. THW>0 (car following)
4. Posted speed > 100 km/h
5. Minimum mileage for each driver in baseline/treatment conditions (100km)

Factors

1. Weight (heavy >30 tons, light < 30 tons)

Performance indicators (PIs)

1. Average speed

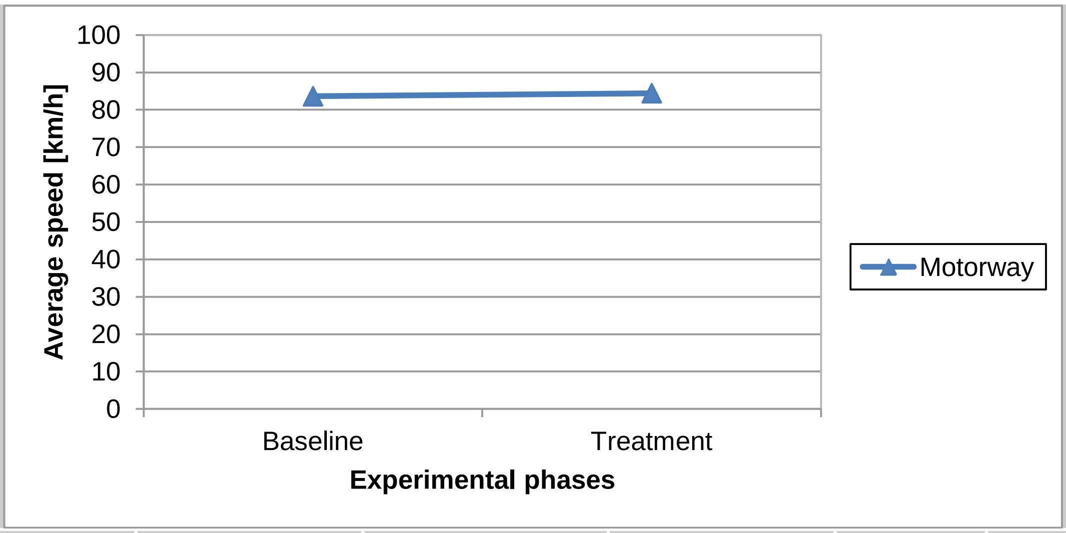
Data

All drivers (N), which have sufficient number of accumulated kilometres (>100 km) in Baseline and Treatment, were used for the analyses. N=53 for motorway (570183 km).

Statistical Methods

Repeated measures ANOVA

Results



Conditions	Baseline	Treatment	% Increase/ Reduction	N	Mileage [km]
	Mean	Mean			
motorway	83.61	84.33	0.87	53	570183

Conclusions

The average speed increases by 0.87% when driving with ACC on motorways.

ACC+FCW use increases over time

Comparison situations

Comparison between 9 consecutive time intervals of equal length (1 month) during treatment

Filtering criteria

1. Trip duration > 5 min.
2. Vehicle speed > 30 km/h

Factors

Over all factors

Performance indicators (PIs)

1. PI1-U3: Duration travelled with active ACC during time interval x, divided by total travel time of time interval x
2. PI2-U3: Number of ACC activations during time interval x, divided by total travel time of time interval x.

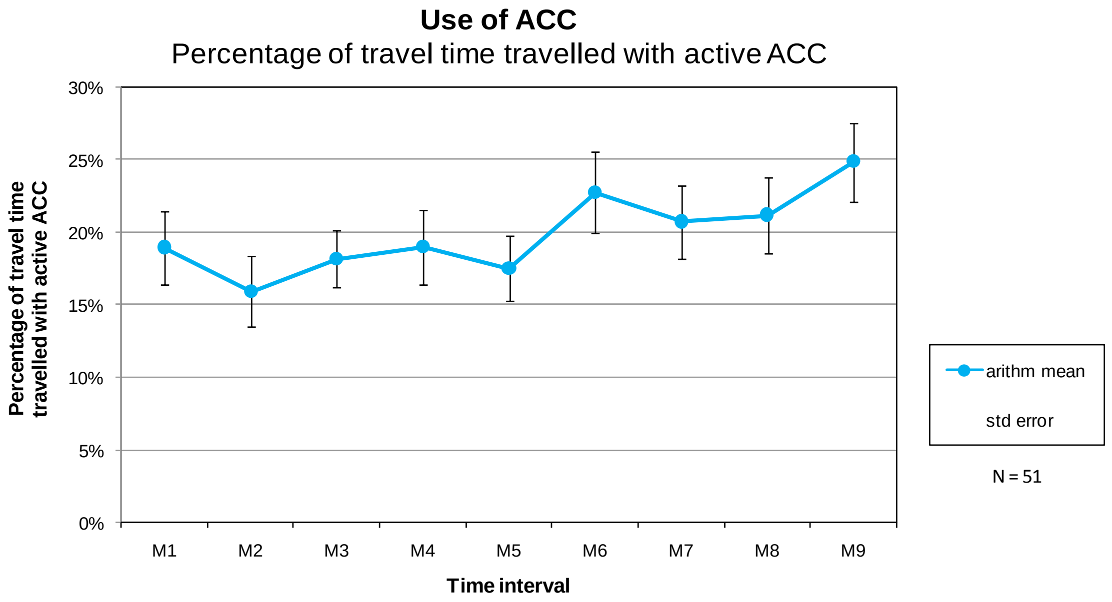
Data

All of the available data in DB divided per driver. N = 93 drivers

Statistical Methods

1. Kolmogorov-Smirnov test for assessing normality of data
2. Friedman test, one-way repeated measures analysis of variance by ranks
3. Wilcoxon test between pairs of samples, only in case that Friedman test indicated an effect of a factor

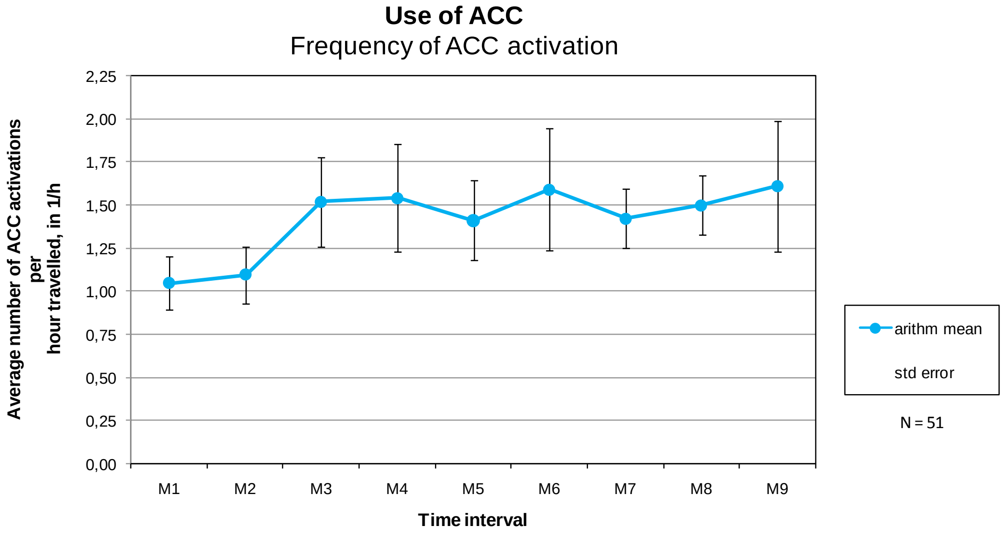
Results



	N	Percentiles			Mean	Standard error
		25th	Median	75th		
PI1-U3_M1: Time travelled with ACC=active divided by total time travelled during interval 1.	51	0.01	0.17	0.32	0.19	0,03
PI1-U3_M9: Time travelled with ACC=active divided by total time travelled during interval 9.	51	0.07	0.23	0.39	0.25	0,03

Statistics of Friedman test	
N	51
Chi-Quadrat	18.864
df	8
Asymptotic significance p	0.016

Statistics of Wilcoxon test	
	PI1-U3_M9 – PI1-U3_M1
Z	-2.098
Asymptotic significance p (2-sided)	0.036



	N	Percentiles			Mean	Standard error
		25th	Median	75th		
PI2-U3_M1: Number of ACC activations divided by total time travelled during interval 1. Unit: 1/h	51	0.23	0.78	1.50	1.05	0,16
PI2-U3_M9: Number of ACC activations divided by total time travelled during interval 9. Unit: 1/h	51	0.51	1.03	1.69	1.61	0,38

Statistics of Friedman test	
N	51
Chi-Quadrat	15.713
df	8
Asymptotic significance p	0.047

Statistics of Wilcoxon test	
	PI2-U3_M9 – PI2-U3_M1
Z	-2.405
Asymptotic significance p (2-sided)	0.016

Conclusions

The results confirm hypothesis ACC-U3 for the total data set (over all factors). There is a significant increase of ACC use in the last month of the treatment compared to the first month of the treatment both for duration of travelling with active ACC and frequency of ACC activations. The drivers seem to get used to the positive perception of the ACC system and use the system longer and more often over the time.

The driver changes the use of ACC over time by increasing the occurrence of overriding the ACC function by using the accelerator pedal (passenger cars)

Comparison situations

Comparison between 9 consecutive time intervals of equal length (1 month) during treatment

Filtering criteria

1. Trip duration > 5 min.
2. Only travel times with ACC=active
3. Vehicle speed > 30 km/h

Factors

1. Overall
2. Weather

Performance indicators (PIs)

Number of overriding the ACC by pushing the accelerator pedal during time interval x, divided by time travelled with active ACC during time interval x

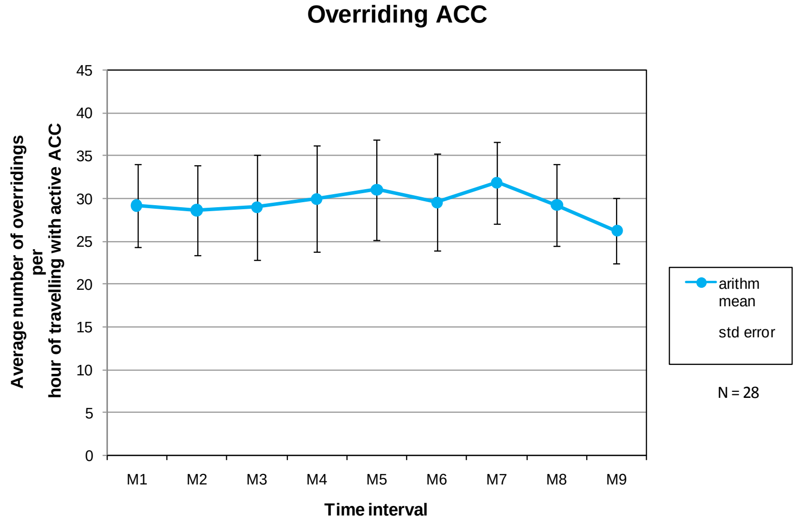
Data

All of the available data in DB divided per driver. N = 93 drivers

Statistical Methods

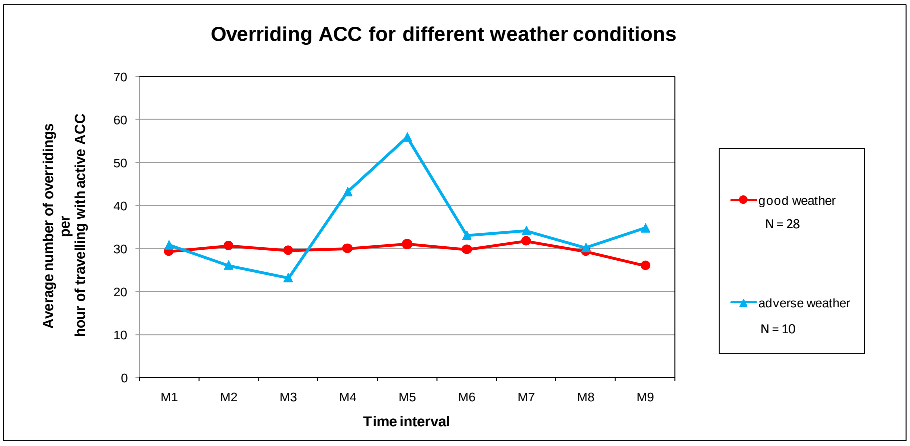
1. Kolmogorov-Smirnov test for assessing normality of data
2. Friedman test, one-way repeated measures analysis of variance by ranks
3. Wilcoxon test between pairs of samples, only in case that Friedman test indicated an effect of a factor

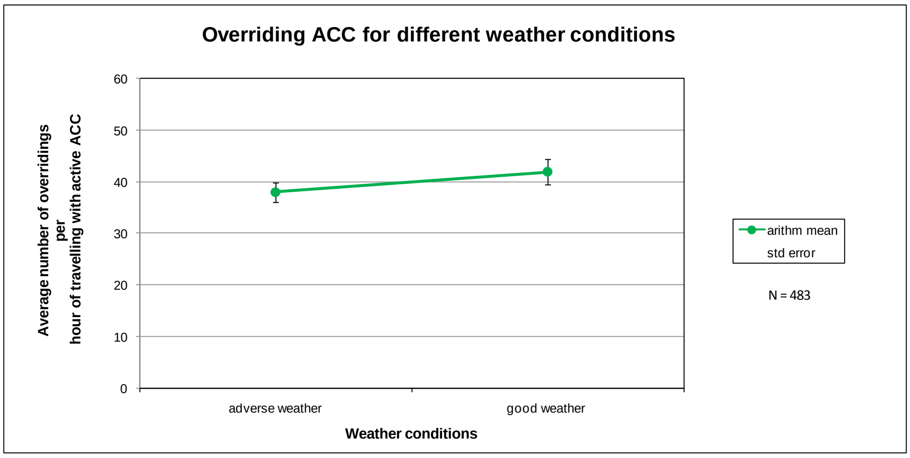
Results



	N	Percentiles			Mean	Standard error
		25th	Median	75th		
PI-U2_M1: Number of overriding divided by time travelled with active ACC during interval M1. Unit: 1/h.	28	8.1	27.2	39.9	29.2	4.9
PI-U2_M9: Number of overriding divided by time travelled with active ACC during interval M9. Unit: 1/h.	28	10.2	23.9	30.4	26.2	3.8

Statistics of Friedman test	
N	28
Chi-Quadrat	7.172
df	8
Asymptotic Significance p	0.518





Statistics of Wilcoxon test	
	PI_Overr_good – PI_Overr_adv
Z	-4.303
Asymptotic significance p (2-sided)	0.000

Conclusions

Overriding the ACC showed a slight decrease over time when comparing the first month and last month of treatment, but the difference is not significant.
It was assumed that time of the year had some influence (adverse weather in winter time). Therefore, additional tests were made in order to analyse the effect of weather conditions on overriding. The hypothesis ACC-U2 could not be confirmed for each of the two weather conditions (adverse weather, good weather). In good weather conditions the number of overriding remained nearly unchanged over the first eight months of treatment and showed a slight decrease only in the last month. In adverse weather conditions the number of overriding strongly varied over time.
However, weather conditions showed a significant effect on overriding, if data of the whole treatment phase was used for the calculation, i.e. no splitting up of data per time interval. Overriding is significant higher in good weather conditions than in adverse weather conditions.
In total, one may conclude that drivers learned quickly how to override the ACC and used overriding when required and weather condition allows doing so. The results show a tendency for a decrease of overriding at the end of the treatment phase which may be an indication for the drivers' increased positive perception of the comfort related to the automatic functions of the ACC.

The driver changes the use of ACC over time by increasing occurrence of overriding the ACC system by using the accelerator pedal (trucks)

Comparison situations

All trips in the treatment period were labeled either “before” or “after” in such a way that for each driver

- Any trip labeled “after” was done later than any trip labeled “before”.
- The total duration of the trips labeled “before” is (approximately) equal to the total duration of the trips labeled “after”.

We then compared the accelerator pedal use given ACC is active “before” (Baseline) and “after” (Treatment).

Filtering criteria

We discarded trips with unknown *driver ID*, and excluded drivers which have not used ACC during Baseline or Treatment, or where the usage was to a large extent unbalanced.

Factors

1. Road type: any or motorway
2. Load: any or loaded

Performance indicators (PIs)

Percentage of time the accelerator pedal is used given ACC is active.

Chunking

None

Data

The data was paired according to *driver ID*. After filtering we had a total of 38 drivers.

Statistical Methods

We did extensive exploratory data analysis using the Matlab toolbox which we have developed exclusively to address this and similar hypotheses, see [1]. We then performed a paired (according to driver ID) t-test in order to see whether the difference in LDW usage between Baseline (“before”) and Treatment (“after”) is statistically significant. The analysis was done separately for all possible choices of factor levels.

Results

Hypothesis	Factors	Response variables	Baseline ("before")	Treatment ("after")	Result
U2, Volvo	Road: any Load: any	Accel. pedal usage: Number of trips: ACC active (h):	6.5% 2198 1 725	5.2% 2154 1 640	0.9% increase. p-value: 0.107
U2, Volvo	Road: motorway Load: any	Accel. pedal usage: ACC active (h):	6.7% 2 923	7.3% 2 345	0.6% increase. p-value: 0.106

Conclusions

We observed that the usage of accelerator pedal when the ACC is active decreased from 6.5% to 5.2% (road type: any) and from 6.2% to 5.2% (road type: motorway). The decrease was not statistically significant (at 5% significance level).

The acceptance of ACC will be positive

Comparison situations

T4: Subjective ratings of acceptance using the Van der Laan scale.

Performance indicators (PIs)

For evaluation of acceptance using the Van der Laan scale the following 9 items are rated on a scale from -2 to +2:

- **useful**
- pleasant
- **good**
- nice
- **necessary**
- likeable
- **assisting**
- desirable
- **raising alertness**

In the Van der Laan scale, acceptance is also broken down into Usefulness and Satisfaction. The average rating of the bold elements is considered to be a measure of **usefulness** and the average of the remaining items is a measure of satisfaction.
In addition to the nine Van der Laan items, eleven additional items which also gives an indication of level of acceptance were included in the questionnaire:

- effective
- raises confidence
- simple
- satisfying
- trustworthy
- intuitive
- competent
- reliable
- attractive to buy
- intend to use
- social pressure

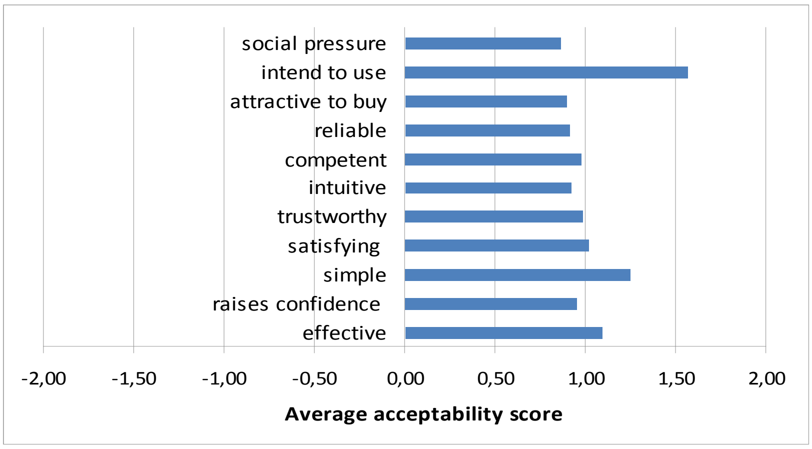
Data

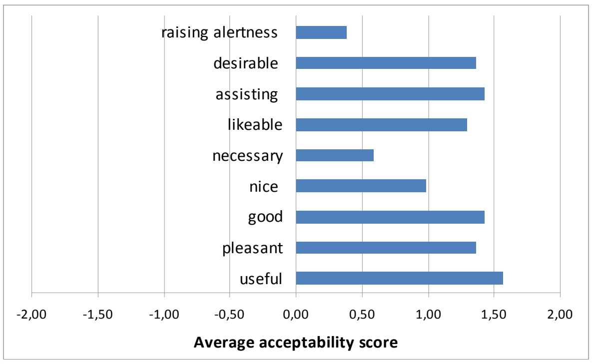
Items under ACC_ac_1_4 in the questionnaire

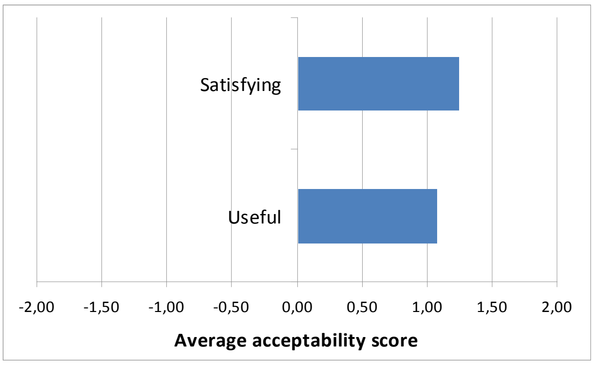
Statistical Methods

None

Results







Conclusions

Acceptance (i.e. usefulness and satisfaction) of the ACC system is very high. For the items used in the Van der Laan scale the system is, among others, considered as both very useful and assisting.

ACC increases driving perceived safety and comfort

Comparison situations

T4 Questionnaire: Evaluation of system at end of the FOT

Performance indicators (PIs)

1. Subjective rating if comfort of the driving task was affected.
2. Subjective rating of increased safety.

Data

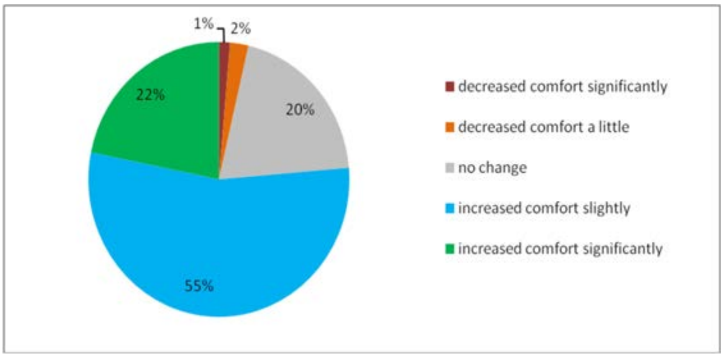
- Subjective rating of comfort according to the question “Please indicate, by circling the appropriate number, how the Adaptive Cruise Control system has affected the following: Comfort of the driving task.” Item ACC_sys_1h_4 is included in questions on system effects and coded on a five score scale from 1 (decreased comfort significantly) to 5 (increased comfort significantly).
- Subjective rating of increased safety according to the question “Please indicate whether you found the system increasing safety or not. “ Item ACC_use_2d_4 is included in questions on perceived usefulness and coded yes/ no.

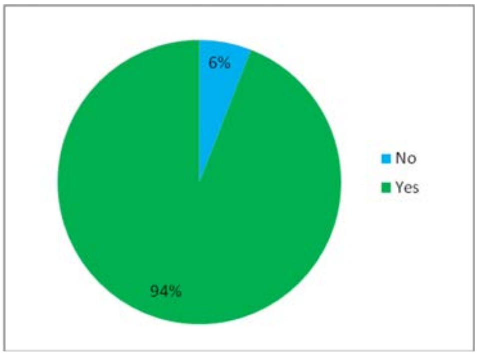
Statistical Methods

$\chi 2$ test performed to establish if differences exist.

Results

- Affect comfort of the driving task: $\chi 2$ = 3.96E-36
- Increased safety: $\chi 2$ = 5.12E-36





Conclusions

ACC increases driving perceived safety and comfort significantly. 3% of all drivers felt that comfort of the driving task decreased when using ACC. 20% perceived no changes in comfort. The majority perceived an increase in comfort of which 22% rated the increase as significant.
94% of all drivers which were asked if the ACC system increases safety answered yes, 6% answered no.

Certain features of the systems, in terms of usability, influence acceptance

Comparison situations

T4 Questionnaire: Subjective ratings of acceptance using the Van der Laan scale.

Performance indicators (PIs)

For evaluation of acceptance 33 items under the concept of Perceived Ease of Use (usability) have been rated on a scale from -2 to +2 (Strongly disagree to Strongly agree).

Data

Items under ACC_eas_1_4 in the questionnaire

Statistical Methods

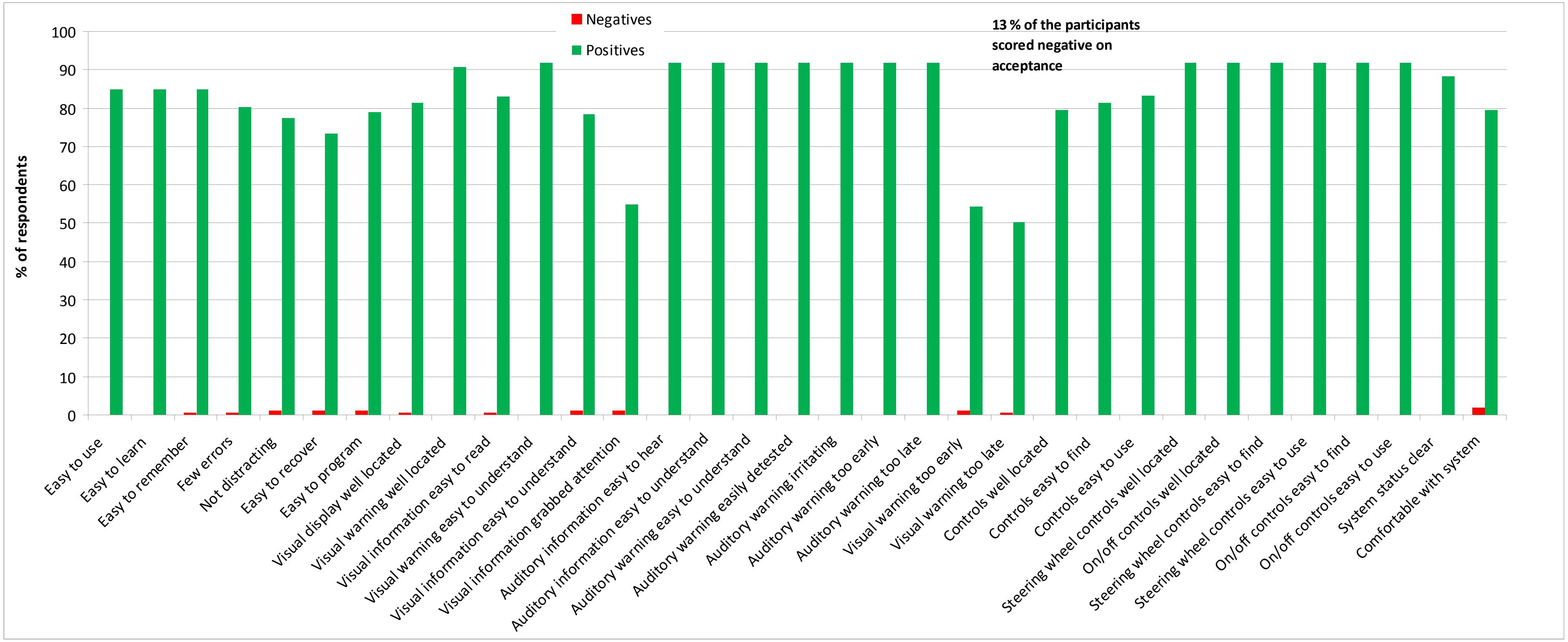
The task is to identify the usability items that influence acceptance scores
Each participant is considered separately, such that if a participant scored the system positively on the Van der Laan scale in ACC9, then those scores that score high (>0) on usability were deemed to have impacted on that score. Conversely, if a participant scored the system negatively on the Van der Laan scale, then there will be certain items relating to usability that would contribute to this.

Results

(See next page)

Conclusions

3 % of the drivers scored negative on acceptance. In general the green bars, which represent the number of positive drivers for each usability item, are very high. Only some items concerning visual information were rated lower than the others.



Explanations of the diagram:
The height of the red bars indicates where a “negative” participant rated the system as negative on that particular item. A “negative” participant is one whose average acceptability score is negative.
The height of the green bars indicates where a “positive” participant rated the system as positive on that particular item. A “positive” participant is one whose average acceptability score is positive.

Certain features of the systems, in terms of usefulness, influence acceptance

Comparison situations

T4 Questionnaire: Do participants with negative acceptance to the system rate usability items different from the positive drivers?

Performance indicators (PIs)

9 items under the concept of Perceived Usefulness have been rated on a scale from -2 to +2 (Strongly disagree to Strongly agree). Usefulness is rated by the driver at different driving scenarios, i.e. driving on different road types under various conditions.

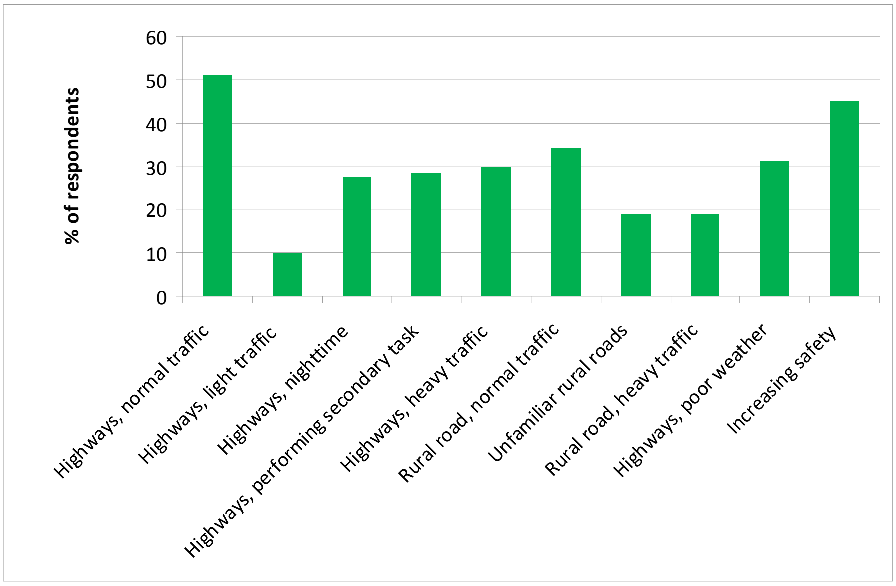
Data

Items under ACC_use_1_4 in the questionnaire

Statistical Methods

Each participant is considered separately, such that if a participant scored the system positively on the Van der Laan scale in ACC9, then those scores that scored high (>0) on usability were deemed to have impacted on that score.

Results



Conclusions

Usefulness on highways in normal traffic contributed the most to positive acceptability scores. Also a relative high proportion of the respondents felt that the system increased safety.

Trust in system changes over time with system use

Comparison situations

1. T2 Questionnaire: Expectance in system; evaluation before usage
2. T3 Questionnaire: Evaluation of system during usage
3. T4 Questionnaire: Evaluation of system at end of the FOT

The hypothesis is interpreted as suggesting that acceptability changes once the system has been used. Therefore time 2 (before use) data is included in the analysis.

Performance indicators (PIs)

1. Subjective rating of trust on van der Laan scale (subscales reliable, trustworthy & raises confidence).

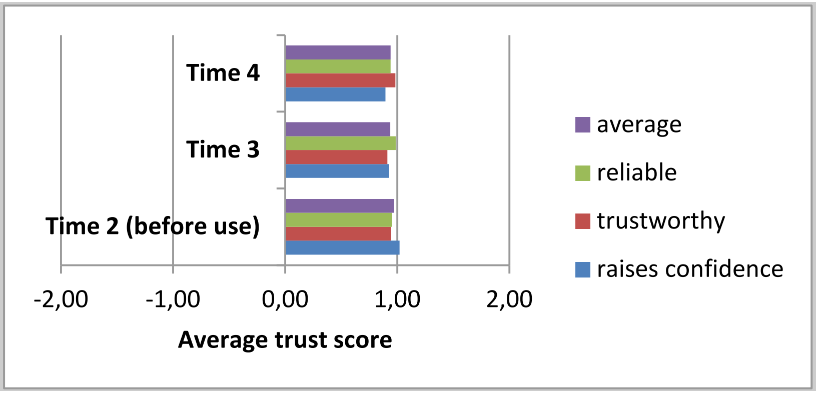
Data

Subjective ratings per drivers according to the question "Thinking about the Adaptive Cruise Control system and how it might affect driving, please indicate how appealing the system is to you by ticking the box that most accurately expresses your feelings on each line." Items are included in van der Laan scale (items ACC_tr_1 "raises confidence - creates uncertainty", ACC_tr_2 "trustworthy - untrustworthy" and ACC_tr_3 "reliable - unreliable") and are coded on a five score scale from +2 (positive rating) to -2 (negative rating).

Statistical Methods

T-tests conducted to compare the trust results at time 2, time 3, and time 4.

Results



	Average trust			Raises confidence			Trustworthy			**Reliable**		
	df	t	p	df	t	p	df	t	**p**	**df**	**t**	**p**
T2 vs T3	198	1.05	0.29	198	2.09	<0.05	198	0.65	0.52	198	-0.07	0.94
T3 vs T4	199	-0.04	0.97	199	0.61	0.54	199	-1.36	0.17	199	0.74	0.46
T2 vs T4	194	0.77	0.44	194	2.13	<0.05	194	-0.44	0.66	194	0.28	0.78

Significant changes are marked in red

Conclusions

Confidence in the system decreases significantly from T2 (before the system use) to T3 (when system is used) with an effect size of 0.49 (Pearson's r) as well as from T2 (before the system use) to T4 (end of FOT) with an effect size of 0.39 (Pearson's r). Changes in trustworthy and reliable are not significant. Same applies for average trust which is based on all three items confidence, trustworthy, and reliable.

Average trust in the ACC system is not changing over time. Nevertheless, confidence in the system is decreasing significantly when system is used compared to before use which means that the driver had higher expectations regarding "raises confidence" than the system could fulfil.

User practices (heuristics/rules) will change over time during the FOT

Comparison situations

T4 Questionnaire: Evaluation of system at end of the FOT

Performance indicators (PIs)

% Frequency count of number of participants who responded to the question on user practice change

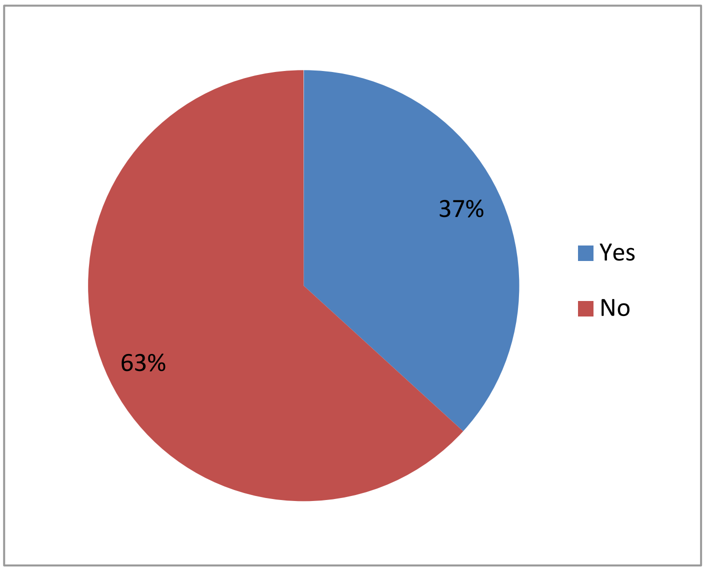
Data

223 Driver's answers according to the question (user practice): "Do you use the Adaptive Cruise Control system differently now from the way you did when you first started using the system?" and "If yes, in what ways?" First item (ACC_upr1a_4) requires a yes/ no response. Second item (ACC_upr1b_4) is open ended.

Statistical Methods

None, descriptive

Results



Conclusions

63% of the drivers did not use the ACC system differently at the end of the FOT from the way they did when they first started using the system. 37% of the drivers changed their usage of the system over time during the FOT.

Drivers will not abuse or misuse ACC

Comparison situations

T4 Questionnaire: Evaluation of system at end of the FOT

Performance indicators (PIs)

Frequency count of number of participants who responded items under abuse/ misuse

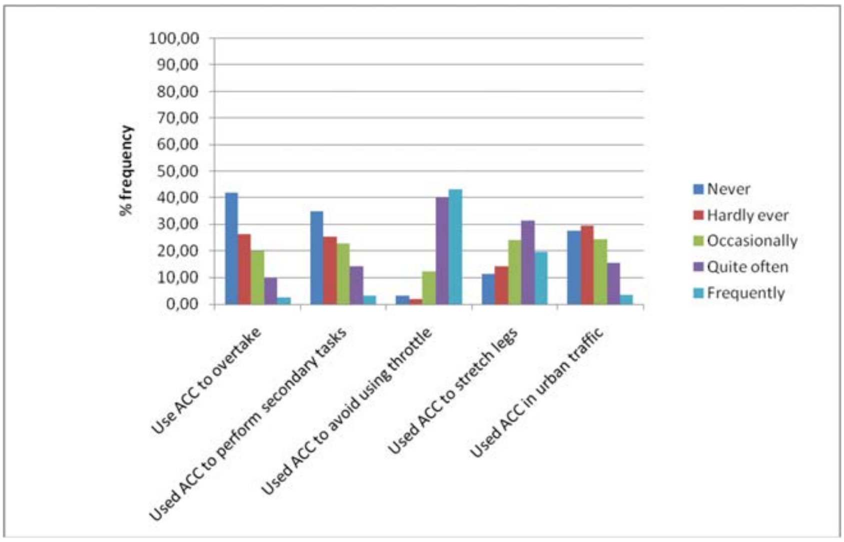
Data

Items for ACC_mis_1_4 are included in questions on system use and coded on a five score scale from 0 to 4: never (0), hardly ever (1), occasionally (2), quite often (3) and frequently (4).

Statistical Methods

None

Results



Conclusions

Some of the expected changes in driver behaviour also occurred, e.g. drivers take their foot off the accelerator and stretch out when using ACC. For cars, engagement in secondary tasks also increased, but interestingly, only for non-critical driving episodes, not during actual critical events. This indicates that drivers do make use of the “freedom” to think and move that ACC provides when engaged, but do so in a selective and safe manner.

Acceptance changes over time with system use

Comparison situations

1. T2 Questionnaire: Evaluation of system before use
2. T3 Questionnaire: Evaluation of system after use
3. T4 Questionnaire: Evaluation of system after end of condition

Performance indicators (PIs)

For evaluation of acceptance using the Van der Laan scale the following 9 items are rated on a scale from -2 to +2 at different times during use.

- useful
- pleasant
- good
- nice
- necessary
- likeable
- assisting
- desirable
- raising alertness

Data

Item: Please indicate how appealing you find the ACC system by ticking the box that most accurately expresses your feeling on each line. (Useful- Useless; Pleasant- Unpleasant; Good-Bad; Nice-Annoying; Necessary-Superfluous; Likeable-Irritating; Assisting-Worthless; Desirable-Undesirable; Raising alertness-Sleep-inducing).

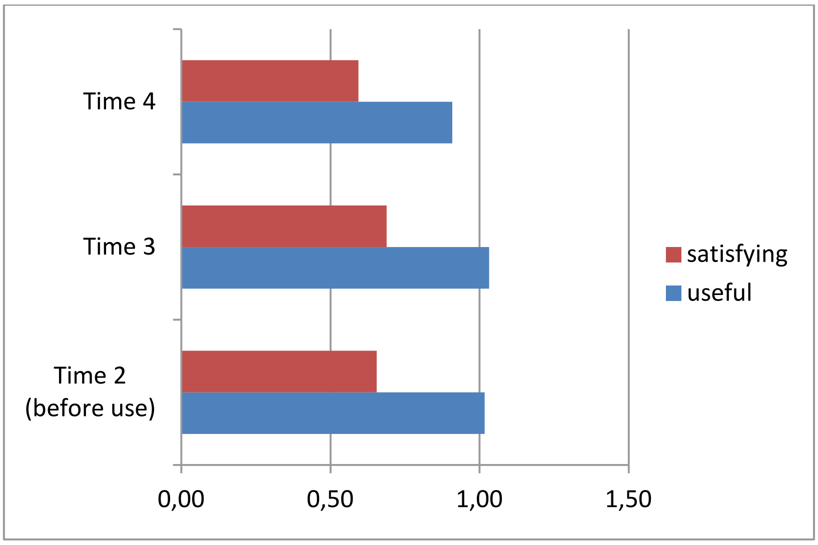
Statistical Methods

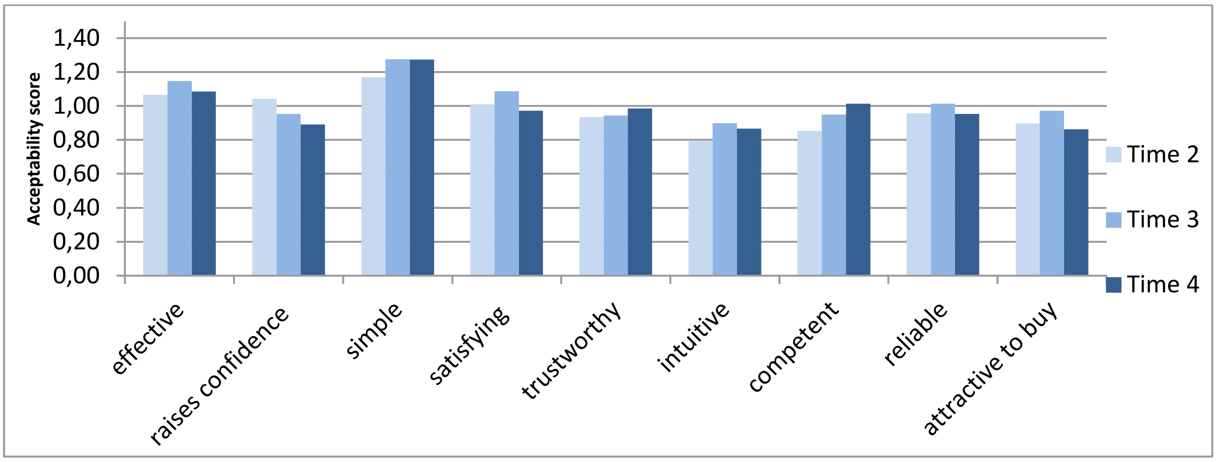
Wilcoxon Signed Rank Test **useful and satisfaction**: T3 vs T4

	Median		N	Z	Amp. Sig (2-tailed)
Useful	T3	1.1	210	-0.561	0.575
	T4	1.0			
Satisfaction	T3	0.8	290	-2.234	0.025
	T4	0.6			

A Wilcoxon Signed Rank Test revealed there are not statistically significant differences in usefulness between Time 3 and Time 4 but there was a difference in satisfaction with a reduction in satisfaction score, $z=-2.234$, $p<0.05$, with a small effect ($r=0.092$). The median of T3 decreases from 0.8 to 0.6 (T4).

Results





Conclusions

Regarding changes over time for the satisfying and useful criteria it was appreciated that useful increase over the time from T2 to T3, but it has a minimum decrease from T3 to T4 although this difference is not statistically significant. With regard of satisfaction, similar trend is found. In this case, the difference is statistically significant although the effect is small. Anyway, as it can be observed in the graphs, the bars have positive scores.

With reference to acceptability scores, the values are more or less similar among the three times. All the values are positive for the 9 adjectives used to assess the satisfactoriness of drivers using ACC. The highest values are for the item which assesses the simplicity of the system. Therefore drivers' perception is very positive using this scale.

Using ACC, focus and level of engagement on secondary tasks will increase

Comparison situations

1. T4 Questionnaire: Subjective rating of number secondary tasks when use ACC vs. not using ACC
2. T1 Questionnaire: Subjective rating of frequency drive on highways

Performance indicators (PIs)

1. Subjective rating for change of use ACC while to perform other tasks between 1 = never and 5 = frequently.

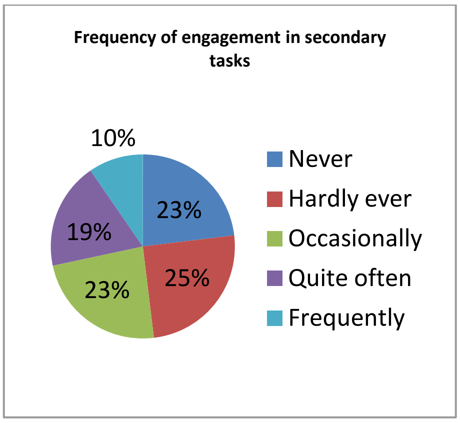
Data

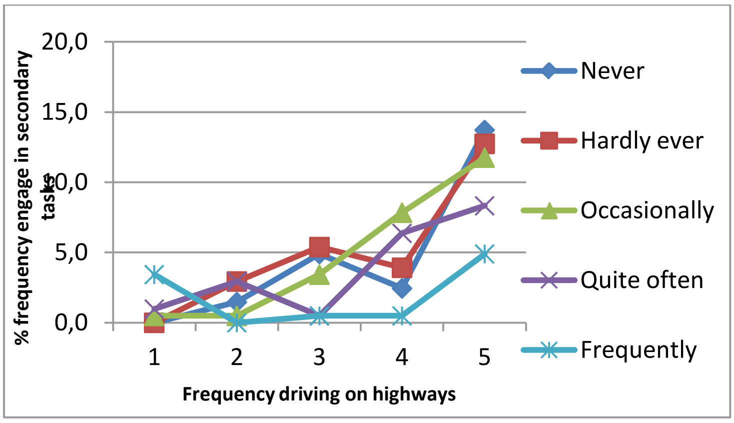
mis_1b_4: Use the ACC in order to have longer time to perform other tasks (e.g. eating, changing radio) 0= Never 4=Frequently
dex_5a_r: How often do you drive on highways? 1=Never, 5=Often

Statistical Methods

None

Results





Conclusions

This variable is only measured in T4. Therefore, no measure of change over time is available. Around 23% of participants did not engage in secondary tasks, 25% engaged hardly ever, and 23% engaged occasionally. Only 19% engaged with other tasks different from the primary task and 10% does that frequently. Therefore, it seems that most of the drivers are not involved in secondary tasks, and if they are, they do not spend too much time on it.

The more frequently drivers use highways, the more they engage in secondary tasks (even though overall this likelihood is small). Regardless, those who frequently drive on highways have low scores of percentages of frequency engage in secondary tasks. It could be explained that most experienced are drivers running in highways, less implicated are them with secondary task. Moreover, the percentages about implication in secondary task are lower of 15%.

Driver workload decreases over time with the system

Comparison situations

T3 Questionnaire: Evaluation of system during of usage
T4 Questionnaire: Evaluation of system after end of condition

Performance indicators (PIs)

1. Subjective impression how much effort it took for the drive in those situations
2. Subjective scale coded 0-150

Data

Item on mental efforts while driving with ACC

Statistical Methods

Friedman test

Results

	Median		N	Chi-square	Gl	Amp. Sign.
Everyday driving	T3	20	161	0.225	1	0.635
	T4	20				
On highways normal traffic	T3	20	161	0.743	1	0.389
	T4	20				
On rural roads normal traffic	T3	20	164	0.263	1	0.652
	T4	20				
On highways in high traffic	T3	40	8	0.143	1	0.705
	T4	45				
On highways in bad weather conditions	T3	40	7	3.571	1	0.059
	T4	35				
On trajectories with changing speed limits	T3	37.5	10	0	1	1
	T4	50				

Conclusions

With regards to driver workload the scores increase after trying the system between Time 3 and Time 4. However, Friedman Tests revealed that there are no statistically significant differences between the six conditions. Conditions as “On highways in high traffic”, “On highways in bad weather conditions” and “On trajectories with changing speed limits” have scores of around 50%.

Annex 2 Forward Collision Warning (FCW)

List of selected hypothesis

List of selected hypothesis for FCW is the following one:

Table 2: List of hypothesis for FCW

Certain features of the FCW system, in terms of usability, influence acceptance
Certain features of the FCW system, in terms of usefulness, influence acceptance
Acceptance changes over time with system use
Trust in system changes over time with system use
User practices (heuristics/rules) will change over time during the FOT
Focus on forward roadway in crash relevant events is lower when using FCW+ACC
In normal (non-conflict) driving, focus and level of engagement on secondary tasks will increase when drivers use FCW+ACC
Drivers will not abuse or misuse FCW
Using FCW, focus and level of engagement on secondary tasks will increase
Driver workload decreases over time with the system
Using FCW+ACC, driver's reaction time (time to reach the brake pedal) will increase if ACC is used most of the time and decrease if only the FCW function is actually used
ACC+FCW use increases over time

The acceptance FCW will be positive

Comparison situations

T4: Subjective ratings of acceptance using the Van der Laan scale.

Performance indicators (PIs)

For evaluation of acceptance using the Van der Laan scale the following 9 items are rated on a scale from -2 to +2:

- useful
- pleasant
- good
- nice
- necessary
- likeable
- assisting
- desirable
- raising alertness

In the Van der Laan scale, acceptance is also broken down into Usefulness and Satisfaction. The average rating of the bold items is considered to be a measure of usefulness and the average of the remaining items are satisfaction.

2.In addition to the nine Van der Laan items, eleven additional items which also gives an indication of level of acceptance were included in the questionnaire:

- effective
- raises confidence
- simple
- satisfying
- trustworthy
- intuitive
- competent
- reliable
- attractive to buy
- intend to use
- social pressure

These items were also rated on a scale from -2 to +2.

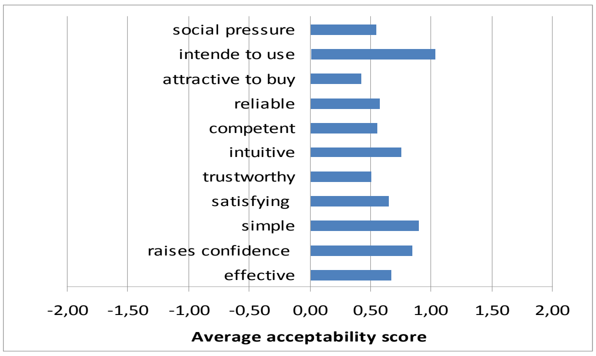
Data

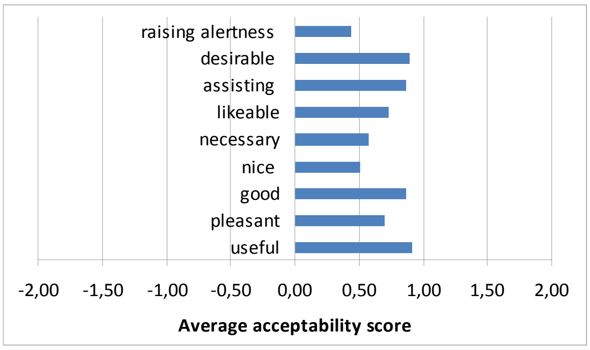
Items under ACC_ac_1_4 in the questionnaire

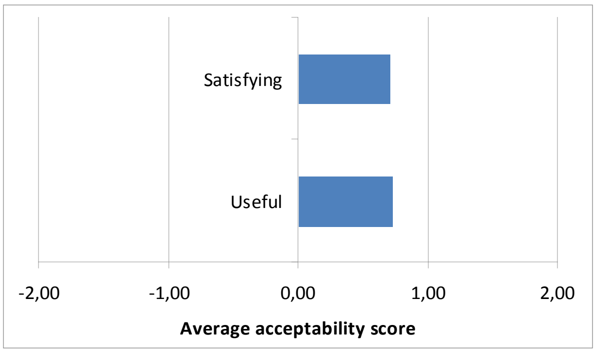
Statistical Methods

None

Results







Conclusions

The FCW is considered as a good system which is useful as well as assisting and desirable. It is also a system that the participant intends to use. Satisfaction and usefulness is rated at the same levels.

Certain features of the FCW system, in terms of usability, influence acceptance

Comparison situations

T4: Subjective ratings of acceptance using the Van der Laan scale. Given that this is not a well defined hypothesis, we will only present the data descriptively.

Performance indicators (PIs)

For evaluation of acceptance 33 items under the concept of Perceived Ease of Use (usability) have been rated on a scale from -2 to +2 (Strongly disagree to Strongly agree).

Data

Items under FCW_eas_1_4 in the questionnaire

Statistical Methods

The task is to identify the usability items that influence acceptance scores

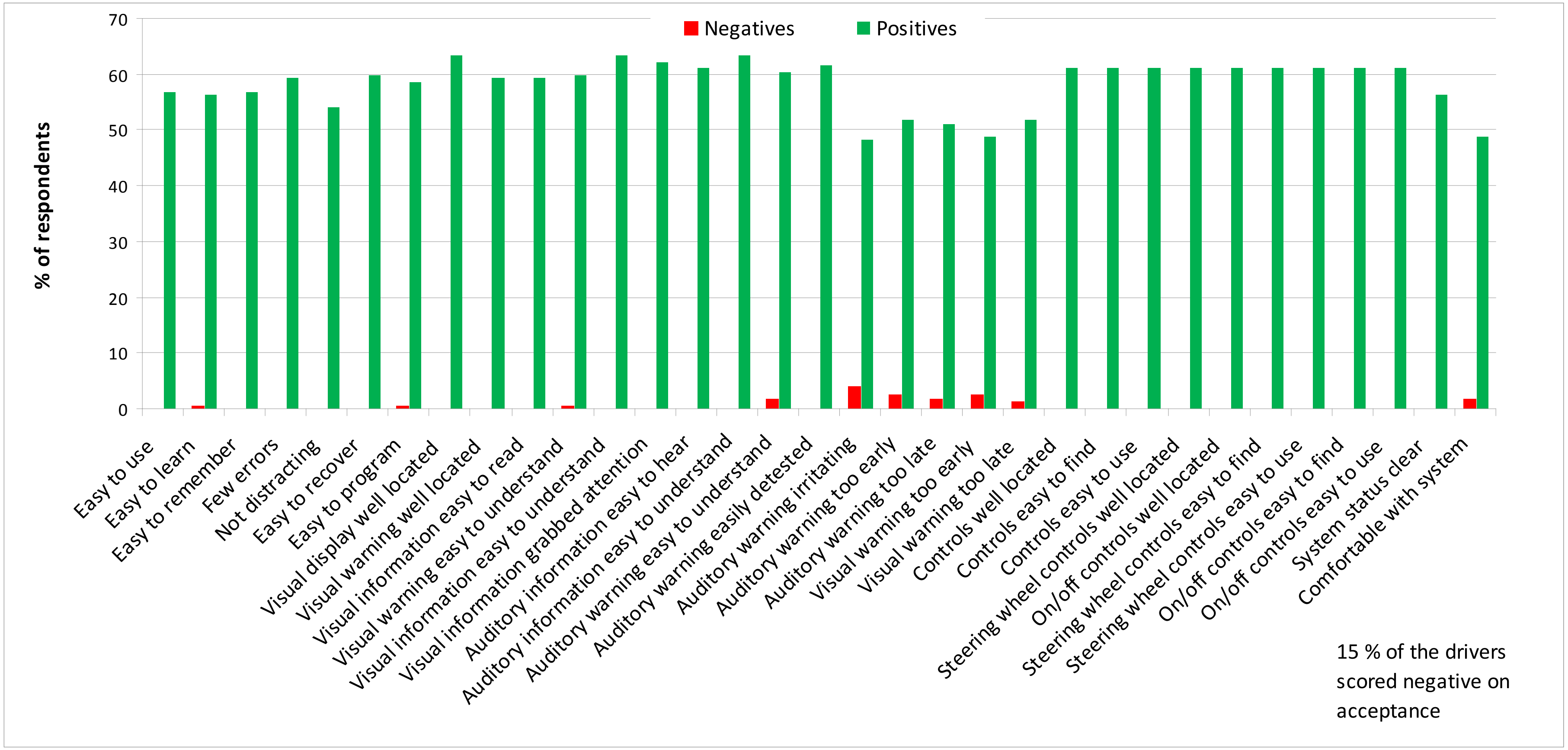
Each participant is considered separately, such that if a participant scored the system positively on the Van der Laan scale in FCW9, then those scores that score high (>0) on usability were deemed to have impacted on that score. Conversely, if a participant scored the system negatively on the Van der Laan scale, then there will be certain items relating to usability that would contribute to this.

Results

See Figure on next page.

Conclusions

In general the green bars, which represent the number of positive drivers for each usability item are very high. Only items related to the auditory and visual warning systems have less positive rating.



Explanations of the diagram:

The height of the red bars indicates where a “negative” participant rated the system as negative on that particular item. A “negative” participant is one whose average acceptability score is negative.

The height of the green bars indicates where a “positive” participant rated the system as positive on that particular item. A “positive” participant is one whose average acceptability score is positive.

Certain features of the FCW system, in terms of usefulness, influence acceptance

Comparison situations

T4: Do participants with negative acceptance to the system rate usability items different from the positive drivers? Given that this is not a well defined hypothesis we will only present the data descriptively.

Performance indicators (PIs)

9 items under the concept of Perceived Usefulness have been rated on a scale from -2 to +2 (Strongly disagree to Strongly agree). Usefulness is rated by the driver at different driving scenarios, i.e. driving on different road types under various conditions.

Data

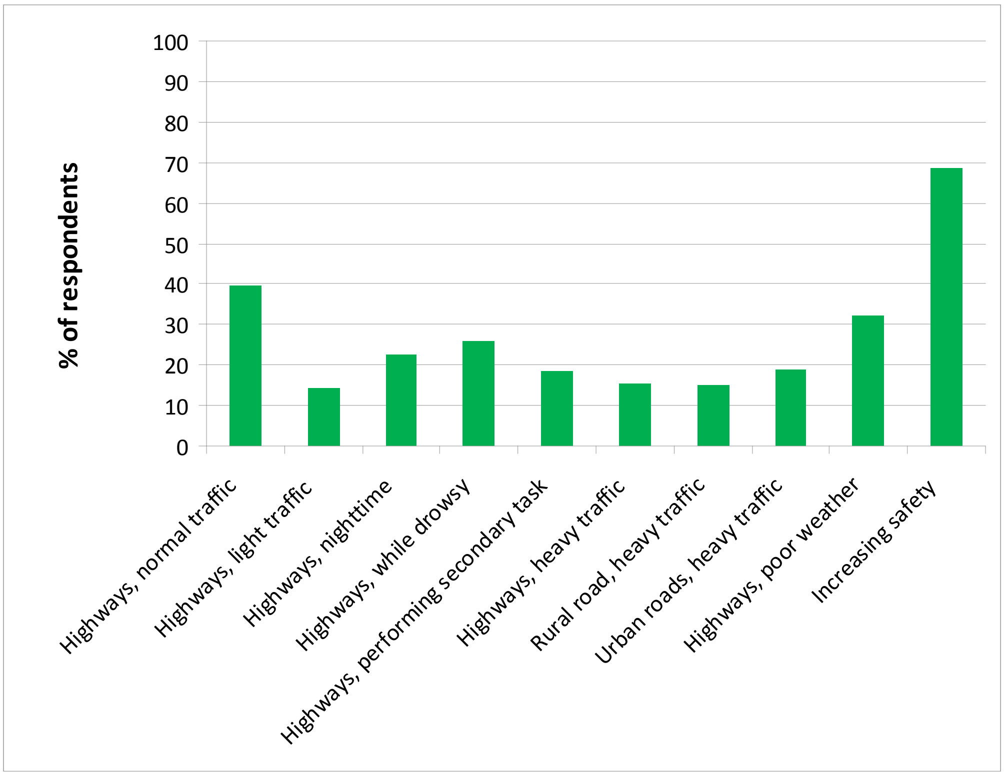
Items under FCW_use_1_4 in the questionnaire.

Statistical Methods

The task is to identify the usefulness items that influence the positive acceptance scores

Each participant is considered separately, such that if a participant scored the system positively on the Van der Laan scale in FCW9, then those scores that score high (>0) on usability were deemed to have impacted on that score.

Results



Conclusions

Usefulness on highways in normal traffic contributed the most to positive acceptability scores. Also a relative high proportion of the respondents felt that the system increased safety.

Acceptance changes over time with system use

Comparison situations

T2: Evaluation of expectations of system before they are activated in the car.
T3: Evaluation of the system once the drivers had accumulated relatively extensive experience with the system, i.e. after approximately half of the treatment period had passed.
T4: Evaluation of system after Treatment period is completed.

Performance indicators (PIs)

For evaluation of acceptance using the Van der Laan scale the following 9 items are rated on a scale from -2 to +2 at different times during use.

- useful
- pleasant
- good
- nice
- necessary
- likeable
- assisting
- desirable
- raising alertness

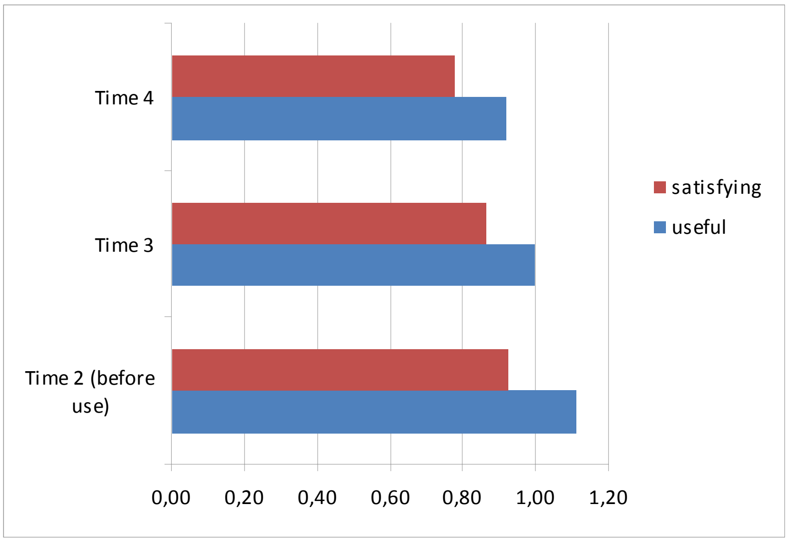
Data

Items under
FCW_ac_1_2 .
FCW_ac_1_3 and
FCW_ac_1_4 in the questionnaire.

Statistical Methods

Paired T-test is conducted to compare the usefulness and satisfaction results in T3 vs. T4.
As a reference, also acceptance at T2 (before use) is presented.

Results



Conclusions

Usefulness and satisfaction does not change over time with use. Perceived usefulness is however judged to a little bit lower than expected before use of the system.

Drivers overall found FCW both useful and satisfying to use. For Usefulness the expectations are not fulfilled since there is a significant decrease in the scores between T2 and T3.
Over time with system use, Usefulness and Satisfaction remains on a high level and does not change significantly.

Satisfaction		
Time	N	Mean score
T2	155	0,89
T3	155	0,83
T4	155	0,79
p value T2->T3	0,291	
p value T3->T4	0,612	

Usefulness		
Time	N	Mean score
T2	157	1,11
T3	157	0,98
T4	157	0,93
p value T2->T3	0,026	
p value T3->T4	0,456	

Trust in system changes over time with system use

Comparison situations

1. **T2:** Expectance in system; evaluation before usage
2. **T3:** Evaluation of system during usage
3. **T4:** Evaluation of system at end of the FOT

Performance indicators (PIs)

1. Subjective rating of trust on van der Laan scale (subscales reliable, trustworthy & raises confidence).

Data

Subjective ratings per drivers according to the question "Thinking about the Forward Collision Warning system and how it might affect driving, please indicate how appealing the system is to you by ticking the box that most accurately expresses your feelings on each line." Items are included in van der Laan scale (items FCW_tr_1 "raises confidence - creates uncertainty", FCW_tr_2 "trustworthy - untrustworthy" and FCW_tr_3 "reliable - unreliable") and are coded on a five score scale from +2 (positive rating) to -2 (negative rating).

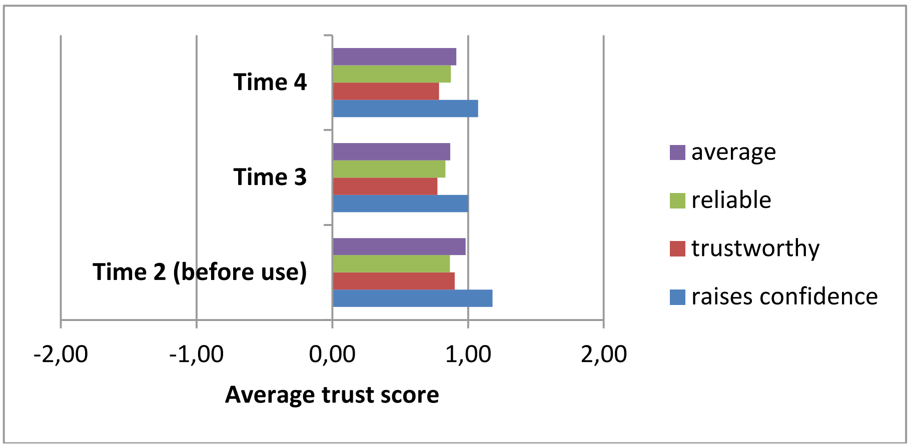
Statistical Methods

T-tests conducted to compare the trust results at time 2, time 3, and time 4.

Results

Results of the t-tests conducted to compare the trust results at time 2, time 3, and time 4 are shown in table. Significant changes are marked red.
Confidence in the system decreases significantly from T2 (before the system use) to T3 (when system is used) with an effect size of 0.54 (Pearson's *r*) as well as from T2 (before the system use) to T4 (end of FOT) with an effect size of 0.43 (Pearson's *r*). Changes in trustworthy and reliable are not significant. Same applies for average trust which is based on all three items confidence, trustworthy, and reliable.

	Average trust			Raises confidence			Trustworthy			Reliable		
	df	t	p	df	t	p	df	t	p	df	t	p
T2 vs T3	160	1.69	0,09	160	2.64	<0.01	160	1.36	0.18	160	0.46	0.64
T3 vs T4	150	0.14	0.89	150	-0.10	0.92	150	0.17	0.86	150	0.24	0.81
T2 vs T4	153	1.46	0.15	153	2.16	<0.05	153	1.49	0.14	153	0.14	0.89



Conclusions

Average trust in the FCW system is not changing over time. Nevertheless confidence in the system is decreasing significantly when system is used compared to before use which means that the driver had higher expectations regarding "raises confidence" than the system could fulfil.

User practices (heuristics/rules) will change over time during the FOT

Comparison situations

For subjective indicators
T4: Evaluation of system at end of the FOT

Performance indicators (PIs)

% Frequency count of number of participants who responded to the question on user practice change.

Data

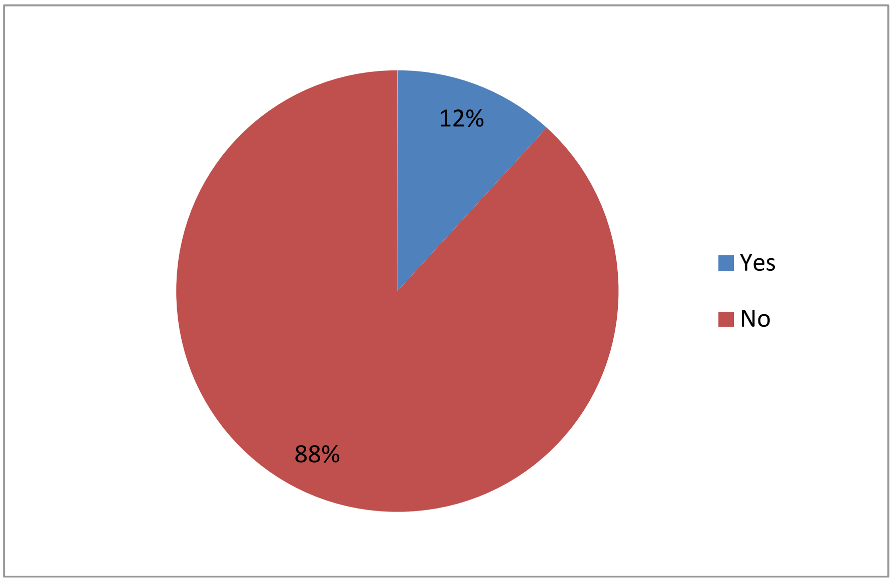
Driver's answers according to the question (user practice): "Do you use the Forward Collision Warning system differently now from the way you did when you first started using the system?" and "If yes, in what ways?" First item (FCW_upr1a_4) requires a yes/ no response. Second item (FCW_upr1b_4) is open ended.

Statistical Methods

None, descriptive

Results

Results are shown in the figure below. 187 drivers have answered the question. 12% of the drivers answered "yes" while 88% answered "no".



Conclusions

The majority of the drivers didn’t use the Forward Collision Warning system differently at the end of the FOT from the way they did when they first started using the system. It can be stated that user practices of the FCW system didn’t change significantly over time during the FOT.

Focus on forward roadway in crash relevant events is lower when using FCW+ACC

Comparison situations

1. **Baseline**: All baseline with vehicle speed above 50km/h **and** THW is not null **and** posted speed > 100km/h.
2. **Treatment**: All treatment with vehicle speed above 50km/h **and** THW is not null **and** posted speed > 100km/h **and** ACC ON (Active) **and** plus five seconds after ACC shut off.

Filtering criteria

1. Vehicle speed > 50 km/h
2. THW is not null (car following)
3. Posted speed > 100km/h
4. Minimum 100km in each one of the four combinations of time (baseline, treatment) and weight (heavy, light)

Factors

Looking at the road vs. not looking at the road

Performance indicators (PIs)

Count of events

Chunking

None

Data

28 crash relevant events

Statistical Methods

Odds ratios with confidence intervals

Results

Odds ratios show increased probability of eyes-off-road in crash relevant events In the treatment phase compared to baseline; however, this result is not significant.

Table 3: Odds ratios

	Odds Ratios	Confidence Interval
Crash Relevant Events	1.50	0.26 - 8.64

Conclusions

The probability of looking away from road in safety critical situations did not significantly change while using ACC+FCW. Note that the number of crash relevant events used was rather small, so results ought to be viewed more as a trend.

In normal (non-conflict) driving, focus and level of engagement on secondary tasks will increase when drivers use FCW+ACC

Comparison situations

1. **Baseline**: All baseline with vehicle speed above 50km/h **and** THW is not null **and** posted speed > 100km/h.
2. **Treatment**: All treatment with vehicle speed above 50km/h **and** THW is not null **and** posted speed > 100km/h **and** ACC ON (Active) **and** plus five seconds after ACC shut off.

Filtering criteria

1. Vehicle speed > 50 km/h
2. THW is not null (car following)
3. Posted speed > 100km/h
4. Minimum 100km in each one of the four combinations of time (baseline, treatment) and weight (heavy, light).

Factors

Secondary Task (yes / no)

Performance indicators (PIs)

Count of events for:

1. General Secondary Task
2. Use of Nomadic Device
3. Manual Secondary Task
4. Visual Secondary Task
5. Cognitive Secondary Task

Data

150 normal driving epochs with video annotation

Statistical Methods

Odds ratios with confidence intervals

Results

All odds ratios did not indicate change in the proportion of secondary tasks between treatment and baseline, further none was not significant.

	Odds Ratios	**Confidence Interval**
General Secondary Task	1.09	0.28 - 4.19
Use of Nomadic Device	4.36	0.36 - 53.3
Manual Secondary Task	0.64	0.14 - 2.97
Visual Secondary Task	3.45	0.50 - 23.9
Cognitive Secondary Task	2.09	0.26 - 16.9

Conclusions

Using ACC+FCW does not increase secondary tasks for truck drivers.

Drivers will not abuse or misuse FCW

Comparison situations

For subjective indicators
T4: Evaluation of system at end of the FOT

Performance indicators (PIs)

Frequency count of number of participants who responded items under abuse/ misuse.

Data

Driver's answers according to the question: "Please indicate how often you have engaged in the following behaviours:

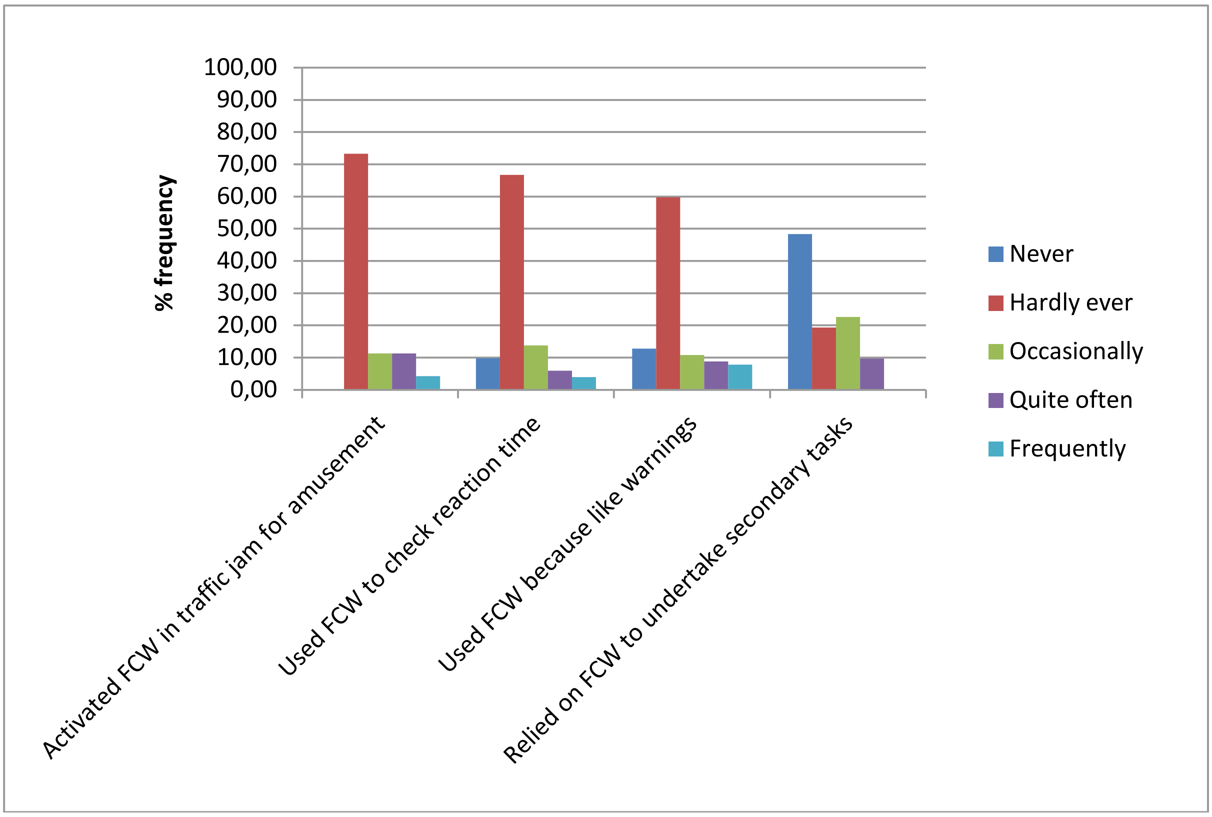
- Used FCW in a traffic jam simply to activate the system for amusement
- Used FCW to check your reaction time
- Used FCW because you like to receive warnings

The drivers rely on the FCW in order to perform other tasks (e.g. eating, changing radio).
Items for FCW_mis_1_4 are included in questions on system use and coded on a five score scale from 0 to 4: never (0), hardly ever (1), occasionally (2), quite often (3) and frequently (4).

Statistical Methods

None, frequency bar charts.

Results



Conclusions

It can be stated that user practices of the FCW system didn't change significantly over time during the FOT.

Using FCW, focus and level of engagement on secondary tasks will increase

Comparison situations

1. **T4**: Subjective rating of number secondary tasks when use ACC vs. not using ACC
2. **T1:** Subjective rating of frequency drive on highways

Performance indicators (PIs)

1. Subjective rating for change of use ACC while to perform other tasks between 1 = never and 5 = frequently.

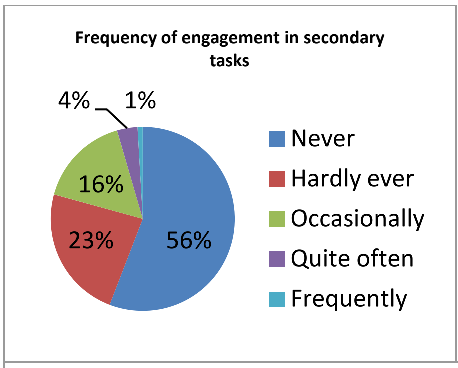
Data

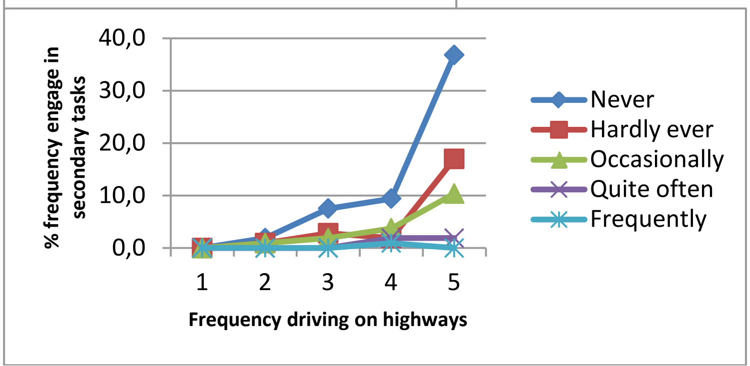
Subjective rating per drivers.
mis_1b_4: Use the ACC in order to have longer time to perform other tasks (e.g. eating, changing radio) 0= Never 4=Frequently
dex_5a_r: How often do you drive on highways? 1=Never 5=Often

Statistical Methods

None.

Results





Conclusions

This variable is only measured in Time 4, therefore no measure of change over time is available. 56% of participants did not engage in secondary tasks, about 23% engaged hardly ever, and 16% engaged occasionally. Less than 5% were engaged with other tasks different from the primary task and only 1% does that frequently. Therefore, it seems that most of the drivers are not involved in secondary task, and if they are, they don’t spend too much time on it.
More drivers run in highways, more they are implicated in secondary tasks. Anyway, those who frequently drive on highways have low scores of percentages of frequency engage in secondary tasks. It could be explained that most experienced are drivers running in highways, less implicated are them with secondary task.

Driver workload decreases over time with the system

Comparison situations

For subjective indicators

1. **T3:** Evaluation of system during of usage
2. **T4:** Evaluation of system after end of condition

Performance indicators (PIs)

1. Subjective impression how much effort it took for the drive in those situations.
2. Subjective scale coded 0-150

Data

Item: The next set of questions is designed to gauge your impression of how much mental effort you experienced when driving. Please think about when you were driving with ACC system in the following situations and indicate, by placing a horizontal line on each scale, how much effort it took for you to drive in those situations. Please leave blank if you have not driven with the system activated in any of the following situations in the last month: “Every day driving”, “On highways in normal traffic” and “On rural roads in normal traffic”.

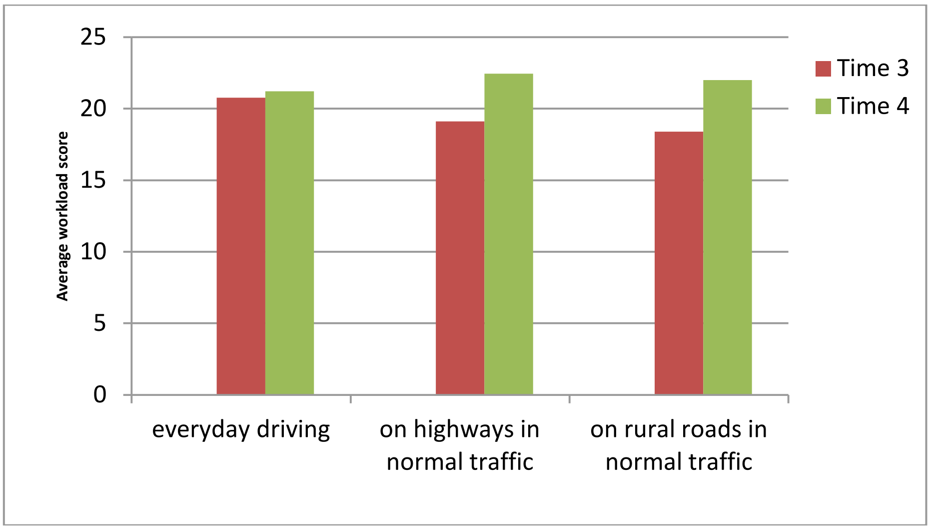
Statistical Methods

Friedman test for the three items

	Median		N	Chi-square	Gl	Amp. Sign.
Everyday driving	T3	20,00	147	,160	1	,689
	T4	20,00				
On highways normal traffic	T3	15,00	83	6,231	1	,013
	T4	20,00				
On rural roads normal traffic	T3	15,00	85	5,586	1	,018
	T4	20,00				

The results of the Friedman Test showed that there was not a statistically significant difference in the first condition but there were statistically significant differences evaluated between both times. The results of this test indicated that there was a statistically significant difference in On highways in normal traffic scores across the two time points (T3 and T4), $\chi^2(1,n=83)=6.231$, $p<.05$. Inspection of the median values showed an increase in workload score from T3 (Md=15) to T4 (Md=20) and On rural roads in normal traffic ($\chi^2(1,n=85)=5.586$, $p<.05$) where the workload increase too (Md=15 for T3 and Md=20 for T4).

Results



Conclusions

With regards to driver workload the scores of driver workload increase after trying the system between Time 3 and Time 4. The increase pattern between “On highways in normal traffic” and “On rural roads in normal traffic” scores showed statistically differences between the two conditions. However, the scores are less than 23%.

Using FCW+ACC, driver's reaction time (time to reach the brake pedal) will increase if ACC is used most of the time and decrease if only the FCW function is actually used

Comparison situations

- Treatment1: Whole treatment with vehicle speed above 50km/h and THW is not null and posted speed > 100km/h and ACC ON and plus five seconds after ACC shut off.
- Treatment2: Whole treatment with vehicle speed above 50km/h and THW is not null and posted speed > 100km/h and ACC OFF (five seconds added in the definition Treatment1 are excluded here so that we avoid an overlap between conditions).

In both conditions 1 and 2, FCW was ON.

Filtering criteria

- Vehicle speed > 50 km/h
- THW is not null
- Expected speed > x (x = 95km/h for fleet1 and x = 115km/h for fleet2)

Factors

None

Performance indicators (PIs)

- Reaction time: Time from the beginning of a forward collision warning until the brake pedal position reaches 5% within a window of three seconds. If the driver was braking within three seconds prior to the warning, this particular reaction time was disregarded.
- Percentage of early reaction: Percentage of time the drivers initiate braking before the warning was issued within a window of three seconds.

Chunking

None.

Data

258 warnings from 16 drivers for PI “reaction time” and 332 warnings from 20 drivers for PI “percentage of early reaction” were used.

Statistical Methods

The non-parametric Wilcoxon signed rank test was used.

Results

Results were only significant for the PI *Percentage of early reaction*, Z = -2.11, p = 0.035, indicating a higher percentage In the treatment phase**2.**

Conclusions

We found no significant difference between the reaction time In the treatment phase**1** and **Treatment2**. Nevertheless, the number or drivers who initiated a reaction before the warning was issued was significantly higher In the treatment phase**2**, i.e., when only FCW was used and ACC was OFF.

ACC+FCW use increases over time

Comparison situations

Al trips in the treatment period were labeled either “before” or “after” in such a way that for each driver

- Any trip labeled “after” was done later than any trip labeled “before”.
- The total duration of the trips labeled “before” is (approximately) equal to the total duration of the trips labeled “after”.
  We then compared the usage of ACC+FCW “before” (Baseline) and “after” (Treatment).

Filtering criteria

Trips with unknown *driver ID were* discarded. Drivers which have made less than 10 trips or have driven less than 20 hours were excluded.

Factors

1) Road type: any or motorway.
2) Load: any or loaded.

Performance indicators (PIs)

Percentage of time the ACC+FCW system is “On”.

Data

The data was paired according to *driver ID.* A brief summary on the amount of data used in the analysis can be found in Table 1.

Statistical Methods

Extensive exploratory data analysis was made using the MatLab toolbox which have been developed exclusively to address this and similar hypotheses. A paired (according to *driver ID*) t-test was performed, in order to see whether the difference in ACC+FCW usage between Baseline (“before”) and Treatment (“after”) is statistically significant. The analysis was done separately for all possible choices of factor levels.

Results

The ACC+FCW system was "Off" during the entire trip in 24% of the trips. In particular, during the entire treatment period, 4 drivers had ACC+FCW always "Off". For the remaining 41 drivers a decrease of ACC+FCW usage from 40% to 37% was observed (p-value 0.0045). The ACC+FCW system usage was highest on motorways, where the decrease was from 56% to 53% (p-value 0.0050). Varying *Lighting* and *Weather* levels did not reveal any substantial difference in the ACC+FCW usage. The combined (i.e. for all drivers) ACC+FCW usage is given in the following table.

Hypothesis	Factors	Response variables	Baseline ("before")	Treatment ("after")	Result
U2	Road: any Lighting: any Load: any Fleet: both	ACC+FCW usage: Number of trips: Time travelled (h): Distance travelled (km):	39% 2333 37 891 2 612 900	36% 2269 38 904 2 692 400	3% decrease.
U2	Road: motorway Load: any Fleet: both	ACC+FCW usage: Number of trips: Time travelled (h): Distance travelled (km):	54% 8133 20 731 1 686 000	51% 8565 21 980 17 906 00	3% decrease.

Conclusions

The usage of ACC+FCW has decreased from 39% to 36% (overall) and from 54% to 51% (motorways).

Annex 3 Cruise Control (CC) and Speed Limiter (SL)

List of selected hypothesis

The list of hypothesis for CC / SL is:

Table 4: List of CC / SL hypothesis

The level of SL acceptance will increase with SL experience
Using SL will increase comfort and pleasure to drive
The level of SL trust will increase with SL experience
The level of CC acceptance will increase with CC experience
The level of CC trust will increase with CC experience
Using CC will increase comfort and pleasure to drive
Certain features of the functions, in terms of usability, influence acceptance
Certain features of the functions, in terms of usefulness, influence user acceptance
Driver workload decreases over time with function use
User practices (heuristics, rules) will change over time during the FOT
Drivers will not abuse or misuse SL/CC
SL will be used more on roads with few curves or intersection.
CC will be used more on roads with few curves or intersection.
The SL/CC selected speed will be below legal speed for non-sensation seekers drivers and will be above legal speed for sensation seekers drivers.
Using CC or CC, the number of incidents will decrease
Using SL will reduce over speeding occurrences.
Using SL, will increase the occurrences of strong jerks
Using SL, the number of hard braking decelerations will decrease.
SL decreases the number of critical time gaps to the lead vehicle
SL use increases over time
Using CC will reduce over speeding occurrences.
Using CC will reduce strong jerk occurrences.
Using CC will reduce hard braking occurrences.
Using CC will reduce critical time gap occurrences.
CC use increases over time
Using SL decreases the average speed.
Using SL decreases the fuel consumption.
Using CC decreases the average speed.
Using CC decreases the fuel consumption.
The number of trips made will increase
The number of vehicle km travelled will increase

The level of SL acceptance will increase with SL experience

Comparison situations

1. **T2:** Expectance in system; evaluation before usage
2. **T3:** Evaluation of system after two months of usage
3. **T4:** Evaluation of system after end of experiment

Performance indicators (PIs)

1. Subjective rating of acceptance on van der Laan scale (subscales satisfying and useful)

Factors

None

Data

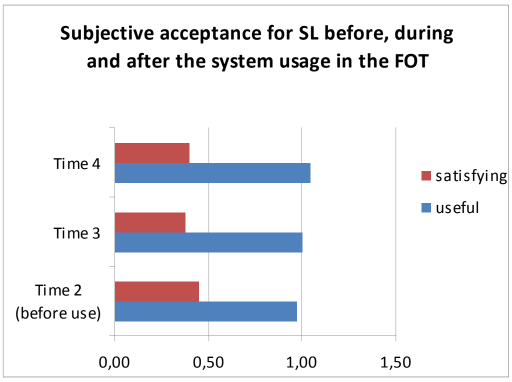
Subjective rating per drivers

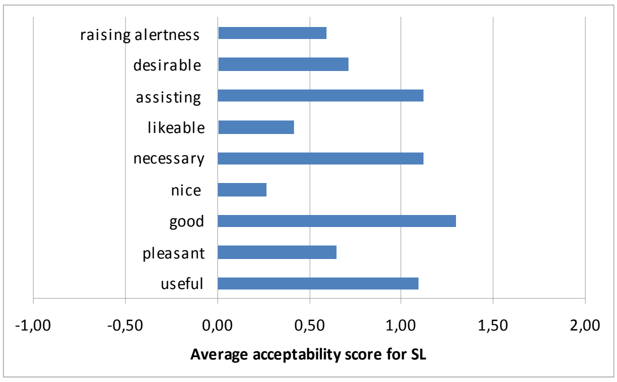
Statistical Methods

Friedman test

Results

System	Item	N	dll	χ^2	p
SL	Useful	34	2	0.778	0.678
	Satisfaction	34	2	4.333	0.115





Conclusions

For SL system, drivers have positive expectations at the beginning of the FOT and expectations are confirmed and overall there is no significantly change of acceptance over time. The system was judged as necessary, good, assisting the driving and useful.

Using SL will increase comfort and pleasure to drive

Comparison situations

1. **Subjective rating** of change of comfort and pleasure to drive vs. expected rating for comfort and pleasure to drive is unchanged

Factors

None

Performance indicators (PIs)

1. Subjective rating for change of comfort between 1 = decreased comfort significantly and 5 = increased comfort significantly.
2. Subjective rating for change of pleasure to drive between 1 = decreased pleasure to drive significantly and 5 = increased pleasure to drive significantly.

Data

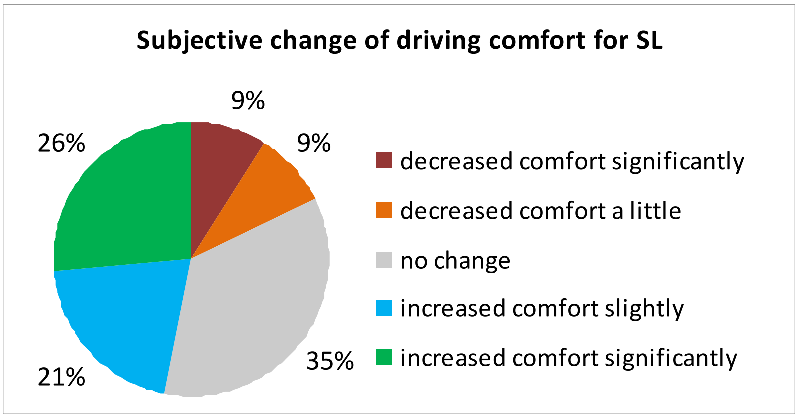
Subjective rating per drivers

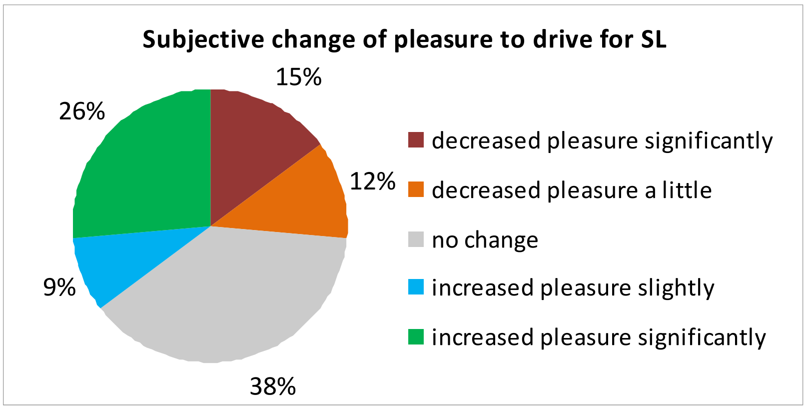
Statistical Methods

χ^2 Squares test of independence

Results

System	df	χ^2	p
SL comfort	1	0.118	0.732
System	**df**	χ^2	**p**
SL pleasure to drive	1	2.941	0.086





Conclusions

With the speed limiter system, subjective driving comfort and pleasure to drive are not significantly increased.

The level of SL trust will increase with SL experience

Comparison situations

1. **T2:** Expectance in system; evaluation before usage
2. **T3:** Evaluation of system after two months of usage
3. **T4:** Evaluation of system after end of experiment

Performance indicators (PIs)

1. Subjective rating of trust (subscales reliable, trustworthy and raise confidence)

Factors

None

Data

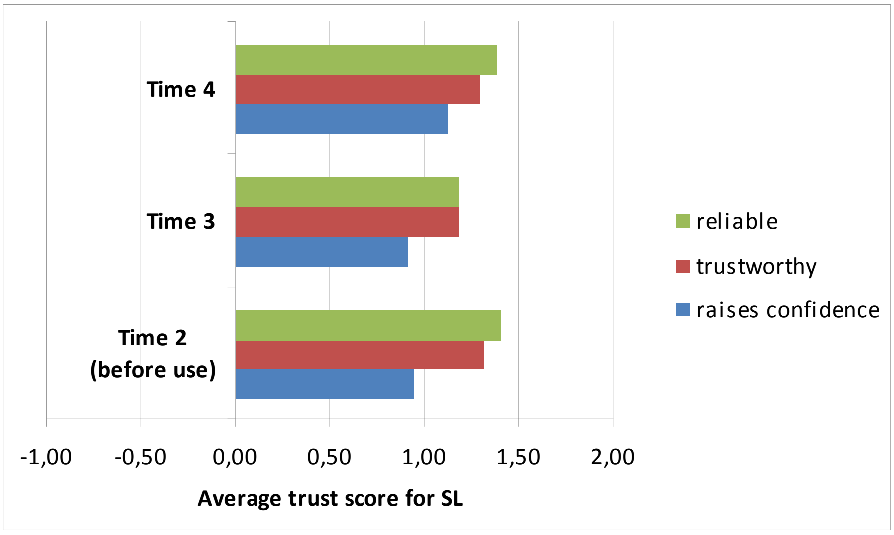
Subjective rating per drivers

Statistical Methods

Friedman test

Results

System	Item	N	df	χ^2	p
SL	Raises confidence	33	2	0.096	0.953
	Trustworthy	33	2	0.567	0.753
	Reliable	33	2	2.638	0.267



Conclusions

For SL system, drivers have positive expectations at the beginning of the FOT and expectations are confirmed and overall there is no significantly change of trust over time.

The level of CC acceptance will increase with CC experience

Comparison situations

1. **T2:** Expectance in system; evaluation before usage
2. **T3:** Evaluation of system after two months of usage
3. **T4:** Evaluation of system after end of experiment

Performance indicators (PIs)

Subjective rating of acceptance on van der Laan scale (subscales satisfying and useful)

Data

Subjective rating per drivers

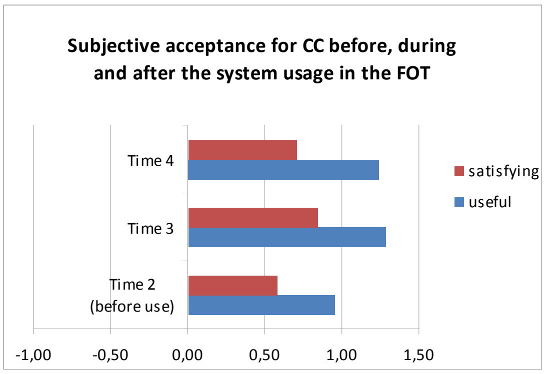
Statistical Methods

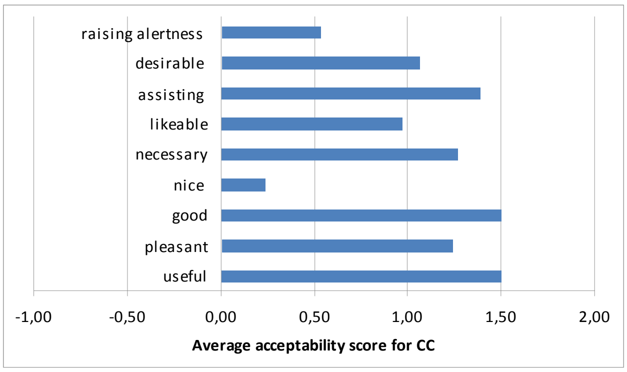
Friedman Test and Wilcoxon test for post hoc test

Results

System	Pair	Z	p
CC	T2_Useful/T3_Useful	-2.269	0.023
	T2_Useful/T4_Useful	-2.357	0.018
	T3_Useful/T4_Useful	-0.302	0.763
	T2_Satisfying/T3_ Satisfying	-2.153	0.031
	T2_ Satisfying /T4_ Satisfying	-1.209	0.227
	T3_ Satisfying /T4_ Satisfying	-1.213	0.225

System	Item	N	df	χ^2	p
SL	Useful	33	2	9.651	0.008
	Satisfaction	33	2	7.303	0.026





Conclusions

For CC system, drivers have positive expectations at the beginning of the FOT and expectations are confirmed. The satisfaction and useful sub scales are significantly increased after system use.
For usefulness, there is change of acceptance (not significant after Bonferroni adjustment but it shows a tendency) between before use and Time 2 but no significantly change between Time 3 and Time 4. The use of the system increases the perceived utility very quickly and it remains the same until the end of the experiment.
For satisfaction, there is change of acceptance (not significant after Bonferroni adjustment but it shows a tendency) between before use and Time 2 but no significantly change between Time 3 and Time 4.
The use of the system increases the perceived satisfaction quickly and it decreases a little the end of the experiment.
The main items which impact this acceptance were necessary, good, assisting the driving desirable, pleasant and useful.

The level of CC trust will increase with CC experience

Comparison situations

1. **T2:** Expectance in system; evaluation before usage
2. **T3:** Evaluation of system after two months of usage
3. **T4:** Evaluation of system after end of experiment

Performance indicators (PIs)

1. Subjective rating of trust (subscales reliable, trustworthy and raise confidence)

Data

Subjective rating per drivers

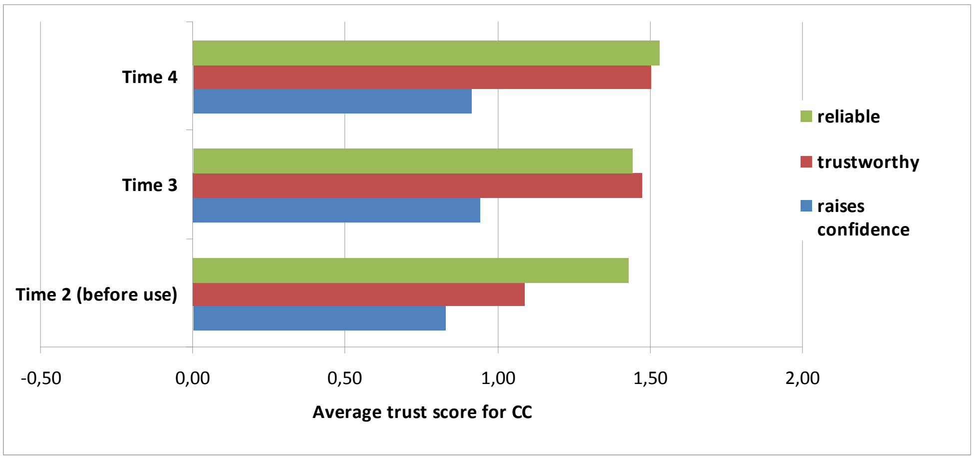
Statistical Methods

Friedman test

Results

System	Item	N	dll	χ^2	p
CC	Raises confidence	34	2	1.210	0.546
	Trustworthy	34	2	13.30 0	0.001
	Reliable	34	2	0.304	0.859

System	Pair	Z	p
CC	T2_Reliable/T3_ Reliable	-,277	,782
	T2_ Reliable /T4_ Reliable	-,535	,593
	T3_ Reliable /T4_ Reliable	-,302	,763
	T2_Trustworthly/T3_ Trustworthy	-2,681	0.007
	T2_ Trustworthy /T4_ Trustworthy	-2,829	0.005
	T3_ Trustworthy /T4_ Trustworthy	-,277	,782
	T2_Confidence/T3_ Confidence	-,615	,539
	T2_ Confidence /T4_ Confidence	-,338	,735
	T3_ Confidence /T4_ Confidence	-,209	,835



Conclusions

For CC system, drivers have positive expectations at the beginning of the FOT and expectations are confirmed. In terms of reliability and raise confidence, there is no significantly change over time. In terms of trustworthy, there is significantly change of acceptance (with Bonferroni adjustment α=0.017 %) between before use and Time 2 but no significantly change between Time 3 and Time 4. The use of the system increases the perceived trustworthy very quickly and it remains the same till the end of the experiment.

Using CC will increase comfort and pleasure to drive

Comparison situations

1. **Subjective rating** of change of comfort and pleasure to drive vs. expected rating for comfort and pleasure to drive is unchanged

Performance indicators (PIs)

1. Subjective rating for change of comfort between 1 = decreased comfort significantly and 5 = increased comfort significantly.
2. Subjective rating for change of pleasure to drive between 1 = decreased pleasure to drive significantly and 5 = increased pleasure to drive significantly.

Data

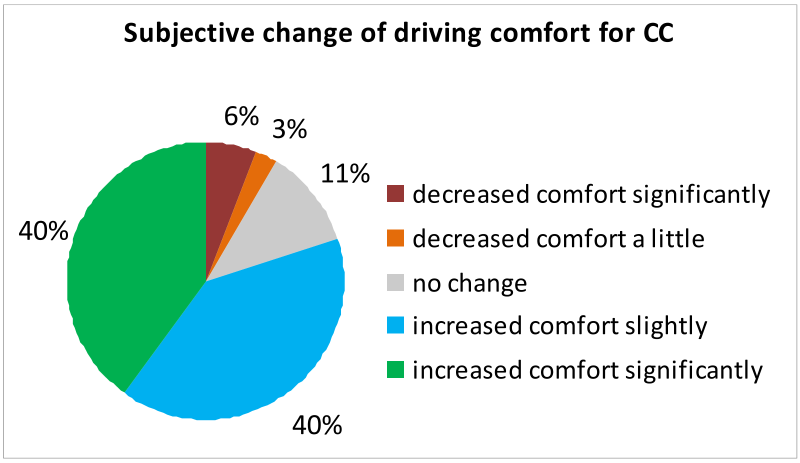
Subjective rating per drivers

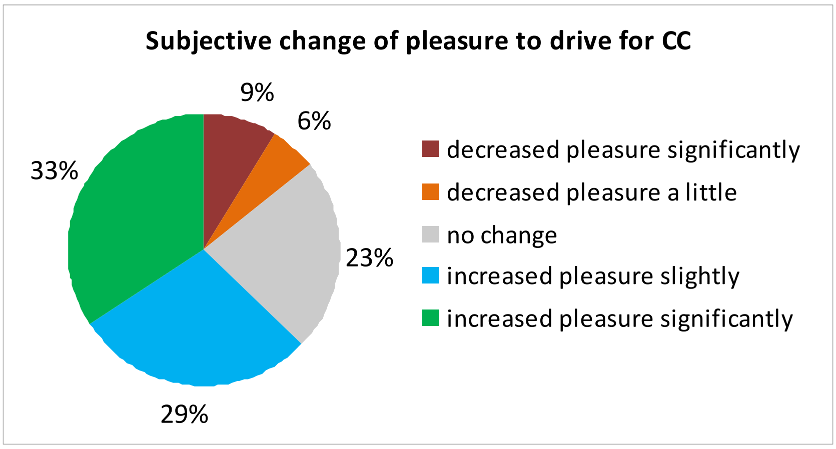
Statistical Methods

χ^2 Squares test of independence

Results

System	**df**	χ^2	**p**
CC comfort	1	12.6	<0,001
System	**df**	χ^2	**p**
CC pleasure to drive	1	2.314	0.128





Conclusions

The Comfort increases significantly with CC usage but not the pleasure to drive. The lack of significance is due to the number of participant which is not enough.

Certain features of the functions, in terms of usability, influence acceptance

Comparison situations

1. Subjective ratings

Performance indicators (PIs)

1. Count the percentage of "positive" participant (participant with a positive acceptance) who have estimated that the item is positive and
2. Count percentage of "negative" participant (participant with a negative acceptance) who have estimated that the item is negative.

Data

Subjective rating per drivers

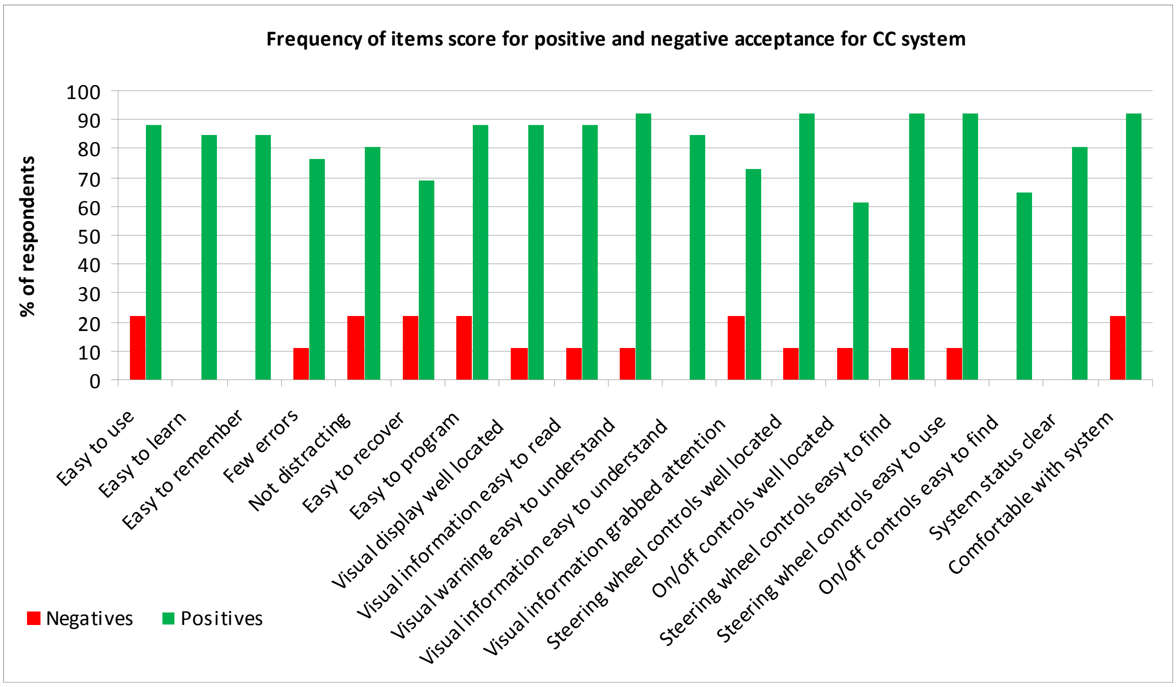
Statistical Methods

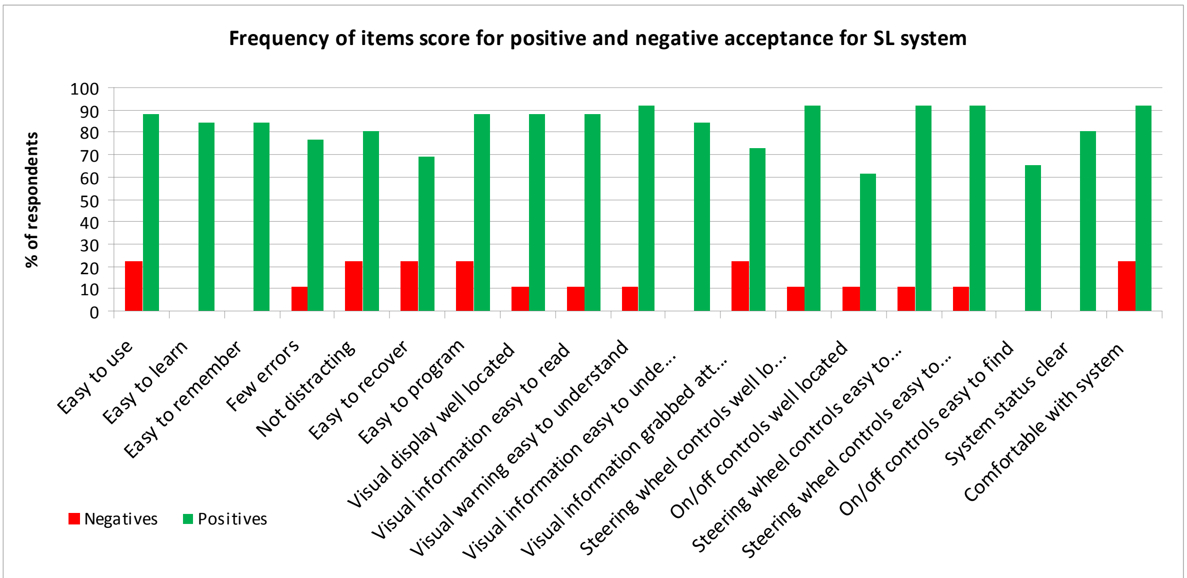
Count the percentage of "positive" participant (participant with a positive acceptance) who have estimated that the item is positive and the percentage of "negative" participant (participant with a negative acceptance) who have estimated that the item is negative.
The height of the red bars indicates the likelihood that a "negative" participant rated the system as negative on that particular item. The height of the green bars indicates the likelihood that a "positive" participant rated the system as positive on that particular item.

Results

Item	Positive SL	Negative SL	Positive CC	Negative CC
Easy to use	88	22	84	25
Easy to learn	85	0	84	0
Easy to remember	85	0	84	0
Few errors	77	11	61	25
Not distracting	81	22	77	0
Easy to recover	69	22	71	0
Easy to program	88	22	77	25
Visual display well located	88	11	77	0
Visual information easy to read	88	11	84	0
Visual warning easy to understand	92	11	87	0
Visual information easy to understand	85	0	87	0
Visual information grabbed attention	73	22	58	0

Steering wheel controls well located	92	11	90	0
On/off controls well located	62	11	68	25
Steering wheel controls easy to find	92	11	84	0
Steering wheel controls easy to use	92	11	87	25
On/off controls easy to find	65	0	74	25
System status clear	81	0	81	25
Comfortable with system	92	22	81	0





Conclusions

The items of the functions, in terms of usability, which influence positive acceptance, are the fact that the two systems are easy to use, to learn, to remember and to program. The systems are not considered distracting. The visual information is well located, easy to read and to understand. The visual warning is easy to understand. The steering wheel controls are well located, easy to find and to use. In general the system status clear and the drivers are comfortable with system.
The number of driver with negative acceptance is too low to identify the items which influence acceptance.

Certain features of the functions, in terms of usefulness, influence user acceptance

Comparison situations

1. Subjective ratings

Performance indicators (PIs)

For CC system
1. Perceived usefulness on Highways with:
   a. normal traffic, b. high traffic c. in terms of increased safety

For SL system
1. Perceived usefulness on:
- urban roads, normal traffic
- rural roads, light traffic
- exiting unfamilar highways
- roads with few speed changes
- complex crossings
- reducing speeding fines
- rural roads, poor weather
- unfamiliar roads
- increasing safety

Data

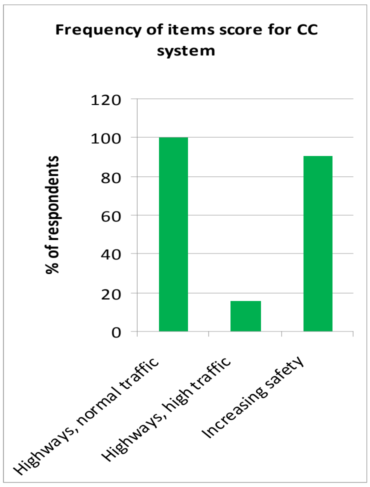
Subjective rating per drivers

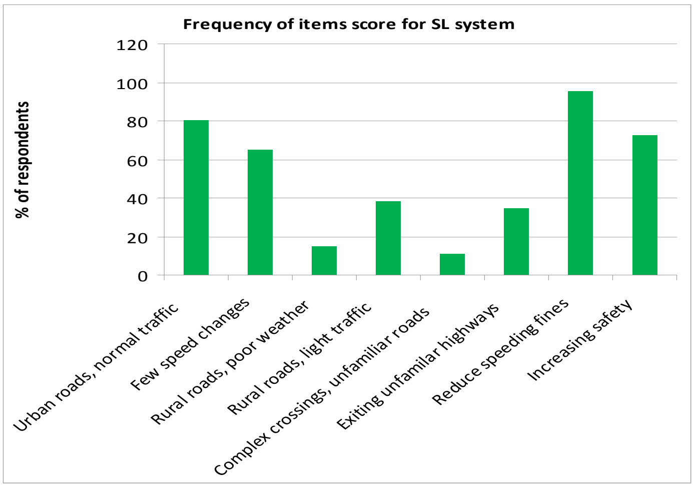
Statistical Methods

Count the percentage of "positive" participant (participant with a positive acceptance) who have estimated that the item is positive and the percentage of "negative" participant (participant with a negative acceptance) who have estimated that the item is negative.
The height of the red bars indicates the likelihood that a "negative" participant rated the system as negative on that particular item. The height of the green bars indicates the likelihood that a "positive" participant rated the system as positive on that particular item.

Results

System	Item	Frequency
SL	Urban roads, normal traffic	81
	Few speed changes	65
	Rural roads, poor weather	15
	Rural roads, light traffic	38
	Complex crossings, unfamiliar roads	12
	Exiting unfamilar highways	35
	Reduce speeding fines	96
	Increasing safety	73
CC	Highways, normal traffic	100
	Highways, high traffic	16
	Increasing safety	90





Conclusions

The drivers perceived that the CC system is useful on highways with normal traffic and the SL system on rural road with normal traffic. They think that the both systems increase safety and that the SL can reduce speeding fines.

Driver workload decreases over time with function use

Comparison situations

1. **T3:** Evaluation of system after two weeks of usage
2. **T4:** Evaluation of system after end of condition

Performance indicators (PIs)

1. Subjective rating of workload on RSME-scale for different driving situations

Data

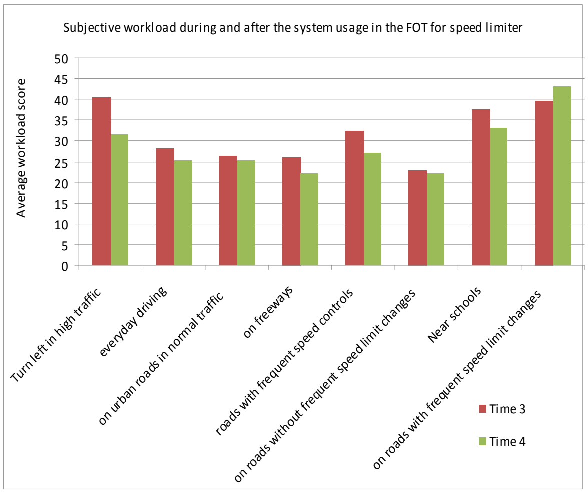
Subjective rating per drivers

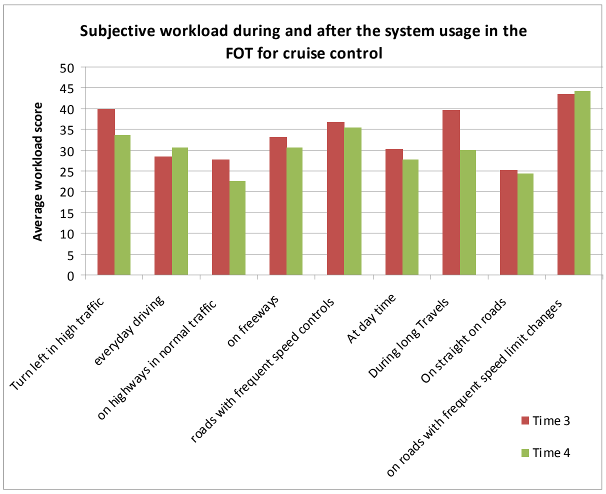
Statistical Methods

Test de Wilcoxon comparing the rating at T3 and T4.

Results

Type of system	Item	t	p
Speed limiter	Turn left in high traffic	-1,406	,160
	everyday driving	-,195	,846
	on urban roads in normal traffic	-,216	,829
	on freeways	-,471	,638
	roads with frequent speed controls	-1,225	,220
	on roads without frequent speed limit changes	-,137	,891
	Near schools	-1,048	,294
	on roads with frequent speed limit changes	-,843	,399
Cruise control	Turn left in high traffic	-,486	,627
	everyday driving	-1,037	,300
	on highways in normal traffic	-,496	,620
	on freeways	-,161	,872
	roads with frequent speed controls	-,447	,655
	At day time	-,037	,970
	During long Travels	-1,514	,130
	On straight on roads	-,990	,322
	on roads with frequent speed limit changes	-,628	,530





Conclusions

For both systems there is no systematic change of workload over the period of system usage.

User practices (heuristics, rules) will change over time during the FOT

Comparison situations

1. Subjective ratings

Performance indicators (PIs)

1. **Subjective rating** of change of user practices vs. expected rating for user practices is unchanged

Data

Subjective rating per drivers

Performance indicators (PIs)

1. Subjective rating for user practices between 1 = change and 0 = no change.

Data

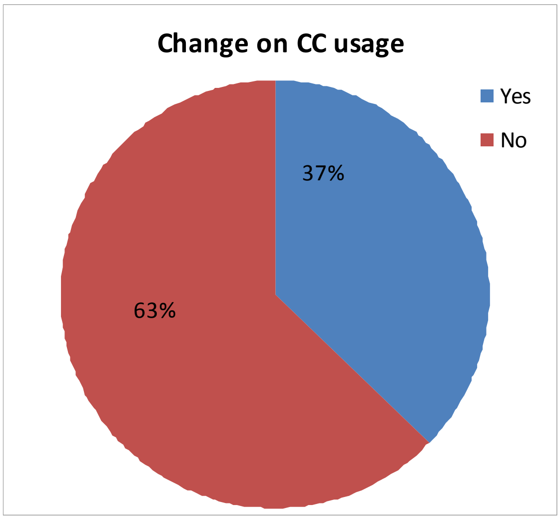
Subjective rating per drivers

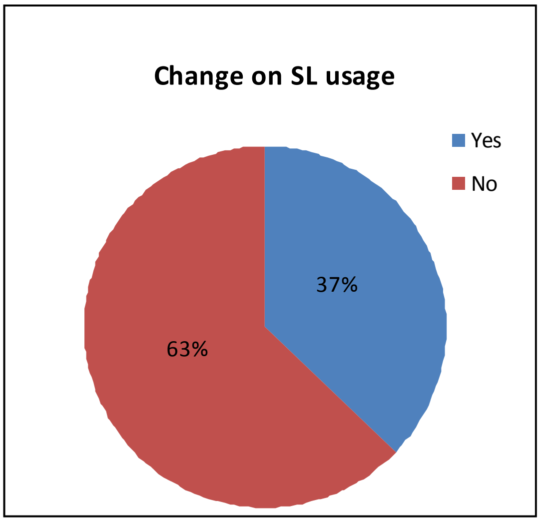
Statistical Methods

Chi Squares test of independence

Results

System	**df**	χ^2	**p**
Change in SL usage	1	1.882	0.170
System	**df**	χ^2	**p**
Change in CC usage	1	2.314	0.128





Conclusion

The user practices are not significantly change for the two systems.

Drivers will not abuse or misuse SL/CC

Comparison situations

1. Subjective ratings vs. value indicating no misuse

Performance indicators (PIs)

1. Subjective rating of frequency of misuse behaviour

Data

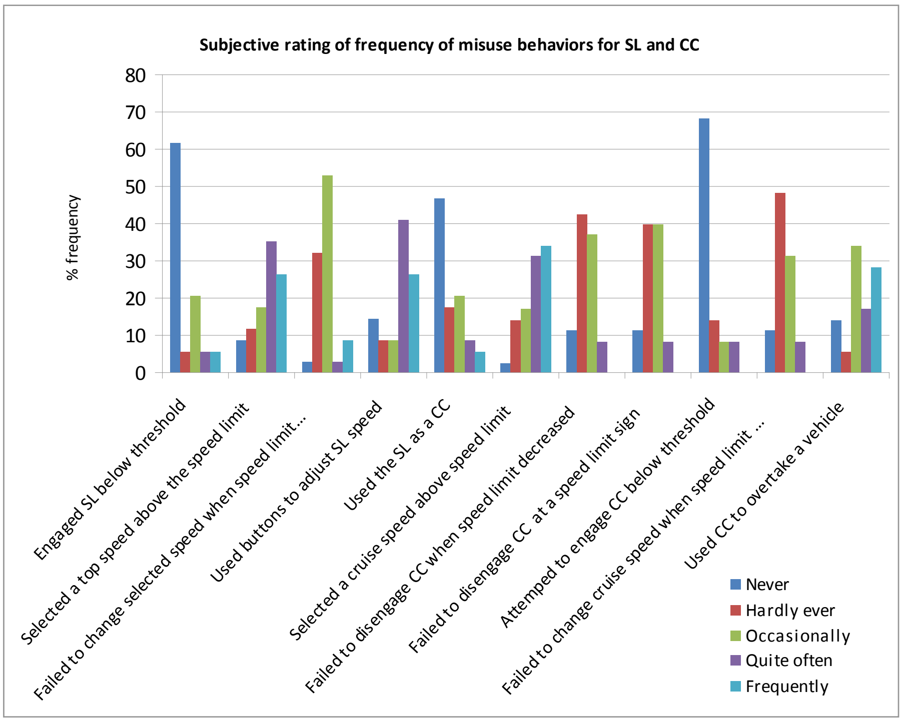
Subjective rating per drivers

Statistical Methods

Chi Squares test of independence

Results

System	Misuse type	mean	df	χ^2	p
SL	Engaged SL below threshold	,8824	19,882	1	<0.01
SL	Selected a top speed above the speed limit	2,5882	1,882	1	,170
SL	Failed to change selected speed when speed limit decreased	1,8235	19,882	1	<0.01
SL	Used buttons to adjust SL speed	2,5588	4,235	1	<0.05
SL	Used the SL as a CC	1,0882	16,941	1	<0.01
CC	Selected a cruise speed above speed limit	2,8000	3,457	1	,063
CC	Failed to disengage CC when speed limit decreased	1,4286	24,029	1	<0.01
CC	Failed to disengage CC at a speed limit sign	1,4571	24,029	1	<0.01
CC	Attempted to engage CC below threshold	,5714	24,029	1	<0.01
CC	Failed to change cruise speed when speed limit decreased	1,3714	24,029	1	<0.01
CC	Used CC to overtake a vehicle	2,4000	,257	1	,612



Conclusions

With the SL system drivers state that they engage in misuse behaviours only to select a top speed above the speed limit and to use buttons to adjust SL speed instead of accelerator pedal. With the CC system drivers state that they engage in misuse behaviours only to select a cruise speed above speed limit and to use CC to overtake a vehicle.

SL will be used more on roads with few curves or intersection.

Comparison situations

1. Baseline: Randomly sampled chunks from treatment data set with system not in use.
2. Treatment: Chunks where SL-active event is present (system used).

Filtering criteria

- Average speed >5km/h.
- Map speed limit information available

Factors

1. Curve indicator being 1 if curve density>20%, 0 instead.
2. Intersection indicator being 1 if intersection density>20%, 0 instead.
3. Speed limit (50, 70, 90, 110, 130 km/h)

Performance indicators (PIs)

1. Presence of a SL-active event in the chunk.

Chunking

The chunk process is the same for all hypotheses: See “chunking process at the French VMC” introduction section.

Data

35 drivers, which have sufficient number of accumulated kilometres (>5000 km) in Baseline and Treatment was used for the analyses. Unknown Roads and speed limits are not included in the analyses.

Statistical Methods

See the “method for EBA analysis” in French VMC introducion section in deliverable 6.4.

Results

Significant results (p<0.05) are displayed in the following table.

	Intersections (>20% of the time) Versus few intersections				Curves (>20% of the time) Versus few Curves			
Factor (Speed limits)	Type III fixed effects p-value	Estimated odds ratio	Lower bound	Upper bound	Type III fixed effects p-value	Estimated odds ratio	Lower bound	Upper bound
30 km/h	-	-	-	-	-	-	-	-
50 km/h	0,9365	1,00	0,97	1,04	<0,0001	0,67	0,65	0,69
70 km/h	0,033	0,94	0,88	0,99	<0,0001	0,67	0,63	0,72
90 km/h	<0,0001	0,82	0,78	0,86	<0,0001	0,62	0,58	0,66
110 km/h	0,0155	1,27	1,05	1,54	0,0005	0,63	0,48	0,82
130 km/h	0,0475	0,69	0,47	1,00	<0,0001	3,57	2,53	5,05

Conclusions

1. Intersection density impact

Intersection density impact on system use is not significant for 50km/h roads, and significance is not high for 70km/h roads (estimated OR is close to 1 indicating a weak influence). On 90km/h limited roads the odds of using the SL when intersection density is high is 0.82 times the odds of using SL when few intersections are encountered. The effect is less significant for 110km/h roads and in the opposite direction: A driver is 1.27 more likely to use the system when intersection density is high. Effect for 130km/h limited roads is significant at 5% but not at 2.5% level, and some caution is necessary considering the interpretation of “intersection density” on motorways.

2. Curve density impact

Curve density has always a significant impact on SL use. From 50km/h to 110km/h roads the effect is similar: the odds of using the system on high curve density roads is 0.6 times the odds of using it when few curves are encountered. SL is unlikely to be used on roads with many curves.

The effect for 130km/h roads is opposite to the others and significant, leading to the conclusion that the system is more often used when curves are present. This may be due to the ability of SL system to reduce the likelihood of being caught by speed enforcement cameras (often present on motorways in France, especially when the driving context is dangerous). Drivers may want to use it preferably when the risk of being caught when over speeding is high (curves).

CC will be used more on roads with few curves or intersection.

Comparison situations

This kind of hypothesis needs to be analysed with an event approach. The events of interest are the chunks with the presence of CC active (treatment), and baseline chunks are selected from treatment data without CC in use. This is analogous to a case-control study. Comparison is done between chunks according to some situational variables.

1. Baseline: Randomly sampled chunks from treatment data set with system not in use.
2. Treatment: Chunks where CC-active event is present (system used).

Filtering criteria

- Average speed >5km/h.
- Map speed limit information available

Factors

1. Curve indicator being 1 if curve density>20%, 0 instead.
2. Intersection indicator being 1 if intersection density>20%, 0 instead.
3. Speed limit (50, 70, 90, 110, 130 km/h)

Baseline and treatment data are stratified according to speed limits and separate analysis are conducted.

Performance indicators (PIs)

1. Presence of a CC-active event in the chunk.

Chunking

The chunk process is the same for all hypotheses: See “chunking process at the French VMC” introduction section.

Data

35 drivers, which have sufficient number of accumulated kilometres (>5000 km) in Baseline and Treatment was used for the analyses. Unknown Roads and speed limits are not included in the analyses.

Statistical Methods

See the “method for EBA analysis” in French VMC introduction section in Deliverable 6.4.

Results

Significant results (p<0.05) are displayed in the following table.

	Intersections (>20% of the time) Versus few intersections				Curves (>20% of the time) Versus few Curves			
Factor (Speed limits)	Type III fixed effects p-value	Estimated odds ratio	Lower bound	Upper bound	Type III fixed effects p-value	Estimated odds ratio	Lower bound	Upper bound
30 km/h	-	-	-	-	-	-	-	-
50 km/h	<0,0001	0,51	0,48	0,55	<0,0001	0,23	0,21	0,25
70 km/h	<0,0001	0,76	0,69	0,82	<0,0001	0,38	0,34	0,42
90 km/h	<0,0001	0,63	0,60	0,66	<0,0001	0,16	0,15	0,18
110 km/h	<0,0001	0,58	0,50	0,68	<0,0001	0,03	0,02	0,04
130 km/h	0,1844	0,79	0,56	1,12	<0,0001	0,01	0,00	0,01

Conclusions

1. Intersection density impact

Intersection density impact on system use is highly significant except on motorways (130km/h roads). The OR estimates ranges between 0,51 to 0,76. The odds of using the system versus not using it, when intersection density is high, are approximately 0.6 times the odds of using it when intersection density is low.

2. Curve density impact

Curve density has always a significant impact on CC use. At 70km/h roads, the odds of using the system when curves are highly present are 0.34 times the odds of using it when curves are not present. The effect increase until a maximum for 130km/h roads, for which CC is almost never used when curves are present.

The SL/CC selected speed will be below legal speed for non-sensation seekers drivers and will be above legal speed for sensation seekers drivers.

The following hypotheses are answered in that section:

- The SL selected speed will be below legal speed for non-sensation seekers drivers
- The SL selected speed will be above legal speed for sensation seekers drivers
- The CC selected speed will be below legal speed for non-sensation seekers drivers
- The CC selected speed will be above legal speed for sensation seekers drivers

Comparison situations

No comparisons are made as only treatment data with SL/CC available are used.

Filtering criteria

Chunks are filtered before selection according to the following parameters:

- Average speed >5km/h.
- Map speed limit information available

1. Sensation seeker
2. Percentage of time while over-speeding
3. Interaction between the two previous factors

Performance indicators (PIs)

1. Differences between SL or CC selected speed and legal speed limit.

Chunking

The chunk process is the same for all hypotheses: See “chunking process at the French VMC” introduction section.

Data

35 drivers, which have sufficient number of accumulated kilometres (>5000 km) in Baseline and Treatment was used for the analyses. Unknown Roads and speed limits are not included in the analyses.

Statistical Methods

Analysis of variance and exact Fisher test.
Analysis tool: SAS software.

Results

SL

Factor (sources of variations)	F	p-value
Sensation seeker (positive vs negative)	685.63	<0,0001
Over-speeding (presence vs absence)	3096.84	<0,0001
Interaction	0	1

CC

Factor (sources of variations)	F	p-value
Sensation seeker (positive vs negative)	7.83	0.0052
Over-speeding (presence vs absence)	12377.7	<0,0001
Interaction	57.82	<0,0001

Conclusions

For SL, both factors are relevant but the interaction is not, leading to the conclusion that the amount of exceeded speed is related to the sensation seeking level of the driver, and also to the will of exceeding speed. The absence of interaction is confirmed using an exact Fisher test to a contingency table crossing sensation seeking scale and selected speed (1 if over the limit, 0 if not).

For CC, the effects are different with a significant although small effect of the sensation seeking level. The desire to exceed the speed limit has a much more important effect on the amount of exceeded speed. The interaction is significant showing that the will of over-speeding can lead to different selected speed depending on the sensation seeking scale (sensation seekers drivers tend to exceed speed more than others when over-speeding, but not when did not intend to over-speed).

Using CC or CC, the number of incidents will decrease

Comparison situations

Two different approaches are adopted here. The first one is a simple aggregated analysis with the following data:

1. Baseline-ABA: All baseline
2. Treatment-ABA: Treatment data (SL and CC available, but not always active).

The second way to study SL and CC impact on incident frequency is to analyse it using an event approach. As these events of interest are rare (incidents), they all need to be stored as the treatment data, while a corresponding baseline needs to be extracted. This is analogous to a case-control study.

1. Baseline-EBA: Randomly sampled chunks from treatment data set (system available)
2. Treatment-EBA: Chunks where an incident event is present.

Filtering criteria

- Average speed >5km/h.
- Map speed limit information available

Factors

2. Lighting
3. Weather
4. Experimental condition

Performance indicators (PIs)

1. Number of incidents per 100 driven km.

Chunking

The chunk process is the same for all hypotheses: See “chunking process at the French VMC” introduction section.

Data

35 drivers, which have sufficient number of accumulated kilometres (>5000 km) in Baseline and Treatment was used for the analyses. Unknown Roads and speed limits are not included in the analyses.

Statistical Methods

For the ABA analysis, the 3 factors (experimental condition, weather, and lighting) are evaluated without the interactions in a single analyse: repeated measure ANOVA (GLMM models see introducing section).
For the EBA part, please refer to the introducing “method for EBA analysis” introducing section in French VMC introduction section in Deliverable 6.4.

Results

Repeated measures ANOVA results are presented in the following table.

Factor (Speed limits)	Type III fixed effect F	Type III fixed effects p-value	Estimated average value of the effect
Baseline vs experiment	2.83	0,092	Baseline: 3,91 Treatment: 2,76
Day light vs dark	0.62	0,429	Day light: 3,07 Dark: 3,60
No Rain vs Rain	2.45	0,118	No rain: 2,72 Rain: 3,95

For the EBA analysis, the odds of experiencing an incident (with π being the probability of an incident) while driving with SL active is 0,6828 times the odds while driving without AL active (p-value<0.0001). The odds of experiencing an incident while driving with CC active is 0.1648 times the odds while driving without CC (p-value<0.0001).

Conclusions

Results of the ANOVA did not show any significant effect among the three factors. There is no significant difference in the incident rate between baseline and treatment. Looking more precisely the situations where system is active leads to adopt an EBA. Incident rate decrease significantly when driving with SL or CC active. The estimated decrease in incident rate is more important for CC.
This last effect may be due to driver’s choice to use the system when traffic is free instead of the system effect itself. This effect is higher for CC usage, leading to an apparently strong positive effect, although not due to the system itself but to driver’s choice to use it depending in driving situations.

Using SL will reduce over speeding occurrences.

Comparison situations

This kind of hypothesis needs to be analysed with an event approach. As these events of interest are rare, they all need to be stored as the treatment data, while a corresponding baseline needs to be extracted. This is analogous to a case-control study.

1. Baseline: Randomly sampled chunks from treatment data set (system available)
2. Treatment: Chunks where a over speeding event is present.

Filtering criteria

Chunks are filtered before selection according to the following parameters:

- Average speed >5km/h.
- Map speed limit information available

Factors

1. Speed limit (30, 50, 70, 90, 110, 130 km/h)

Baseline and treatment data are stratified according to speed limits and separate analysis are conducted.

Performance indicators (PIs)

1. Presence of an over speeding event in the chunk.

Chunking

The chunk process is the same for all hypotheses: See “chunking process at the French VMC” introduction section.

Data

35 drivers, which have sufficient number of accumulated kilometres (>5000 km) in Baseline and Treatment was used for the analyses. Unknown Roads and speed limits are not included in the analyses.

Statistical Methods

See the “method for EBA analysis” in French VMC introduction section in Deliverable 6.4.
Analysis tool: SAS software (PROC GLIMMIX).

Results

Significant results (p<0.05) are displayed in the following table.

Factor (Speed limits)	Type III fixed effects p-value	Estimated effect	Lower bound	Upper bound
30 km/h	<0,0001	1,34	1,22	1,47
50 km/h	0,0018	0,94	0,91	0,98
70 km/h	<0,0001	1,30	1,22	1,39
90 km/h	<0,0001	0,52	0,49	0,55
110 km/h	<0,0001	0,43	0,39	0,47
130 km/h	<0,0001	0,46	0,40	0,52

Conclusions

Very few data are available for 30 and 70 km/h limited roads, and although significance is high for the drivers taken into account, too few drivers with complete data are available to conclude about a real effect for the entire population.
The results for the other speed limits are much more ttrustworthy because data is more consistent. From 90 to 130km/h limited roads the odds of exceeding the speed limit while using the SL are half the odds of exceeding the speed limit under normal conditions (naturalistic driving without using any system). The effect is very small although significant on 50km/h roads, with a tendency to reduce probability of exceeding the speed limit.
The effects of the SL on the over speeding events are higher for high speed limits, with a reduction of up to 50% when using the system.

Using SL, will increase the occurrences of strong jerks

Comparison situations

This kind of hypothesis needs to be analysed with an event approach. As these events of interest are rare, they all need to be stored as the treatment data, while a corresponding baseline needs to be extracted. This is analogous to a case-control study.

1. Baseline: Randomly sampled chunks from treatment data set (system available)
2. Treatment: Chunks where a strong jerk event is present.

Filtering criteria

Chunks are filtered before selection according to the following parameters:

- Average speed >5km/h.
- Map speed limit information available

Factors

1. Speed limit (30, 50, 70, 90, 110, 130 km/h)

Baseline and treatment data are stratified according to speed limits and separate analysis are conducted.

Performance indicators (PIs)

1. Presence of a strong jerk event in the chunk.

Chunking

The chunk process is the same for all hypotheses: See “chunking process at the French VMC” introduction section.

Data

35 drivers, which have sufficient number of accumulated kilometres (>5000 km) in Baseline and Treatment was used for the analyses. Unknown Roads and speed limits are not included in the analyses.

Statistical Methods

See the “method for EBA analysis” in French VMC introduction section in Deliverable 6.4.
Analysis tool: SAS software (PROC GLIMMIX).

Results

Significant results (p<0.05) are displayed in the following table.

Factor (Speed limits)	Type III fixed effects p-value	Estimated effect	Lower bound	Upper bound
30 km/h	0,0047	1,31	1,09	1,57
50 km/h	0,4622	0,98	0,93	1,03
70 km/h	0,004	0,78	0,67	0,93
90 km/h	<0,0001	0,67	0,59	0,77
110 km/h	0,1596	0,82	0,62	1,08
130 km/h	-	-	-	-

Conclusions

Strong jerk events are not frequent, especially on high speed roads where speed profiles are smoother. Collected data is not sufficient for model convergence on 130km/h roads, and few kilometres are collected on 30 and 70km/h roads.
SL effect is non-significant on 50 and 110km/h roads, leading to difficulties in drawing conclusions. SL effect is detected as positive on 90km/h roads leading to an odds of observing a strong jerk event of 0.67 times the odds while driving under normal conditions.
To summarise the SL effect, it is likely to be a positive effect (reduction of the probability of observing a strong jerk event) although small and not significant enough on many conditions

Using SL, the number of hard braking decelerations will decrease.

Comparison situations

This kind of hypothesis needs to be analysed with an event approach. As these events of interest are rare, they all need to be stored as the treatment data, while a corresponding baseline needs to be extracted. This is analogous to a case-control study.

1. Baseline: Randomly sampled chunks from treatment data set (system available)
2. Treatment: Chunks where a hard braking event is present.

Filtering criteria

Chunks are filtered before selection according to the following parameters:

- Average speed >5km/h.
- Map speed limit information available

Factors

1. Speed limit (30, 50, 70, 90, 110, 130 km/h)

Baseline and treatment data are stratified according to speed limits and separate analysis are conducted.

Performance indicators (PIs)

1. Presence of a hard braking event in the chunk.

Chunking

The chunk process is the same for all hypotheses: See “chunking process at the French VMC” introduction section.

Data

35 drivers, which have sufficient number of accumulated kilometres (>5000 km) in Baseline and Treatment was used for the analyses. Unknown Roads and speed limits are not included in the analyses.

Statistical Methods

See the “method for EBA analysis” in French VMC introduction section in Deliverable 6.4.
Analysis tool: SAS software (PROC GLIMMIX).

Results

Significant results (p<0.05) are displayed in the following table.

Factor (Speed limits)	Type III fixed effects p-value	Estimated effect	Lower bound	Upper bound
30 km/h	0,1339	1,13	0,96	1,34
50 km/h	<,0001	0,89	0,85	0,94
70 km/h	0,0007	0,77	0,67	0,90
90 km/h	<,0001	0,70	0,62	0,78
110 km/h	0,4393	0,89	0,67	1,19
130 km/h	0,47	0,74	0,33	1,67

Conclusions

The ability of the SL system to modify the probability of hard braking occurrences is only significant for 50, 70, and 90 km/h roads. As previously stated, 30km/h roads results are not reliable because of the small amount of collected data.
When the effect is significant, the range goes from 0.89 for 50km/h to 0.7 for 90km/h roads. For example, on 90km/h limited roads the odds of observing a hard braking event when driving with the system compared to normal conditions is multiplied by 0.7.
SL system effect on hard braking occurrences is positive, with people using the system having a reduction of the odds of approximately 30%.

SL decreases the number of critical time gaps to the lead vehicle

Comparison situations

This kind of hypothesis needs to be analysed with an event approach. As these events of interest are rare, they all need to be stored as the treatment data, while a corresponding baseline needs to be extracted. This is analogous to a case-control study.

1. Baseline: Randomly sampled chunks from treatment data set (system available)
2. Treatment: Chunks where a critical time gap event is present.

Filtering criteria

Chunks are filtered before selection according to the following parameters:

- Average speed >5km/h.
- Map speed limit information available

Factors

1. Speed limit (30, 50, 70, 90, 110, 130 km/h)

Baseline and treatment data are stratified according to speed limits and separate analysis are conducted.

Performance indicators (PIs)

1. Presence of a critical time gap event in the chunk.

Chunking

The chunk process is the same for all hypotheses: See “chunking process at the French VMC” introduction section.

Data

35 drivers, which have sufficient number of accumulated kilometres (>5000 km) in Baseline and Treatment was used for the analyses. Unknown Roads and speed limits are not included in the analyses.

Statistical Methods

See the “method for EBA analysis” in French VMC introduction section in Deliverable 6.4.
Analysis tool: SAS software (PROC GLIMMIX).

Results

Significant results (p<0.05) are displayed in the following table.

Factor (Speed limits)	Type III fixed effects p-value	Estimated effect	Lower bound	Upper bound
30 km/h	0,0011	0,56	0,40	0,79
50 km/h	0,0007	1,13	1,05	1,21
70 km/h	0,2177	0,92	0,80	1,05
90 km/h	0,1568	0,94	0,85	1,03
110 km/h	0,0121	0,87	0,78	0,97
130 km/h	<0,0001	1,31	1,19	1,45

Conclusions

The ability of the SL system to modify critical time gap occurrences probability is only significant for 30, 50, and 130 km/h roads. As previously stated, 30km/h roads results are not reliable because of the small amount of collected data.
On 50 km/h, the SL system multiplies by 1.13 the odds of observing a critical time gap event when driving with the system compared to normal conditions. The same negative impact is observed on 130km/h limited roads, with an odds of observing a critical time gap event when driving with the system compared to normal conditions multiplied by 1.3.

SL use increases over time

Comparison situations

No comparisons are made as only treatment data with SL/CC available are used

Filtering criteria

- Average speed >5km/h.
- Map speed limit information available

Factors

1. Month
2. Speed limit (50, 90, 130 km/h)

Performance indicators (PIs)

1. Average per month of the driver’s % of SL usage per day.

Chunking

10 to 30 sec chunks with homogeneous values for: TripID, DriverID, speed limit, weather (dry or rain), and lighting (night or day). The other variables are not constant and treated as PI (percentage of time in a specific situation for example).

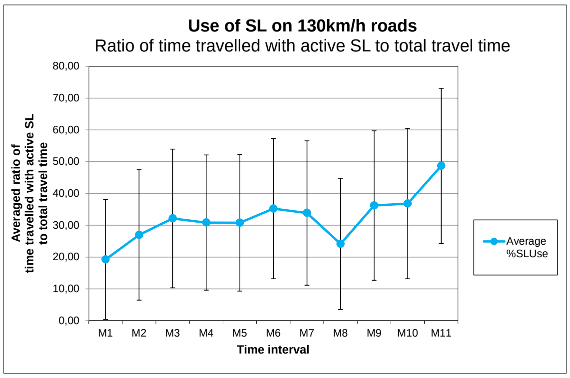
Data

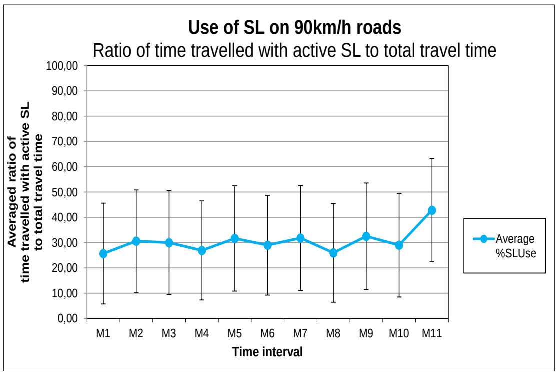
35 drivers, which have sufficient number of accumulated kilometres (>5000 km) in Baseline and Treatment was used for the analyses. Unknown Roads and speed limits are not included in the analyses.

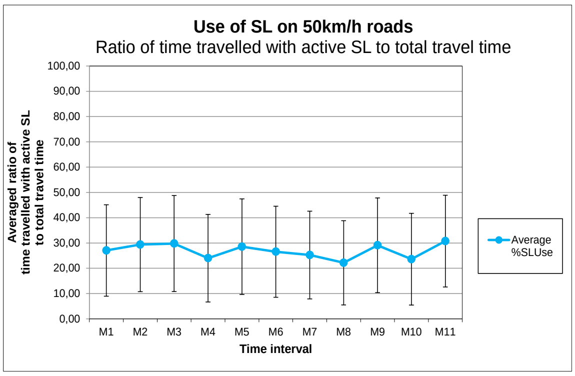
Statistical Methods

Graphical exploration of PI evolution over months, and analysis of variance of PI over months.

Results







Conclusions

SL usage do not vary significantly over time although some significant differences were found between some of the pairs when using a Tukey test. Sheffe test is the more appropriate with unequal sample size, and did not reveal any significant difference between pairs. It cannot be assessed that there is a significant increasing or decreasing trend in SL usage over time. There is a tendency in the graph to show an increase of SL usage rate at the end of the experiment at month 12 but it is never statistically significant and also because of some drivers leaving the experience earlier than others for technical needs. The tendency of drivers to use the system more in the last month of experiment may be due to guilt of not using enough the system for the experiment needs.

Using CC will reduce over speeding occurrences.

Comparison situations

This kind of hypothesis needs to be analysed with an event approach. As these events of interest are rare, they all need to be stored as the treatment data, while a corresponding baseline needs to be extracted. This is analogous to a case-control study.

1. Baseline: Randomly sampled chunks from treatment data set (system available)
2. Treatment: Chunks where an over speeding event is present.

Filtering criteria

Chunks are filtered before selection according to the following parameters:

- Average speed >5km/h.
- Map speed limit information available

Factors

1. Speed limit (30, 50, 70, 90, 110, 130 km/h)

Baseline and treatment data are stratified according to speed limits and separate analysis are conducted.

Performance indicators (PIs)

1. Presence of an over speeding event in the chunk.

Chunking

The chunk process is the same for all hypotheses: See “chunking process at the French VMC” introduction section in Deliverable 6.4.

Data

35 drivers, which have sufficient number of accumulated kilometres (>5000 km) in Baseline and Treatment was used for the analyses. Unknown Roads and speed limits are not included in the analyses.

Statistical Methods

See the “method for EBA analysis” in French VMC introduction section in Deliverable 6.4.
Analysis tool: SAS software (PROC GLIMMIX).

Results

Significant results (p<0.05) are displayed in the following table.

Factor (Speed limits)	Type III fixed effects p-value	Estimated effect	Lower bound	Upper bound
30 km/h	<0,0001	17,77	9,12	34,63
50 km/h	<0,0001	3,40	3,17	3,65
70 km/h	<0,0001	3,84	3,47	4,25
90 km/h	<0,0001	2,18	2,05	2,32
110 km/h	<0,0001	1,56	1,45	1,67
130 km/h	<0,0001	0,77	0,71	0,83

Conclusions

Very few data are available for 30 km/h limited roads, and although significance is high for the drivers taken into account, too few drivers with complete data are available to conclude about a real effect for the entire population.
The results for the other speed limits are much more trustworthy because data is more consistent. From 50 to 110km/h limited roads the odds of exceeding the speed limit while using the CC are two to four times the odds of exceeding the speed limit under normal conditions (naturalistic driving without using any system). The effect of CC increase the probability of exceeding the speed on most roads, but the effect is opposite on motorways (OR=0,77). High speeds like 130km/h seems to be sufficient for a French driver, or the risk of being controlled is estimated to be higher on motorways, leading to a better compliance with the speed limits.

Using CC will reduce strong jerk occurrences.

Comparison situations

This kind of hypothesis needs to be analysed with an event approach. As these events of interest are rare, they all need to be stored as the treatment data, while a corresponding baseline needs to be extracted. This is analogous to a case-control study.

1. Baseline: Randomly sampled chunks from treatment data set (system available)
2. Treatment: Chunks where a strong jerk event is present.

Filtering criteria

- Average speed >5km/h.
- Map speed limit information available

Factors

1. Speed limit (30, 50, 70, 90, 110, 130 km/h)

Baseline and treatment data are stratified according to speed limits and separate analysis are conducted.

Performance indicators (PIs)

1. Presence of a strong jerk event in the chunk.

Chunking

The chunk process is the same for all hypotheses: See “chunking process at the French VMC” introduction section.

Data

35 drivers, which have sufficient number of accumulated kilometres (>5000 km) in Baseline and Treatment was used for the analyses. Unknown Roads and speed limits are not included in the analyses.

Statistical Methods

See the “method for EBA analysis” in French VMC introduction section in Deliverable 6.4.

Results

Significant results (p<0.05) are displayed in the following table.

Factor (Speed limits)	Type III fixed effects p-value	Estimated effect	Lower bound	Upper bound
30 km/h	0,033	0,27	0,08	0,90
50 km/h	<0,0001	0,36	0,30	0,44
70 km/h	<0,0001	0,41	0,29	0,57
90 km/h	<0,0001	0,32	0,26	0,38
110 km/h	<0,0001	0,32	0,26	0,38
130 km/h	-	-	-	-

Conclusions

Strong jerk events are not frequent, especially on high speed roads where speed profiles are smoother. Collected data is not sufficient for model convergence on 130km/h roads, and few kilometres are collected on 30 and 70km/h roads.

Results are significant for all road types, showing a clear positive influence of the CC on the probability of observing a strong jerk event while driving. The odds of observing a strong jerk event when using CC is approximately 0.3 times the odds while driving under normal conditions (no system available). In other terms, the probability of observing this kind of event is divided by 3 when using the system.

Using CC will reduce hard braking occurrences.

Comparison situations

This kind of hypothesis needs to be analysed with an event approach. As these events of interest are rare, they all need to be stored as the treatment data, while a corresponding baseline needs to be extracted. This is analogous to a case-control study.
1. Baseline: Randomly sampled chunks from treatment data set (system available)
2. Treatment: Chunks where a hard braking event is present.

Filtering criteria

- Average speed >5km/h.
- Map speed limit information available

Factors

1. Speed limit (30, 50, 70, 90, 110, 130 km/h)

Baseline and treatment data are stratified according to speed limits and separate analysis are conducted.

Performance indicators (PIs)

1. Presence of a hard braking event in the chunk.

Chunking

The chunk process is the same for all hypotheses: See “chunking process at the French VMC” introduction section.

Data

35 drivers, which have sufficient number of accumulated kilometres (>5000 km) in Baseline and Treatment was used for the analyses. Unknown Roads and speed limits are not included in the analyses.

Statistical Methods

See the “method for EBA analysis” in French VMC introduction section in Deliverable 6.4.

Results

Significant results (p<0.05) are displayed in the following table.

Factor (Speed limits)	Type III fixed effects p-value	Estimated effect	Lower bound	Upper bound
30 km/h	0,1324	0,21	0,03	1,60
50 km/h	<0,0001	0,31	0,23	0,42
70 km/h	<0,0001	0,40	0,33	0,49
90 km/h	<0,0001	0,46	0,41	0,51
110 km/h	<0,0001	0,68	0,63	0,73
130 km/h	-	-	-	-

Conclusions

The ability of the CC system to modify hard braking occurrences probability is significant for all roads except 30km/h roads. As previously stated, 30km/h roads results are not reliable because of the small amount of collected data and collected data is not sufficient for model convergence on 130km/h roads.
Results are highly significant on most road types showing a clear positive effect. For example, on 90km/h limited roads the odds of observing a hard braking event when driving with the system compared to normal conditions is multiplied by 0.46.
CC system effect on hard braking occurrences is positive, with people using the system having a reduction of the odds of approximately 50%.

Using CC will reduce critical time gap occurrences.

Comparison situations

This kind of hypothesis needs to be analysed with an event approach. As these events of interest are rare, they all need to be stored as the treatment data, while a corresponding baseline needs to be extracted. This is analogous to a case-control study.

1. Baseline: Randomly sampled chunks from treatment data set (system available)
2. Treatment: Chunks where a critical time gap event is present.

Filtering criteria

Chunks are filtered before selection according to the following parameters:

- Average speed >5km/h.
- Map speed limit information available

Factors

1. Speed limit (30, 50, 70, 90, 110, 130 km/h)

Baseline and treatment data are stratified according to speed limits and separate analysis are conducted.

Performance indicators (PIs)

1. Presence of a critical time gap event in the chunk.

Chunking

The chunk process is the same for all hypotheses: See “chunking process at the French VMC” introduction section.

Data

35 drivers, which have sufficient number of accumulated kilometres (>5000 km) in Baseline and Treatment was used for the analyses. Unknown Roads and speed limits are not included in the analyses.

Statistical Methods

See the “method for EBA analysis” in French VMC introduction section in Deliverable 6.4.
Analysis tool: SAS software (PROC GLIMMIX).

Results

Significant results (p<0.05) are displayed in the following table.

Factor (Speed limits)	Type III fixed effects p-value	Estimated effect	Lower bound	Upper bound
30 km/h	0,1324	0,21	0,03	1,60
50 km/h	<0,0001	0,31	0,23	0,42
70 km/h	<0,0001	0,40	0,33	0,49
90 km/h	<0,0001	0,46	0,41	0,51
110 km/h	<0,0001	0,68	0,63	0,73
130 km/h	<0,0001	0,74	0,69	0,79

Conclusions

The ability of the CC system to modify critical time gap occurrences probability is significant for all the speed limits. As previously stated, 30km/h roads results are not reliable because of the small amount of collected data.
On 50 km/h roads, the CC system multiplies by 0.31 the odds of observing a critical time gap event when driving with the system compared to normal conditions. The same positive impact is observed for all the speed limits, although the effect is less important for high speed limits.
On motorways, the odds of observing a critical time gap event when driving with the system compared to normal conditions is multiplied by 0.74.

CC use increases over time

Comparison situations

No comparisons are made as only treatment data with SL/CC available are used.

Filtering criteria

- Average speed >5km/h.
- Map speed limit information available

Factors

1. Month
2. Speed limit (50, 90, 130 km/h)

Performance indicators (PIs)

1. Average per month of the driver's % of CC usage per day.

Chunking

10 to 30 sec chunks with homogeneous values for: TripID, DriverID, speed limit, weather (dry or rain), and lighting (night or day). The other variables are not constant and treated as PI (percentage of time in a specific situation for example).

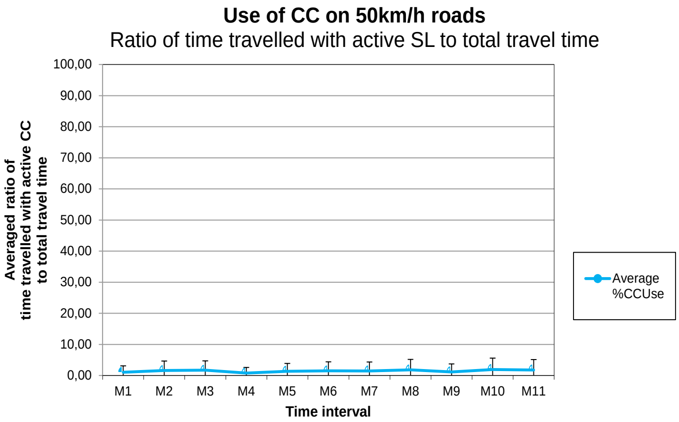
Data

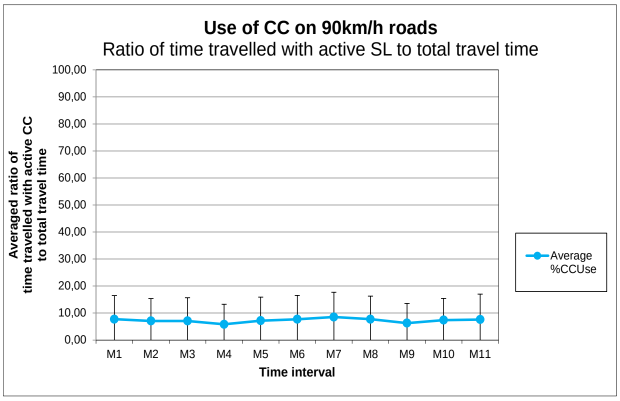
35 drivers, which have sufficient number of accumulated kilometres (>5000 km) in Baseline and Treatment was used for the analyses. Unknown Roads and speed limits are not included in the analyses.

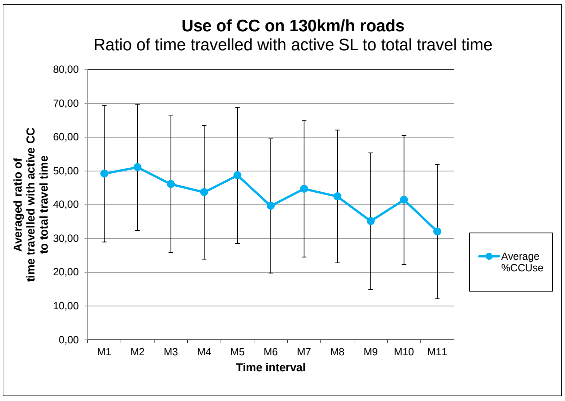
Statistical Methods

Graphical exploration of PI evolution over months, and analysis of variance of PI over months.
Analysis tool: SAS software.

Results







Conclusions

CC usage does not vary significantly over time. A slight difference exist at 50km/h roads between a unique pair of months but significance of the encountered effects is not strong enough to show a clear tendency of the CC usage over time.

Using SL decreases the average speed.

Comparison situations

Driver speed choice is highly dependent on the road design. A high correlation is expected between speed limit, road type, and average measured speed, and there is a need to carefully choose baseline and treatment data for comparison purpose.
If CC is only used on motorways, then the baseline to evaluate effect on speed does not need to incorporate urban data. There is a need to make the exposure information (i.e. speed limit encountered by the driver) comparable between experiment and baseline. Following Guo&Hankey 2009, we adopt a total baseline random sampling scheme: For each driver and for each exposure condition (i.e. speed limits), we sample as many kilometers as needed from the baseline as in the treatment data. For example, if driver "i" has travelled during 2% of the total distance collected during treatment, then 2% of the baseline sampling should correspond to this driver. Moreover, we also sample according to the proportion of data collected for each speed limit value, in order to obtain a baseline dataset close to the observed treatment data. Baseline and treatment data set are obtained by merging corresponding data for each driver.

1. Baseline: Random sampled chunks according to exposure.
2. Treatment: Treatment data are the chunks where the percentage of time with SL in use > 5%.

Filtering criteria

- Average speed >5km/h.
- Map speed limit information available

Factors

1. Speed limits (30, 50, 70, 90, 110, 130 km/h.)

Performance indicators (PIs)

1. Chunked Average Speed.

Chunking

10 to 30 sec chunks with homogeneous values for: TripID, DriverID, road type, speed limit, weather (dry or rain), and lighting (night or day). The other variables are not constant and treated as PI (percentage of time in a specific situation for example).

Data

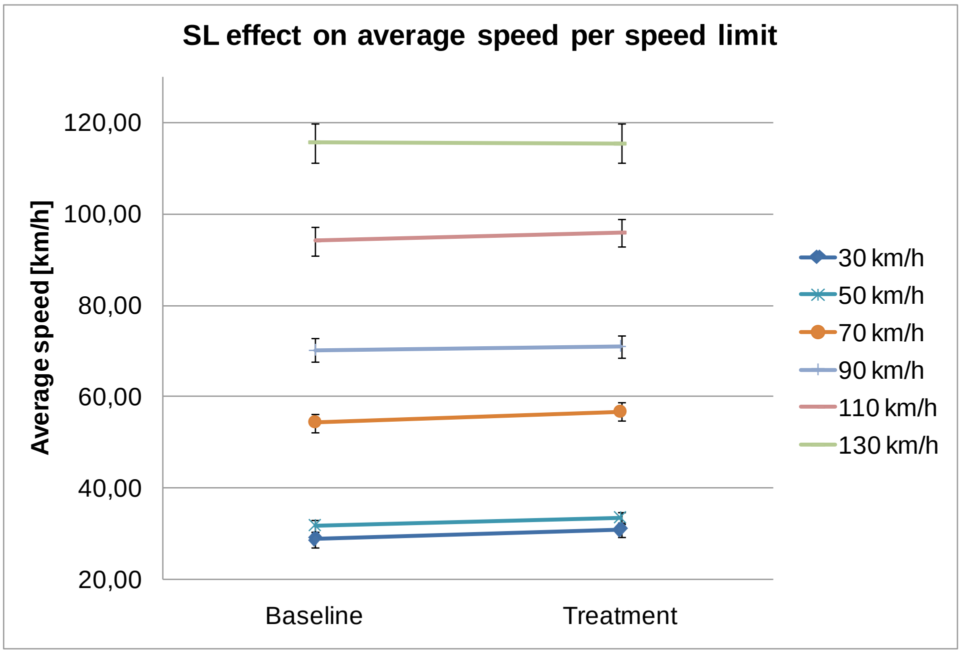
35 drivers, which have sufficient number of accumulated kilometres (>5000 km) in Baseline and Treatment was used for the analyses. Unknown Roads are not included in the analyses.

Statistical Methods

The suitable method for this kind of analysis is the "Generalized Linear Mixed Model" (GLMM) which allows introducing a random effect specific to each subject. In this case, driver ID is used as a random effect specified by the compound-symmetry structure, which has constant variance and constant covariance. The compound symmetry structure arises naturally with nested random effects, such as when sub sampling error is nested within experimental error.

A sufficient number of chunks in all the conditions are needed for the model being able to estimate correctly the fixed effects (SL and CC effects). Due to insufficient observations (for example, SL usage on 30km/h roads), some drivers are not taken into account for some of the analysis. This may induce different fixed effect estimation for baseline data. Average fixed effects are estimated by the mean of a least square estimation using the estimate of the fixed effects parameter vector. Estimated fixed effect values are generally different than the exact means.
Analysis tool: SAS software (PROC GLIMMIX).

Results



Factor (Speed limits)	Least squares estimation for average speed Baseline / SL Active	Lower bound Baseline / Treatment	Upper bound Baseline / Treatment	Type III fixed effects P-value	Increase Km/h	Lower bound effect	Upper bound effect
30 km/h	28,70 / 30,77	27,1 / 29,1	30,3 / 32,4	<.0001	2,07	1,59	2,55
50 km/h	31,77 / 33,41	30,4 / 32,1	33,1 / 34,8	<.0001	1,64	1,45	1,81
70 km/h	54,32 / 56,65	52,4 / 54,7	56,3 / 58,6	<.0001	2,33	1,69	2,87
90 km/h	70,19 / 70,94	67,7 / 68,4	72,7 / 73,4	0.0006	0,75	0,31	1,26
110 km/h	94,04 / 95,82	90,9 / 92,7	97,2 / 99,0	<.0001	1,78	1,18	2,38
130 km/h	115,56 / 115,38	111,3 / 111,1	119,8 / 119,6	0.4875	-0,18	-0,7	0,33
All speed conditions	61,01 / 60,64	56,21 / 55,83	65,82 / 65,44	0.0071	0,37	0,10	0,65

Conclusions

The function SL increases significantly the average speed in all driving contexts except for motorways (130km/h limited roads) where the results are not significant.
Merging all the speed conditions leads to a significant decrease in average speed but this is certainly due to different speed limits proportions between baseline and treatment (SL Active).
Factor analyses show a similar effect for all the situations, but the average speed increase is never above 3km/h, and mostly below 2km/h.

Using SL decreases the fuel consumption.

Comparison situations

1. Baseline: Random sampled chunks according to exposure.
2. Treatment: Chunks where the percentage of time with SL in use > 5%.

Filtering criteria

- Average speed >5km/h.
- Map speed limit information available

Factors

1. Speed limit (30, 50, 70, 90, 110, 130 km/h.)

Performance indicators (PIs)

Average fuel consumption.

Chunking

The chunk process is the same for all hypotheses: See “chunking process at the French VMC” introduction section.

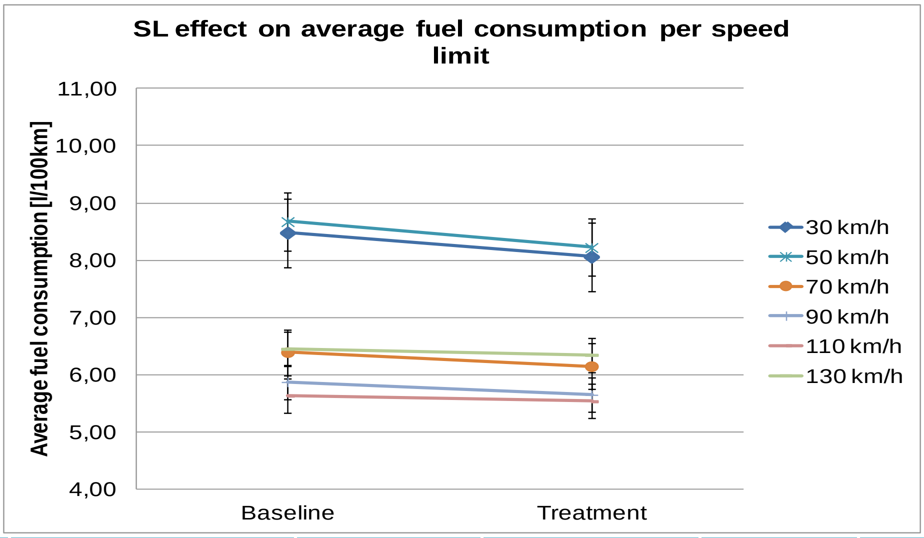
Data

35 drivers, which have sufficient number of kilometres (>5000 km) in Baseline and Treatment was used for the analyses. Unknown Roads and speed limits are not included in the analyses

Statistical Methods

See the introducing “method for ABA analysis” introducing section.

Results



Factor (Speed limits)	Least squares estimation for average fuel consumption (litres/100km) Baseline / Treatment	Lower bound Baseline / Treatment	Upper bound Baseline / Treatment	Type III fixed effects P-value	Increase Litres/100km
30 km/h	8,48 / 8,06	7,9 / 7,5	9,0 / 8,6	<.0001	-0,42
50 km/h	8,67 / 8,22	8,2 / 7,7	9,2 / 8,7	<.0001	-0,45
70 km/h	6,39 / 6,15	6,0 / 5,8	6,8 / 6,5	<.0001	-0,25
90 km/h	5,87 / 5,65	5,6 / 5,4	6,2 / 5,9	<.0001	-0,22
110 km/h	5,63 / 5,54	5,3 / 5,2	5,9 / 5,8	0.0006	-0,10
130 km/h	6,45 / 6,35	6,1 / 6,0	6,8 / 6,7	<.0001	-0,10

Conclusions

The function SL decreases significantly the average fuel consumption in all driving contexts.
Factor analyses show a similar effect for all the situations, but the decrease is stronger for low speed limits values. This is due to thermal engine fuel consumption which is lower for high speeds until 90km/h. After that boundary, fuel consumption start to increase again with speed. The decrease for high speed values is very low although significant, and is certainly a consequence of improving stable speed while using SL.

Using CC decreases the average speed.

Comparison situations

Driver speed choice is highly dependent on the road design. A high correlation is expected between speed limit, road type, and average measured speed, and there is a need to carefully choose baseline and treatment data for comparison purpose.

1. Baseline: Random sampled chunks according to exposure.
2. Treatment: Chunks where the percentage of time with CC in use > 5%.

Filtering criteria

- Average speed >5km/h.
- Map speed limit information available

Factors

1. Speed limit (30, 50, 70, 90, 110, 130 km/h)

Performance indicators (PIs)

1. Chunked Average Speed.

Chunking

10 to 30 sec chunks with homogeneous values for: TripID, DriverID, road type, speed limit, weather ,and lighting. The other variables are not constant and treated as PI.

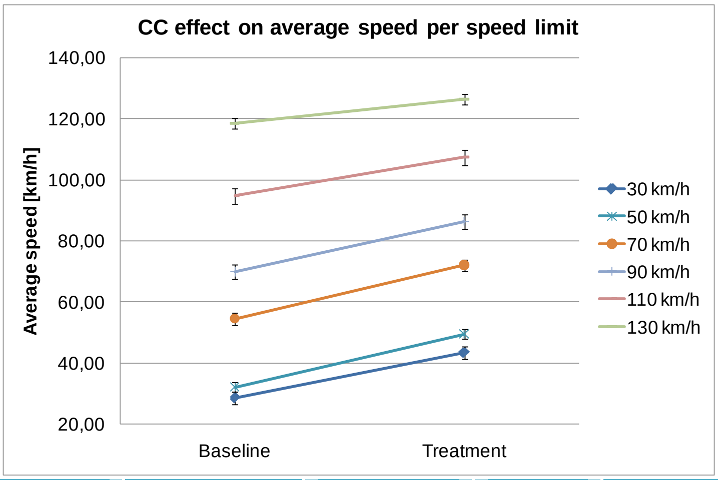
Data

35 drivers, which have sufficient number of accumulated kilometres (>5000 km) in Baseline and Treatment was used for the analyses. Unknown Roads are not included in the analyses.

Statistical Methods

The suitable method for this kind of analysis is the “Generalized Linear Mixed Model” (GLMM) which allows introducing a random effect specific to each subject. In this case, driver ID is used as a random effect specified by the compound-symmetry structure, which has constant variance and constant covariance. The compound symmetry structure arises naturally with nested random effects, such as when sub sampling error is nested within experimental error.

Results



Factor (Speed limits)	Least squares estimation for average speed Baseline / CC Active	Lower bound Baseline / Treatment	Upper bound Baseline / Treatment	Type III fixed effects P-value	Increase Km/h	Lower bound effect	Upper bound effect
30 km/h	28,69 / 43,46	27,2 / 40,8	30,2 / 46,1	<.0001	14,77	12,5	17,02
50 km/h	32,20 / 49,56	30,6 / 47,9	33,8 / 51,2	<.0001	17,36	16,88	17,84
70 km/h	54,54 / 71,99	52,6 / 69,9	56,5 / 74,1	<.0001	17,45	16,53	18,36
90 km/h	69,81 / 86,31	67,4 / 83,9	72,2 / 88,7	<.0001	16,51	16,02	16,98
110 km/h	94,70 / 107,32	92,3 / 104,9	97,1 / 109,8	<.0001	12,62	12,26	12,97
130 km/h	118,58 / 126,45	116,9 / 124,8	120,3 / 128,1	<.0001	7,87	7,67	8,07

Conclusions

The function CC increases significantly the average speed in all driving contexts.
Factor analyses show a similar effect for all the situations, with an average speed increase of more than 10km/h.

Using CC decreases the fuel consumption.

Comparison situations

See the introducing baseline sampling section.

1. Baseline: Random sampled chunks according to exposure. The baseline is the same as for the SL system.
2. Treatment: Chunks where the percentage of time with CC in use > 5%.

Filtering criteria

- Average speed >5km/h.
- Map speed limit information available

Factors

1. Speed limit (30, 50, 70, 90, 110, 130 km/h.)

Performance indicators (PIs)

1. Chunked Average fuel consumption.

Chunking

The chunk process is the same for all hypotheses: See "chunking process at the French VMC" introduction section.

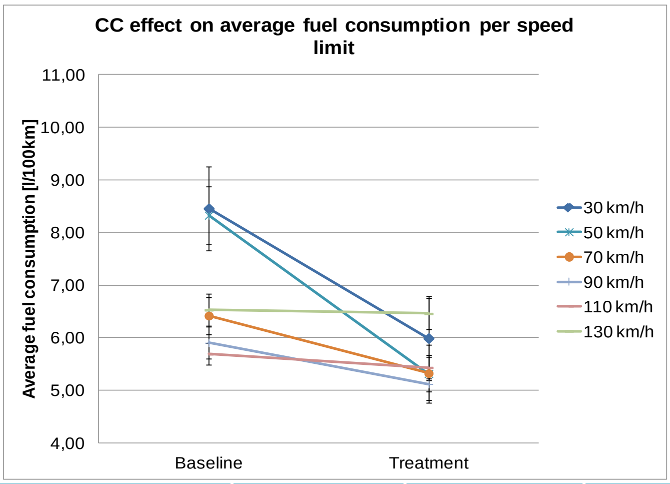
Data

35 drivers, which have sufficient number of accumulated kilometres (>5000 km) in Baseline and Treatment was used for the analyses. Unknown Roads are not included in the analyses,

Statistical Methods

See the introducing "method for ABA analysis" introducing section.

Results



Factor (Speed limits)	Least squares estimation for average fuel consumption (litres/100km) Baseline / Treatment	Lower bound Baseline / Treatment	Upper bound Baseline / Treatment	Type III fixed effects P-value	Increase Litres/100km
30 km/h	8,46 / 5,99	7,9 / 5,0	9,0 / 7,0	<.0001	-2,47
50 km/h	8,33 / 5,32	7,8 / 4,8	8,9 / 5,9	<.0001	-3,01
70 km/h	6,42 / 5,33	6,1 / 4,9	6,8 / 5,7	<.0001	-1,09
90 km/h	5,90 / 5,12	5,6 / 4,8	6,2 / 5,4	<.0001	-0,78
110 km/h	5,69 / 5,43	5,5 / 5,2	5,9 / 5,7	<.0001	-0,26
130 km/h	6,53 / 6,46	6,2 / 6,1	6,9 / 6,8	<.0001	-0,07

Conclusions

The function CC decreases significantly the average fuel consumption in all driving contexts.
Factor analyses show a similar effect for all the situations, but the decrease is stronger for low speed limits values. This is due to thermal engine fuel consumption which is lower for high speeds until 90km/h. After that boundary, fuel consumption start to increase again with speed. This is in line with the increasing average speed, leading to decreasing fuel consumption.
The decrease for high speed values is very low although significant, and is certainly a consequence of improving stable speed while using CC.

The number of trips made will increase

Comparison situations

No comparisons are made as only treatment data with SL/CC available are used.

Filtering criteria

Chunks are filtered before selection according to the following parameters:

- Average speed >5km/h.
- Map speed limit information available

Factors

1. Month

Performance indicators (PIs)

1. Number of trips per month.

Chunking

The chunk process is the same for all hypotheses: See “chunking process at the French VMC” introduction section.

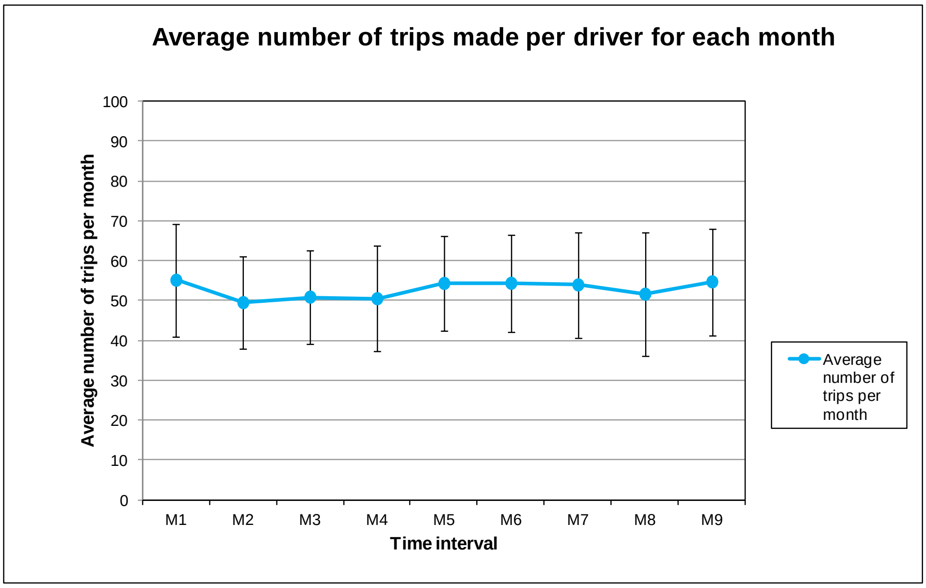
Data

35 drivers, which have sufficient number of accumulated kilometres (>5000 km) in Baseline and Treatment was used for the analyses. Unknown Roads and speed limits are not included in the analyses.

Statistical Methods

Graphical exploration of PI evolution over months, and analysis of variance of PI over months.
Analysis tool: SAS software.

Results



Conclusions

Numbers of trips made do not vary significantly over time.
Analysis of variance together with a Tukey test did not find any relevant differences between month.

The number of vehicle km travelled will increase

Comparison situations

No comparisons are made as only treatment data with SL/CC available are used.

Filtering criteria

- Average speed >5km/h.
- Map speed limit information available

Factors

1. Month

Performance indicators (PIs)

1. Number of km travelled per month.

Chunking

The chunk process is the same for all hypotheses: See “chunking process at the French VMC” introduction section.

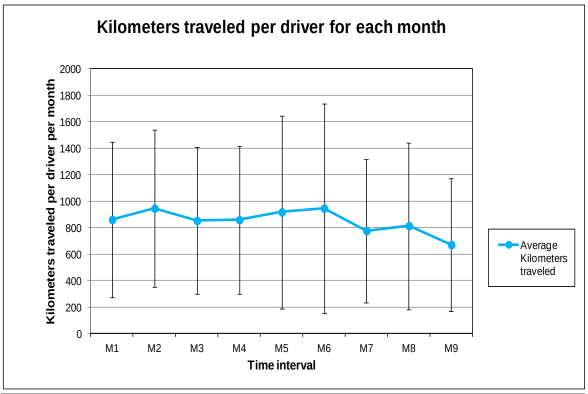
Data

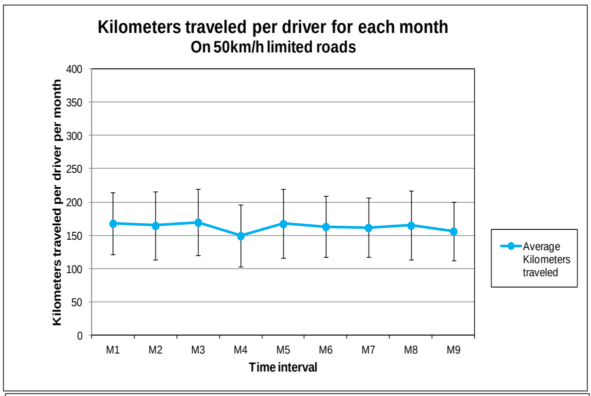
35 drivers, which have sufficient number of accumulated kilometres (>5000 km) in Baseline and Treatment was used for the analyses. Unknown Roads and speed limits are not included in the analyses.

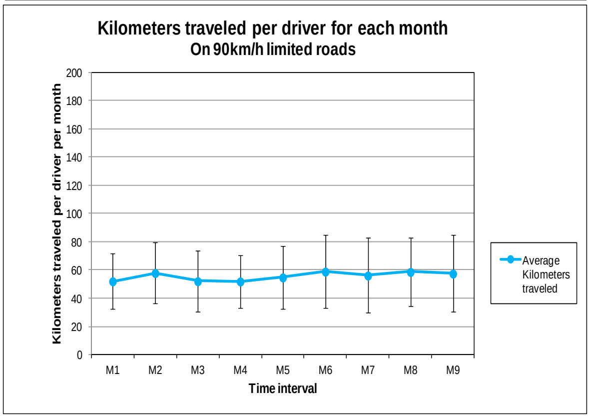
Statistical Methods

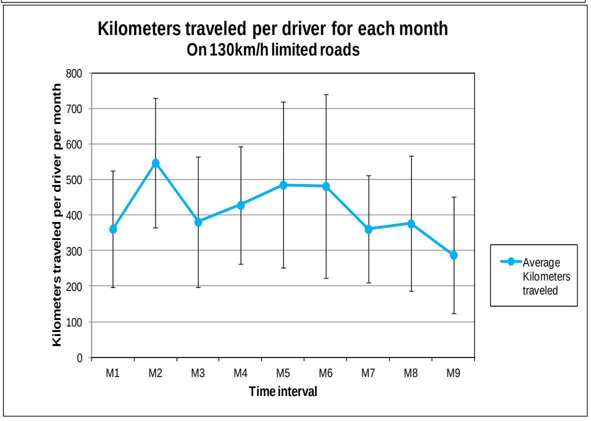
Graphical exploration of PI evolution over months, and analysis of variance of PI over months.
Analysis tool: SAS software.

Results









Conclusions

The amount of kilometres travelled do not vary significantly over time.
Analysis of variance did not find any relevant differences between the months.

Annex 4 Blind Spot Information System (BLIS)

List of selected hypothesis

List of analysed hypothesis for BLIS is:

Table 5: List of BLIS hypothesis

Acceptance changes over time with system use
Certain features of the BLIS system, in terms of usability, influence acceptance
Certain features of the BLIS system, in terms of usefulness, influence acceptance
Trust in the BLIS system changes over time with system use
Drivers workload decreases over time with system use
User practices (heuristics, rules) will change over time during the FOT
Drivers will not abuse or misuse BLIS

Acceptance changes over time with system use

Comparison situations

T2: Evaluation of expectations of system before they are activated in the car.
T3: Evaluation of the system once the drivers had accumulated relatively extensive experience with the system, i.e. after approximately half of the treatment period had passed.
T4: Evaluation of system after Treatment period is completed.

Performance indicators (PIs)

For evaluation of acceptance using the Van der Laan scale the following 9 items are rated on a scale from -2 to +2 :

- **useful**
- pleasant
- **good**
- nice
- **necessary**
- likeable
- **assisting**
- desirable
- **raising alertness**

In the Van der Laan scale, acceptance is also broken down into Usefulness and Satisfaction. The average rating of the bold items are considered to be a measure of usefulness and the average of the remaining items is a measure of satisfaction.

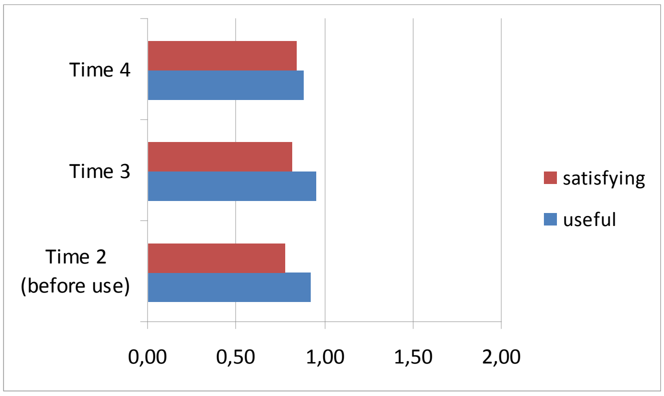
Data

Items under
BLIS_ac_1_2 .
BLIS_ac_1_3 and
BLIS_ac_1_4 in the questionnaire.

Statistical Methods

Paired T-test is conducted to compare the usefulness and satisfaction results in T3 vs T4.
As a reference, also acceptance at T2 (before use) is presented.

Results



Satisfaction		
Time	**N**	**Mean score**
T2	86	0,78
T3	86	0,81
T4	86	0,84
p value T2->T3	0,686	
p value T3->T4	0,759	

Usefulness		
Time	**N**	**Mean score**
T2	86	0,92
T3	86	0,95
T4	86	0,98
p value T2->T3	0,745	
p value T3->T4	0,326	

Conclusions

Acceptance, in terms of usefulness and satisfaction is positive at all times and does not change during use of the system. The drivers found the system more useful then satisfying.
Drivers overall found BLIS useful and satisfying to use. The system in use fulfilled very well the expectations on the system (no significant differences between T2 and T3).
Exposure to the system gives no significant changes of the usefulness and satisfaction scores.

Certain features of the BLIS system, in terms of usability, influence acceptance

Comparison situations

T4: Subjective ratings of acceptance using the Van der Laan scale. Given that this is not a well defined hypothesis, we will only present the data descriptively.

Performance indicators (PIs)

For evaluation of acceptance 11 items under the concept of Perceived Ease of Use (usability) have been rated on a scale from -2 to +2 (Strongly disagree to Strongly agree).

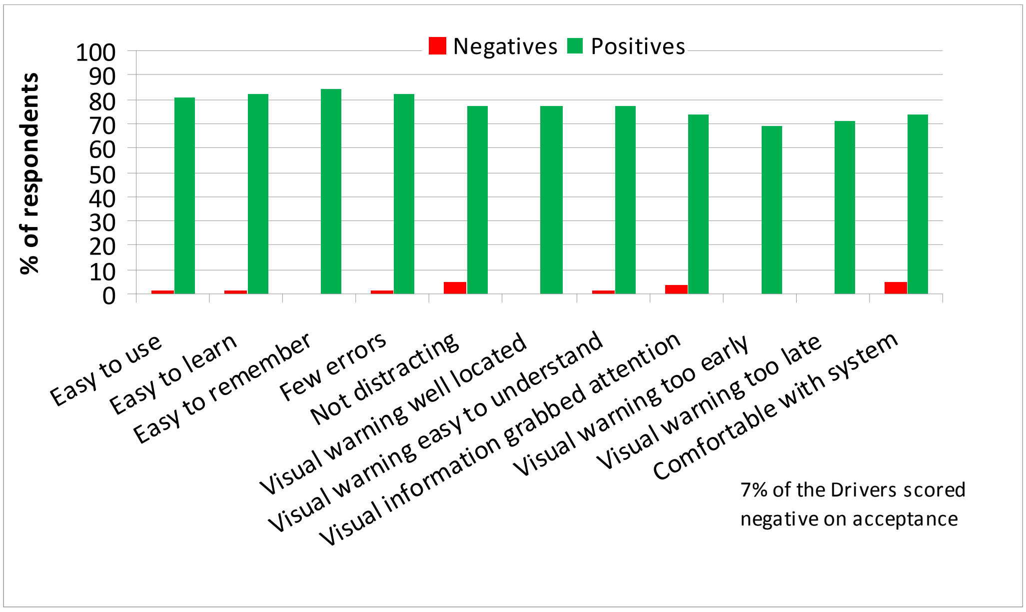
Data

Items under FCW_eas_1_4 in the questionnaire

Statistical Methods

The task is to identify the usability items that influence acceptance scores
Each participant is considered separately, such that if a participant scored the system positively on the Van der Laan scale in FCW9, then those scores that score high (>0) on usability were deemed to have impacted on that score. Conversely, if a participant scored the system negatively on the Van der Laan scale, then there will be certain items relating to usability that would contribute to this.

Results



Explanations of the diagram:

The height of the red bars indicates where a "negative" participant rated the system as negative on that particular item. A "negative" participant is one whose average acceptability score is negative.

The height of the green bars indicates where a “positive” participant rated the system as positive on that particular item. A “positive” participant is one whose average acceptability score is positive.

Conclusions

In general the green bars, which represent the number of positive drivers for each usability item are very high for all items. The 7 % drivers that scored negative on acceptance did not feel comfortable with the system and experienced the system as distracting.

Certain features of the BLIS system, in terms of usefulness, influence acceptance

Comparison situations

T4: Do participants with negative acceptance to the system rate usability items different from the positive drivers? Given that this is not a well defined hypothesis we will only present the data descriptively.

Performance indicators (PIs)

5 items under the concept of Perceived Usefulness have been rated on a scale from -2 to +2 (Strongly disagree to Strongly agree). Usefulness is rated by the driver at different driving scenarios, i.e. driving on different road types under various conditions.

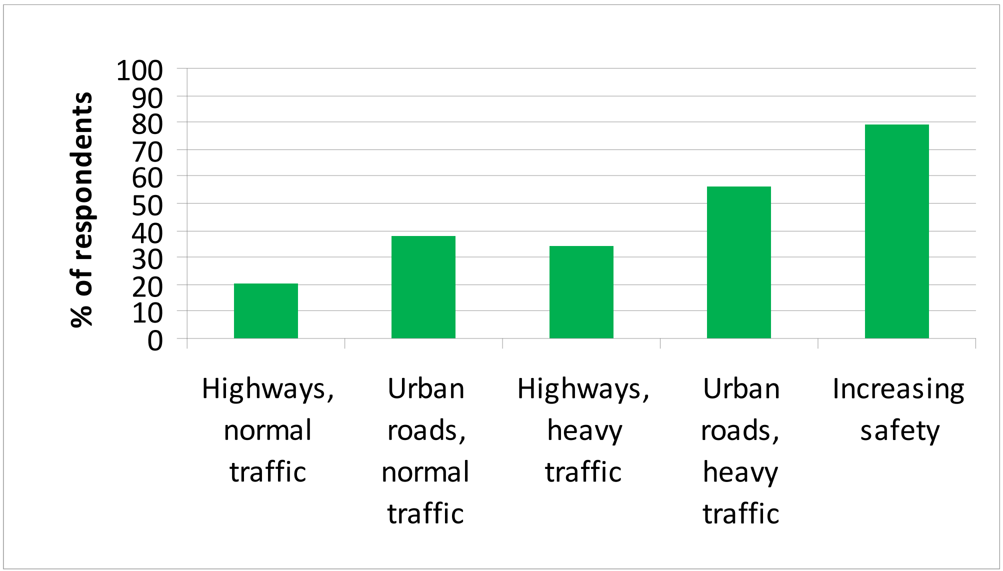
Data

Items under BLIS_use_1_4 in the questionnaire.

Statistical Methods

The task is to identify the usefulness items that influence the positive acceptance scores
Each participant is considered separately, such that if a participant scored the system positively on the Van der Laan scale, then those scores that score high (>0) on usability were deemed to have impacted on that score.

Results



The bars represent the number of positive driver that scored positive on the particular item.

Conclusions

Usefulness on urban roads in heavy traffic contributed the most to positive acceptability scores. Also a very high proportion of the respondents felt that the system increased safety.

Trust in the BLIS system changes over time with system use

Comparison situations

T2: Evaluation of expectations of system before it is activated in the car.
T3: Evaluation of the system once the drivers had accumulated relatively extensive experience with the system, i.e. after approximately half of the treatment period had passed.
T4: Evaluation of system after Treatment period is completed.

Performance indicators (PIs)

For evaluation of the drivers trust in the system the following 3 items are rated on a scale from +2 to - 2 at different times during use.
Raises confidence – creates uncertainty
Trustworthy - untrustworthy
Reliable - unreliable

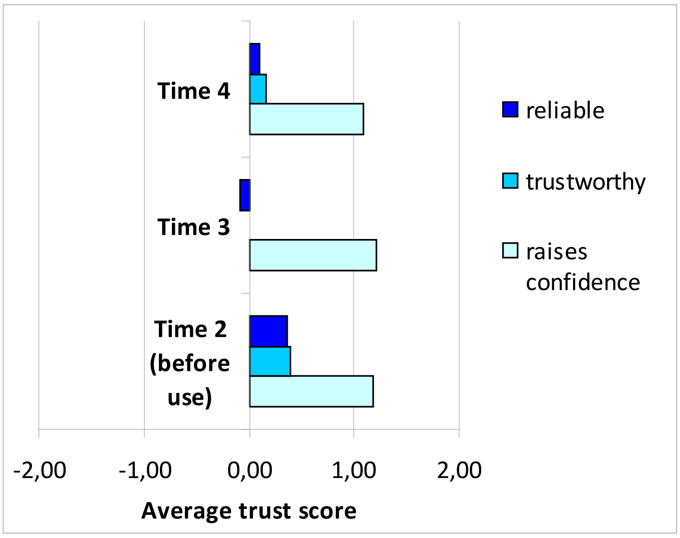
Data

Items under
BLIS_ac_1_2 .
BLIS_ac_1_3 and
BLIS_ac_1_4 in the questionnaire.

Statistical Methods

Paired T-test is conducted to compare the usefulness and satisfaction results in T3 vs T4.
As a reference, also acceptance at T2 (before use) is presented.

Results



Reliable		
Time	N	Mean score
T3	57	-0,08
T4	57	0,1
p value	0,094	

Trustworthy		
Time	N	Mean score
T3	59	0
T4	59	0,17
p value	0,115	

Raises confidence		
Time	N	Mean score
T3	59	1,22
T4	59	1,08
p value	0,117	

Conclusions

Confidence in the system is very high which means that the drivers are not afraid that the system will not warn when there really is a car in the “blind zone”. Reliability and trustworthy is low which most probably is a consequence of false positives, i.e. the camera based BLIS system sometimes reacts on other things than if there are vehicles in the “blind zone”.
Confidence is high but trust and reliability is very low. However, no significant changes T3 to T4. Confidence in the system before use is higher than experienced during use (significant).

Drivers workload decreases over time with system use

Comparison situations

T3: Evaluation of the system once the drivers had accumulated relatively extensive experience with the system, i.e. after approximately half of the treatment period had passed.
T4: Evaluation of system after Treatment period is completed.

Performance indicators (PIs)

Level of Workload on a scale ranging from 0 to 140. 0 is no mental effort and 140 is very high mental effort.

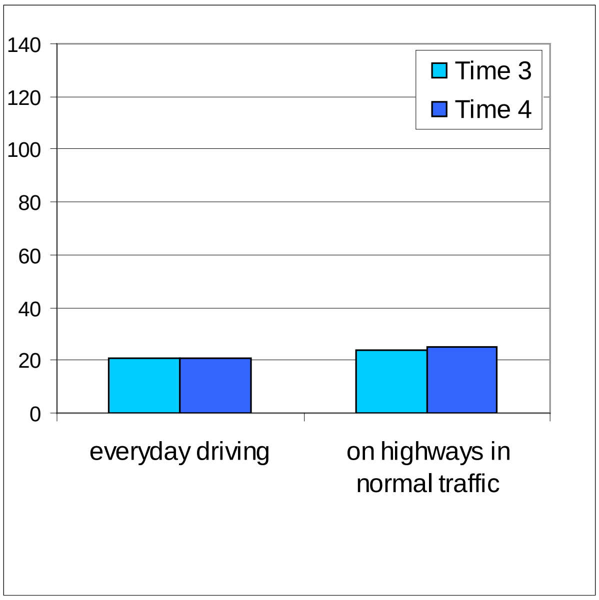
Data

Items under
BLIS_mw_1_3 and
BLIS_mw_1_4
in the questionnaire.

Statistical Methods

Paired T test to compare, between T3 and T4, if the drivers perception of mental workload changes over time with system use when driving in different situations.

Results



Everyday traffic		
Time	N	Mean score
T3	59	21
T4	59	21
p value	0,87	

Highways in normal traffic		
Time	N	Mean score
T3	59	24
T4	59	25
p value	0,436	

Conclusions

Usefulness on highways in normal traffic contributed the most to positive acceptability scores. Also a relative high proportion of the respondents felt that the system increased safety.

The drivers' perception of mental workload while driving with the BLIS system is very low and does not change over time with system use.

User practices (heuristics, rules) will change over time during the FOT

Comparison situations

T4: Evaluation of system after Treatment period is completed.

Performance indicators (PIs)

Drivers' view of using the system different in the end of the treatment period compared to when they first started to use the system.

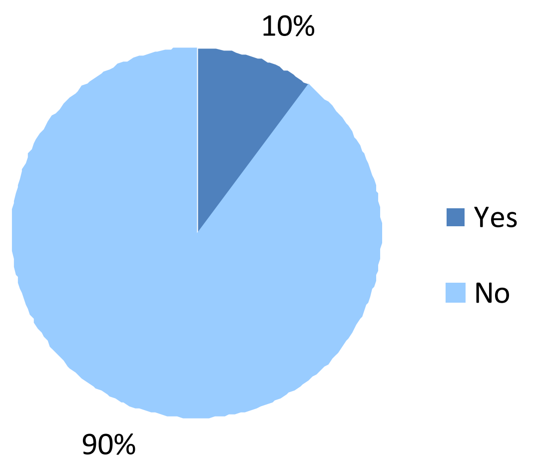
Data

Items under
BLIS_upr_1a_4
in the questionnaire.

Statistical Methods

None. Descriptive presentation only.

Results



Conclusions

10 % of the drivers believe they have changed user practices during use of the system. Free text comments indicate that drivers increase their use of the system.

Drivers will not abuse or misuse BLIS

Comparison situations

T4: Evaluation of system after Treatment period is completed.

Performance indicators (PIs)

Question asked: Relied on BLIS warning, rather than using visual checks

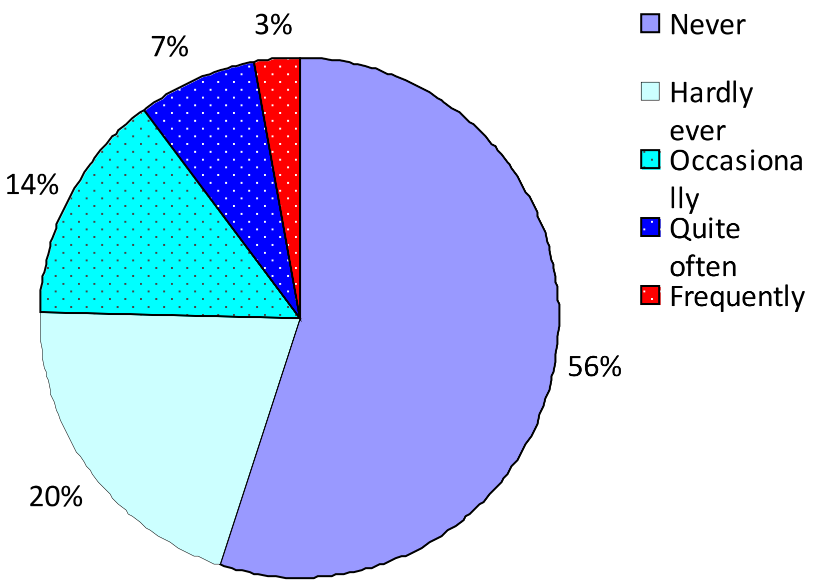
Data

Items under
IW_mis_1_4
in the questionnaire.

Statistical Methods

None. Graphic analyse only.

Results



Conclusions

24% of the drivers are relying on BLIS warning rather than using visual checks at least occasionally. 3 % says they are doing that frequently.

Annex 5 Lane Departure Warning (LDW)

List of selected hypothesis

The list of selected hypothesis for LDW is:

Table 6: LDW selected hypothesis

LDW influences lateral driving performance
LDW increases the use of turn indicators in lane change situations
In normal (non-conflict) driving, focus and level of engagement on secondary tasks will increase when drivers use LDW
Focus and level of engagement on secondary tasks just prior to Crash Relevant Events (CRE) will be higher when drivers are using FCW+ACC+LDW
Focus on forward roadway in crash relevant events is lower when using LDW
With LDW available, the number of lateral crash relevant events will be reduced.
Acceptance changes over time with system use
Driver workload decreases over time with the system
LDW increases usage more and more over time
LDW acceptance increases with LDW usage.
LDW is well accepted by the driver
Certain features of the LDW system, in terms of usability, influence acceptance
Certain features of the LDW system, in terms of usefulness, influence acceptance
Trust in system changes over time with system use
User practices (heuristics/rules) will change over time during the FOT
Drivers will not abuse or misuse LDW

LDW influences lateral driving performance

Comparison situations

- **Baseline**: All Baseline with vehicle speed above 60km/h **and** lane markings available (lane marking type is recognized and quality is high).
- **Treatment**: All Treatment with vehicle speed above 60km/h **and** lane markings available (lane marking type is recognized and quality is high) **and** LDW is active.

Filtering criteria

- Vehicle speed > 60 km/h.
- Lane markings available (lane marking type is recognized and quality is high).
- LDW active (only in Treatment).
- Only motorways.

Factors

- Fleet (fleet1, fleet2)
- Load (loaded, non-loaded)

Performance indicators (PIs)

- Median lateral offset (MLO) – distance to the lane on the right (right-hand traffic) or on the left (left-hand traffic).
- Mean of steering wheel angle (MSW).
- Standard deviation of yaw rate (SYR).

Chunking

180 s per chunk aggregated with a median function.

Data

All of the available data in DB divided *per driver*.

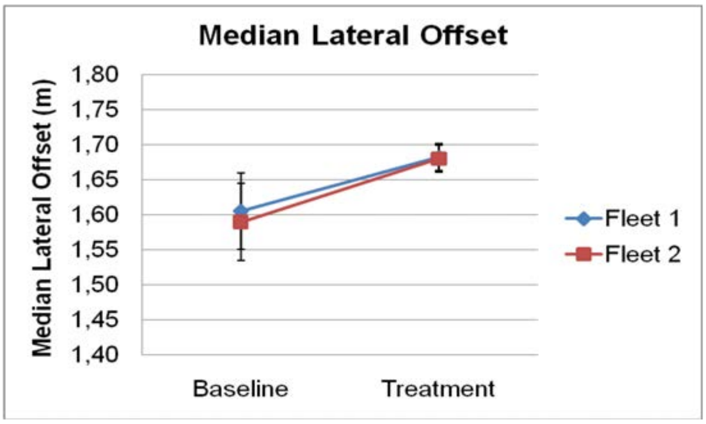
Statistical Methods

3-way repeated measures ANOVA with within factors Load (loaded, non-loaded) and Time (baseline, treatment); and between factor Fleet (fleet1 vs. fleet2).

Results

In Treatment condition, MLO was significantly higher than in Baseline condition (Time factor; $p<0.05$; the other main factors and interactions were not significant for MLO. Load effect was significant ($p<0.05$) for MSW and SYR. A significant ($p<0.05$) interaction between load and fleet for MSW was also found. None of the other main factors and interactions for MSW and SYR were significant.

PI	Effect	df	Error df	F	p	Effect Size	M (baseline)	SE (baseline)	M (treatment)	SE (treatment)
MLO	Time	1	28	**6.57**	**0.016**	0.190	1.597	0.033	1.681	0.011
MSW	Load	1	28	**8.93**	**0.006**	0.242				
MSW	Load Fleet	1	1	**73.8**	**<0.001**	0.725				
SYR	Load	1	28	**18.4**	**<0.001**	0.397				



Conclusions

LDW does influences lateral control. Truck drivers exhibited a higher MLO In the treatment phase than in baseline suggesting drivers were driving further away from road edge. This behaviour tends to increase safety margins.

LDW increases the use of turn indicators in lane change situations

Comparison situations

- Baseline: all trips made during the baseline period.
- Treatment: all trips made during the treatment period.

Filtering criteria

We considered all trips from *Golden List*.

Factors

- Road type: any or motorway.
- Load: any or loaded.

Performance indicators (PIs)

- Number of lane changes in which turn indicator was used.
- Total number of lane changes

Chunking

None.

Data

For a brief summary on the amount of data used in the analysis see the description of *Golden List*.

Statistical Methods

Binomial model.

Results

We observed that the probability to conduct a lane change (LC) using turn indicator (TI) was higher during the treatment period.

Factors	Response variables	Baseline	Treatment	Total	Result
Road: any Load: any	LC with TI: LC without TI: Total:	26227 9801 36028	41563 13007 54570	67790 22808	TI usage in LC increased from 73% to 76% p-value: 0
Road: motorway Load: any	LC with TI: LC without TI: Total:	16378 3964 20342	25424 4897 30321	41802 8861	TI usage in LC increased from 81% to 84% p-value: 0
Road: any Load: loaded	LC with TI: LC without TI: Total:	18123 5221 23344	28155 6936 35091	46278 12157	TI usage in LC increased from 78% to 80% p-value: 1.6e-14
Road: motorway Load: loaded	LC with TI: LC without TI: Total:	16378 3964 20342	25412 4894 30306	41790 8858	TI usage in LC increased from 81% to 84% p-value: 0

Conclusions

The probability to conduct a lane change (LC) using turn indicator (TI) increased by 3%

In normal (non-conflict) driving, focus and level of engagement on secondary tasks will increase when drivers use LDW

Comparison situations

- Baseline: All Baseline with vehicle speed above 60km/h and lane markings available (lane marking type is recognized and quality is high).
- Treatment: All Treatment with vehicle speed above 60km/h and lane markings available (lane marking type is recognized and quality is high) and LDW is active.

Filtering criteria

- Vehicle speed > 60 km/h
- Lane markings available (lane marking type is recognized and quality is high)
- LDW active (only in Treatment)

Factors

Secondary Task (yes / no).

Performance indicators (PIs)

Count of events for:

- General Secondary Task.
- Use of Nomadic Device.
- Manual Secondary Task.
- Visual Secondary Task.
- Cognitive Secondary Task.

Chunking

None.

Data

150 normal driving epochs with video annotation.

Statistical Methods

Odds ratios with confidence intervals.

Results

All odds ratios did not indicate change in the proportion of secondary tasks between treatment and baseline, further none was not significant.

	Odds Ratios	**Confidence Interval**
General Secondary Task	0.87	0.42-1.80
Use of Nomadic Device	1.31	0.21-8.08
Manual Secondary Task	0.86	0.38-1.93
Visual Secondary Task	0.96	0.28-3.38
Cognitive Secondary Task	NA	NA

Conclusions

Using LDW does not increase secondary tasks for truck drivers during normal driving.

Focus and level of engagement on secondary tasks just prior to Crash Relevant Events (CRE) will be higher when drivers are using FCW+ACC+LDW

Comparison situations

- Baseline: All baseline with vehicle speed above 50km/h and THW is not null and expected speed > x (x = 95km/h for fleet1 and x = 115km/h for fleet2) or Baseline: All Baseline with vehicle speed above 60km/h and lane markings available (lane marking type is recognized and quality is high).
- Treatment: All treatment with vehicle speed above 50km/h and THW is not null and expected speed > x (x = 95km/h for fleet1 and x = 115km/h for fleet2) and ACC ON (Active) and plus five seconds after ACC shut off or Treatment: All Treatment with vehicle speed above 60km/h and lane markings available (lane marking type is recognized and quality is high) and LDW is active.

Filtering criteria

- Vehicle speed > 50 km/h.
- THW is not null.
- Expected speed > x (x = 95km/h for fleet1 and x = 115km/h for fleet2).

or

- Vehicle speed > 60 km/h.
- Lane markings available (lane marking type is recognized and quality is high).
- LDW active (only in Treatment).

Factors

Secondary Task (yes / no).

Performance indicators (PIs)

Count of events for:

- General Secondary Task.
- Use of Nomadic Device.
- Manual Secondary Task.
- Visual Secondary Task.
- Cognitive Secondary Task.

Data

40 crash relevant events with video annotation.

Statistical Methods

Odds ratios with confidence intervals.

Results

Odds ratios indicate no change between treatment and baseline for all type of secondary tasks with a trend toward secondary tasks being less represented in the treatment phase than in baseline.

	Odds Ratios	**Confidence Interval**
General Secondary Task	1.71	0.30-9.71
Use of Nomadic Device	NA	NA
Manual Secondary Task	1.31	0.31-5.49
Visual Secondary Task	0.87	0.20-3.77
Cognitive Secondary Task	1.00	0.09-10.87

Conclusions

While using ACC, FCW, and LDW, truck drivers were not more likely to be engaged in secondary tasks during crash-relevant events.

Focus on forward roadway in crash relevant events is lower when using LDW

Comparison situations

Baseline: All Baseline with vehicle speed above 60km/h **and** lane markings available (lane marking type is recognized and quality is high).
Treatment: All Treatment with vehicle speed above 60km/h **and** lane markings available (lane marking type is recognized and quality is high) **and** LDW is active.

Filtering criteria

- Vehicle speed > 60 km/h
- Lane markings available (lane marking type is recognized and quality is high)
- LDW active (only in Treatment).

Factors

Looking at the road vs. not looking at the road.

Performance indicators (PIs)

Count of events.

Chunking

None.

Data

30 crash relevant events.

Statistical Methods

Odds ratios with confidence intervals.

Results

Odds ratios show no increased probability of eyes-off-road in crash relevant events In the treatment phase compared to baseline; however, this result is not significant.

	Odds Ratios	**Confidence Interval**
Crash Relevant Events	1.18	0.20-7.08

Conclusions

Results are not significant, but no increased probability of eyes-off-road in crash relevant events.

With LDW available, the number of lateral crash relevant events will be reduced.

Comparison situations

- Baseline: All baseline with vehicle speed above 60km/h and lane markings present
- Treatment: All treatment with vehicle speed above 60km/h and LDW ON (Active)

Filtering criteria

See Comparison situations.

Factors

None.

Performance indicators (PIs)

Count of lateral[3] crash relevant events.

Chunking

None.

Data

19 lateral crash relevant events

Statistical Methods

Odds ratios with confidence intervals.

Results

Odds ratios show a decrease in the probability of experiencing lateral crash relevant events when LDW is available, but the difference is not significant.

	Odds Ratios	Confidence Interval
Crash Relevant Events	0.53	0.17-1.59

Conclusions

Drivers did not experience a reduction in the number of lateral crash relevant events when using LDW.

[3] E.g. driver leaving the lane and performing an emergency recovery maneuver

Acceptance changes over time with system use

Comparison situations

1. **T2:** Evaluation of system before use
2. **T3**: Evaluation of system after use
3. **T4:** Evaluation of system after end of condition

Performance indicators (PIs)

For evaluation of acceptance using the Van der Laan scale the following 9 items are rated on a scale from -2 to +2 at different times during use.

- useful
- pleasant
- good
- nice
- necessary
- likeable
- assisting
- desirable
- raising alertness

Data

Acceptance changes over time with system use.
Please indicate how appealing you find the ACC system by ticking the box that most accurately expresses your feeling on each line. Please leave blank if you have not experienced the system. (Useful- Useless, Pleasant- Unpleasant, Good- Bad, Nice- Annoying, Necessary- Superfluous, Likeable- Irritating, Assisting- Worthless, Desirable- Undesirable, Raising alertness- Sleep-inducing).

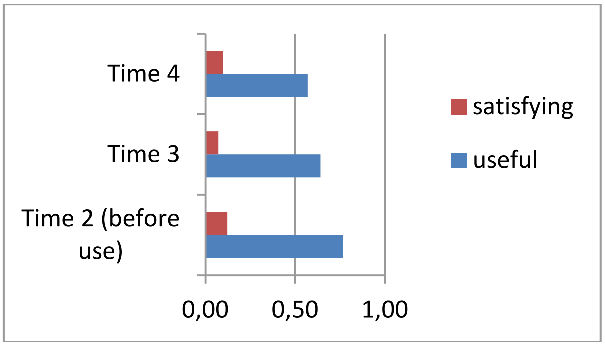
Statistical Methods

Paired T-test is conducted to compare the usefulness and satisfaction results in T3 vs. T4.
As a reference, also acceptance at T2 (before use) is presented.
Wilcoxon Signed Rank Test **useful**: T3 vs. T4

	Median		N	Z	Amp. Sig (2-tailed).
Useful	T3	,80	103	-1,386	,166
	T4	,60			
Satisfaction	T3	,00	255	-,662	,508
	T4	,00			

A Wilcoxon Signed Rank Test showed there are not statistically differences in usefulness and satisfaction results between Time 3 and Time 4.

Results



Conclusions

Changes over time for the satisfying scores are lower than useful values. Useful values decrease over the time although these differences are not statistically significant. With regards tpf satisfaction, the bar graph shows that values are around 0.10 for the 3 times. However, the differences are not statistically significant.
With reference to acceptability scores, the simplicity of the system is the characteristic more positive evaluated by drivers with the highest values. Participants provided highest values before trying the system than later. Even, values about how much attractive the system is to buy have minimum negative scores. This last item is the only one with negative scores, all the others are positive. Only scores about how much intuitive is LDW is similar over the time.
Drivers overall found FCW useful but satisfaction of the system is very low. There is difference in rating before and after use, which indicates that the expectations, especially in terms of satisfaction, was low already before the system was in use. Exposure to the system gives no significant changes of the usefulness and satisfaction scores.

Driver workload decreases over time with the system

Comparison situations

1. **T3:** Evaluation of system during of usage
2. **T4:** Evaluation of system after end of condition

Performance indicators (PIs)

1. Subjective impression how much effort it took for the drive in those situations.
2. Subjective scale coded 0-150

Data

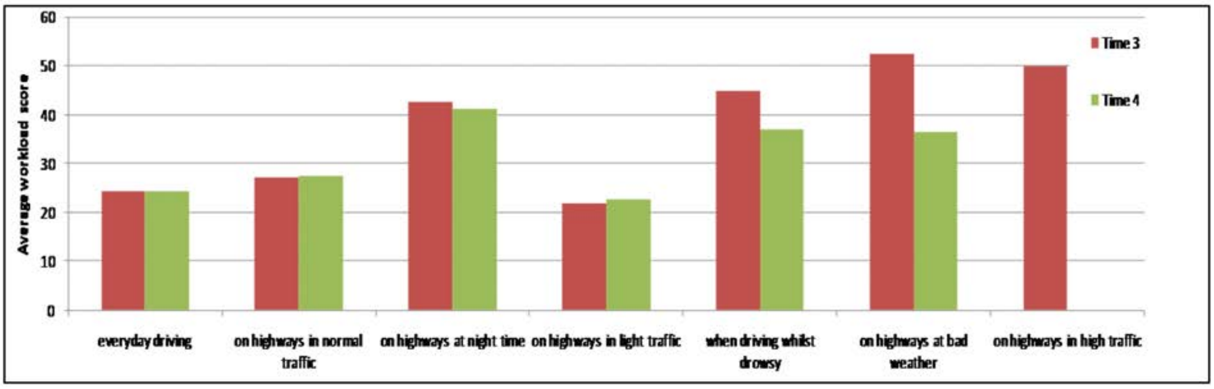
Item: The next set of questions is designed to gauge your impression of how much mental effort you experienced when driving. Please think about when you were driving with ACC system in the following situations and indicate how much effort it took for you to drive in those situations. “Every day driving”, “On highways in normal traffic”, “On rural roads in normal traffic”, “On highways at night time”, “On highways in light traffic”, “When driving whilst drowsy”, “On highways at bad weather” and “On highways in high traffic

Statistical Methods

Friedman test for the 6 items		Median	N	Chi-square	Gl	Amp. Sign.
Everyday driving	T3	20,00	87	2,200	1	,138
	T4	20,00				
On highways in normal traffic	T3	25,00	86	,754	1	,385
	T4	28,00				
On highways in night traffic	T3	28,00	86	1,389	1	,239
	T4	23,00				
On highways in light traffic	T3	20,00	87	2,522	1	,112
	T4	20,00				
When driving whilst drowsy	T3	48,50	8	,143	1	,705
	T4	22,50				
On highways at bad weather	T3	64,50	8	6,000	1	,014
	T4	32,50				

The results of the Friedman Test showed no statistically significant differences between the five conditions evaluated between both times. For “On highways at bad weather” The results of this test indicated that there was a statistically significant difference in “On highways at bad weather” scores across the two time points (T3 and T4), $\chi^2(1,n=8)=6.000$, $p<.05$. Inspection of the median values showed a decrease in workload score from T3 (Md=64,50) to T4 (Md=32,50).

Results



Conclusions

With regards to driver workload the scores of driver workload are similar in the scores for the conditions “Everyday driving” and “On highways in normal traffic”. For the condition “On highways in light traffic the scores are also comparable in both times (21.76% for T3 and 22.59%). The other conditions decrease the workload scores between T3 and T4. Only the differences are statistically significant for “On highways at bad weather” but only 8 drivers answer this question.

U2: “LDW increases usage more and more over time”

Comparison situations

Al trips in the treatment period were labeled either “before” or “after” in such a way that for each driver

- Any trip labeled “after” was done later than any trip labeled “before”.
- The total duration of the trips labeled “before” is (approximately) equal to the total duration of the trips labeled “after”.

We then compared the usage of LDW “before” (Baseline) and “after” (Treatment).

Filtering criteria

We considered only trips from *Golden List*, discarded trips with unknown *driver ID*, and excluded drivers which have made less than 10 trips or have driven less than 20 hours.

Factors

1) Road type: any or motorway. 2) Lighting: any or dark. 3) Load: any or loaded.

Performance indicators (PIs)

Percentage of time the LDW system is on.

Data

The data was paired according to *driver ID.* A brief summary on the amount of data used in the analysis can be found in Table 1.

Statistical Methods

We did extensive exploratory data analysis using the MatLab toolbox which we have developed exclusively to address this and similar hypotheses, see [1]. We then performed a paired (according to *driver ID*) t-test in order to see whether the difference in LDW usage between Baseline (“before”) and Treatment (“after”) is statistically significant. The analysis was done separately for all possible choices of factor levels.

Results

We observed that the LDW system was either “On” or “Off” during the entire trip in 91% of the trips. In particular, during the entire treatment period, 10 drivers had LDW always “Off”. For the remaining 35 drivers we observed a decrease of LDW usage from 52% to 38%, see Fig. 1 (p-value – 0.00003). The combined LDW usage is given in Table 1, and the results were similar for all choices of the factor levels.

Hypothesis	**Factors**	**Response variables**	**Baseline (“before”)**	**Treatment (“after”)**	**Result**
U2, Volvo	Road: any Lighting: any Load: any Fleet: both	LDW usage: Number of trips: Time travelled (h): Distance travelled (km):	43% 2333 41 462 2 961 900	32% 2269 41 458 2 897 800	11% decrease.

Conclusions

The usage of the LDW system in the treatment phase has decreased from 43% to 32%. The average usage of LDW is 35% and 10 out of 45 drivers had the system “Off” during the entire treatment period.

LDW acceptance increases with LDW usage.

This is originally a hypothesis aimed to be answered by questionnaire data only. The analysis here is comparing usage in in-vehicle collected objective usage data with the acceptance results from questionnaires (Van der Laan). The hypothesis tested could be reformulated as *LDW usage increase with acceptance.*

Comparison situations

- Usage compared with Acceptance for all trips for each driver in the entire LDW treatment phase

Filtering criteria

- Only drivers whom have driven more than 100h in total in the treatment phase were used in the analysis.
- Only drivers for which the *Questionnaire 4 - System Acceptability* form was filled in completely was used in the analysis.

Factors

None (too few data points for statistical analysis of subsets)

Performance indicators (PIs)

- **Acceptance** derived from the last System Acceptability questionnaire (questionnaire number 4, administered December 2010 or early 2011)
- Total LDW **Usage** per driver during the entire LDW treatment phase. Usage was defined as the ratio between the time (hours) the user had LDW active (turned on) during a trip and total duration for that trip. All trip's Usage for a driver was merged to total Usage by weighting the individual Usage values for that driver per trip, with respect to duration of each individual trip and total time driven In the treatment phase.

Data

Data from both cars and trucks has been merged. In-vehicle (objective) data was checked for data quality on a per trip basis and trips failing this check were excluded in all analysis. The quality of the subjective data is not considered in this analysis.

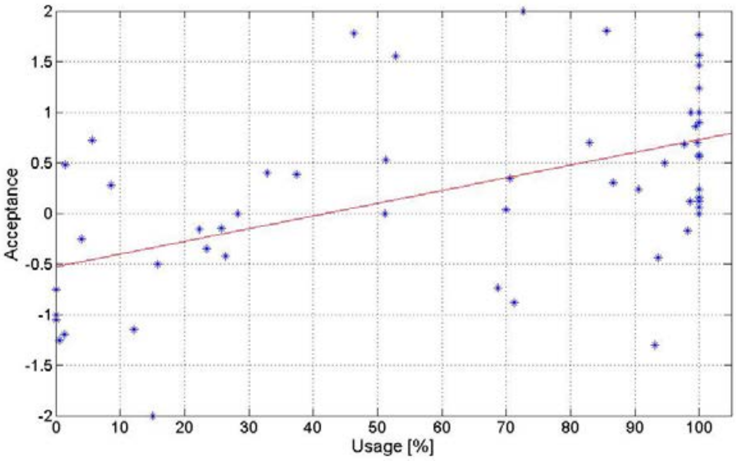
Statistical Methods

Correlation analysis of **Acceptance** and Total **Usage** for all drivers, producing a correlation coefficient and its corresponding p-value

Results

There was a significant positive correlation between usage and acceptance (p=<0.05) with r=0.53.

Correlation coefficient (r)	p	Number of drivers
0.53	<0.05	56



Conclusions

Users with high acceptance use the LDW system more than users with low acceptance.
Many high acceptance users have the systems on all the time, while many low acceptance users have the system turned off most of the time. Users that rate acceptance in the middle of the scale have usage throughout the 0-100% range.

LDW is well accepted by the driver

Comparison situations

T4: Subjective ratings of acceptance using the Van der Laan scale. Given that this is not a well defined hypothesis (positive compared to what?), the data is only presented descriptively.

For evaluation of acceptance using the Van der Laan scale the following 9 items are rated on a scale from -2 to +2:

- useful
- pleasant
- good
- nice
- necessary
- likeable
- assisting
- desirable
- raising alertness

In the Van der Laan scale, acceptance is also broken down into Usefulness and Satisfaction. The average rating of the **bold** items are considered to be a measure of **usefulness** and the average of the remaining items are satisfaction.

2. In addition to the nine Van der Laan items, eleven additional items which also gives an indication of level of acceptance were included in the questionnaire:

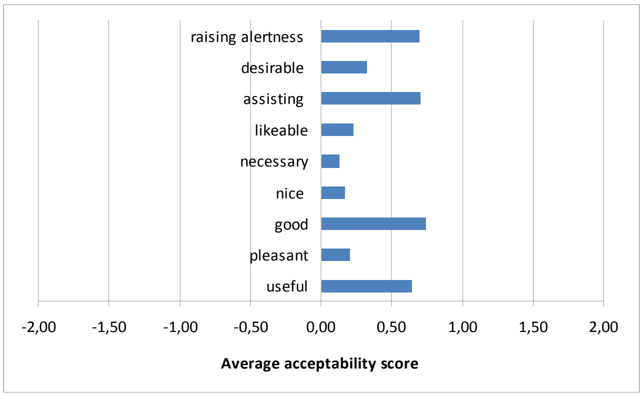
- effective
- raises confidence
- simple
- intend to use
- satisfying
- trustworthy
- intuitive
- social pressure
- competent
- reliable
- attractive to buy

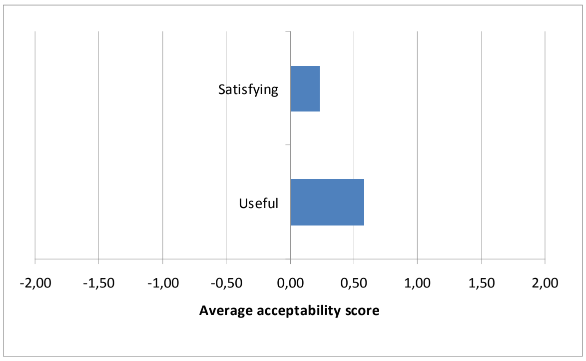
These items were also rated on a scale from -2 to +2.

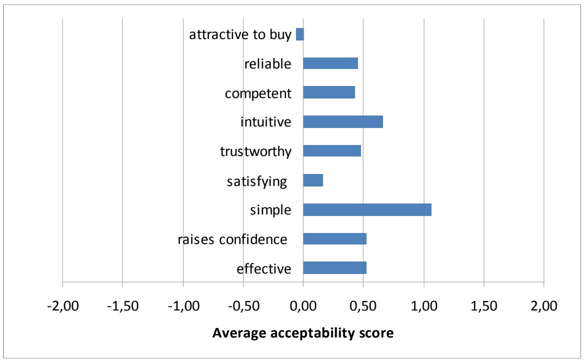
Data

Items under LDW_ac_1_4 in the questionnaire

Results







Conclusions

Participants find the LDW system useful but the satisfaction with the system is low. That fact is also reflected among the additional items in the questionnaire where the participants perceived the system as effective and intuitive but not attractive to buy.

Certain features of the LDW system, in terms of usability, influence acceptance

Comparison situations

T4: Subjective ratings of acceptance using the Van der Laan scale. Given that this is not a well defined hypothesis, we will only present the data descriptively.

Performance indicators (PIs)

For evaluation of acceptance 33 items under the concept of Perceived Ease of Use (usability) have been rated on a scale from -2 to +2 (Strongly disagree to Strongly agree).

Data

Items under FCW_eas_1_4 in the questionnaire

Statistical Methods

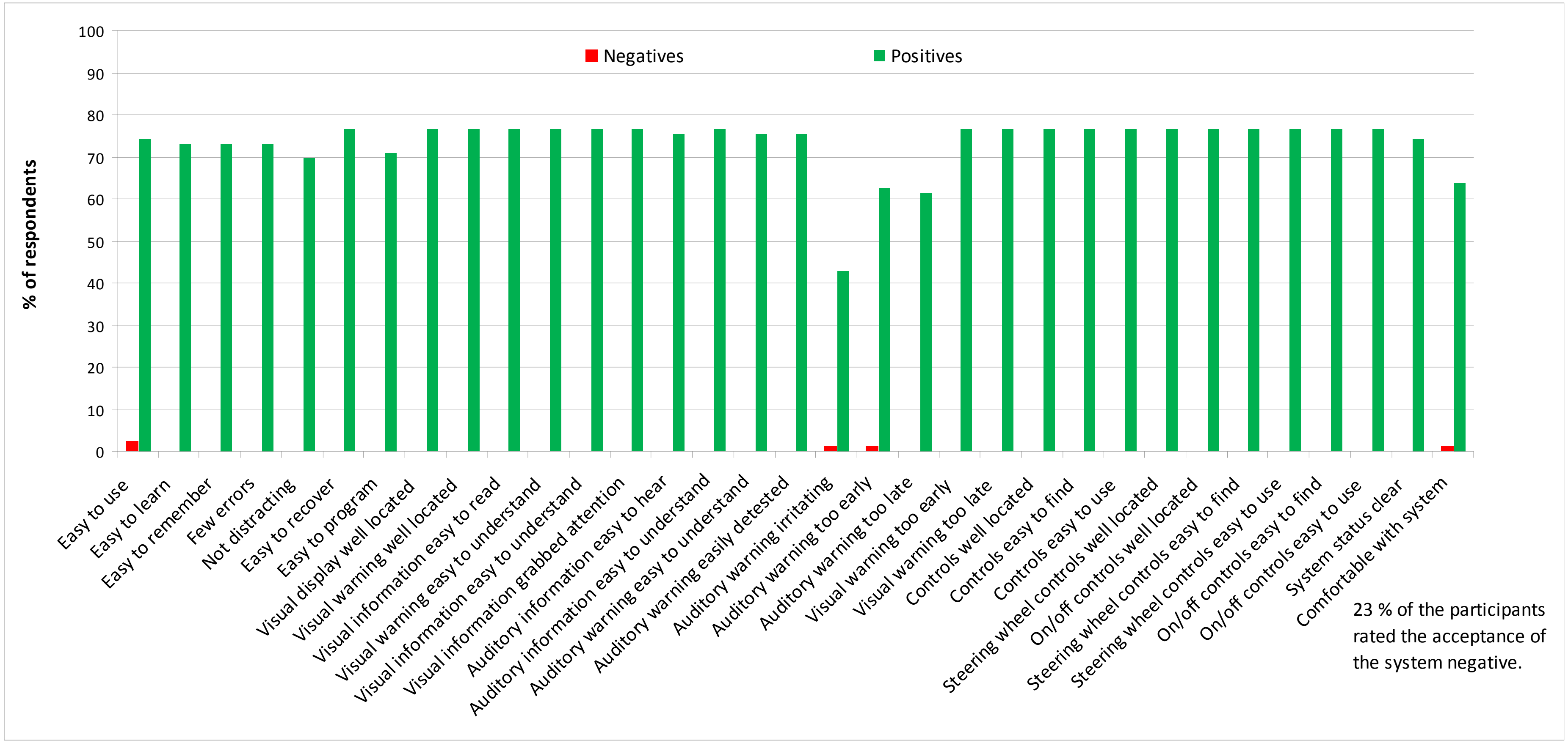
The task is to identify the usability items that influence acceptance scores
Each participant is considered separately, such that if a participant scored the system positively on the Van der Laan scale in FCW9, then those scores that score high (>0) on usability were deemed to have impacted on that score. Conversely, if a participant scored the system negatively on the Van der Laan scale, then there will be certain items relating to usability that would contribute to this.

Results

See Figure on next page.

Conclusions

Approximately 70 % of the participants are positive to most of the items listed in the questionnaire. The only exception is for the auditory and visual warnings where the participants are less positive to the timing of the warning. This creates irritation among the drivers which is indicated in the diagram as well.



Explanations of the diagram:
The height of the red bars indicates where a “negative” participant rated the system as negative on that particular item. A “negative” participant is one whose average acceptability score is negative.
The height of the green bars indicates where a “positive” participant rated the system as positive on that particular item. A “positive” participant is one whose average acceptability score is positive.

Certain features of the LDW system, in terms of usefulness, influence acceptance

Comparison situations

T4: Do participants with negative acceptance to the system rate usability items different from the positive drivers? Given that this is not a well defined hypothesis we will only present the data descriptively.

Performance indicators (PIs)

9 items under the concept of Perceived Usefulness have been rated on a scale from -2 to +2 (Strongly disagree to Strongly agree). Usefulness is rated by the driver at different driving scenarios, i.e. driving on different road types under various conditions.

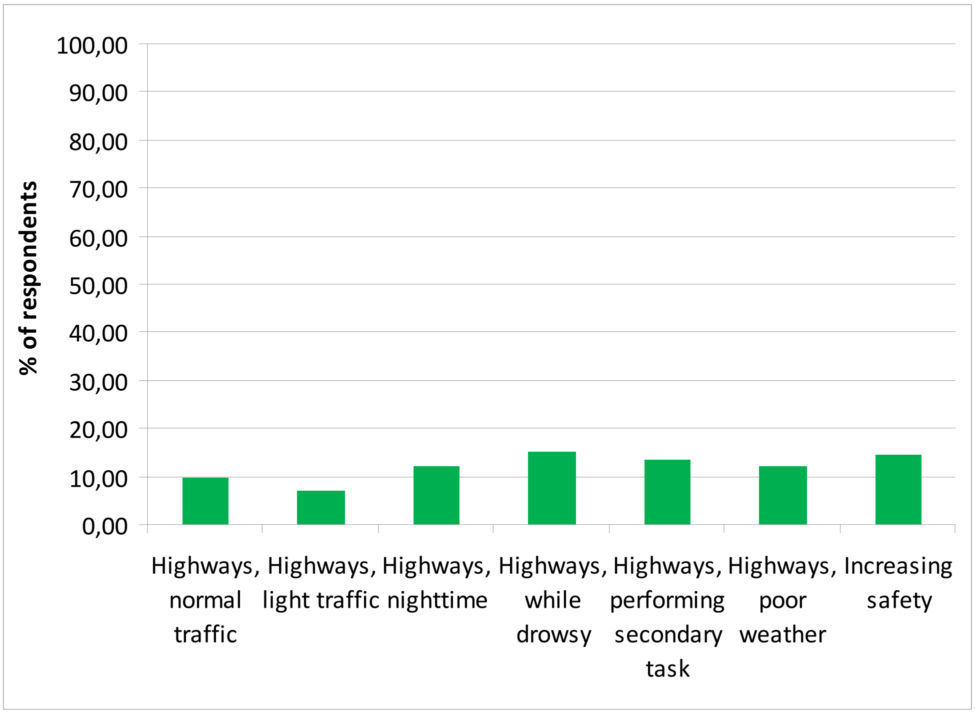
Data

Items under LDW_use_1_4 in the questionnaire.

Statistical Methods

The task is to identify the usefulness items that influence the positive acceptance scores
Each participant is considered separately, such that if a participant scored the system positively on the Van der Laan scale in FCW9, then those scores that score high (>0) on usability were deemed to have impacted on that score.

Results



Conclusions

Overall, the participants rate the usefulness under all driving conditions on highways that was included in the questionnaire.

Trust in system changes over time with system use

Comparison situations

1. T2: Expectance in system; evaluation before usage
2. T3: Evaluation of system during usage
3. T4: Evaluation of system at end of the FOT

The hypothesis is interpreted as suggesting that acceptability changes once the system has been used. Therefore time 2 (before use) data is included in the analysis.

Performance indicators (PIs)

Subjective rating of trust on van der Laan scale (subscales reliable, trustworthy & raises confidence).

Data

Subjective ratings per drivers according to the question ”Thinking about the Lane Keeping Support system and how it might affect driving, please indicate how appealing the system is to you by ticking the box that most accurately expresses your feelings on each line.” Items are included in van der Laan scale (items LDW_tr_1 “raises confidence - creates uncertainty”, LDW_tr_2 “trustworthy - untrustworthy” and LDW_tr_3 “reliable - unreliable”) and are coded on a five score scale from +2 (positive rating) to -2 (negative).

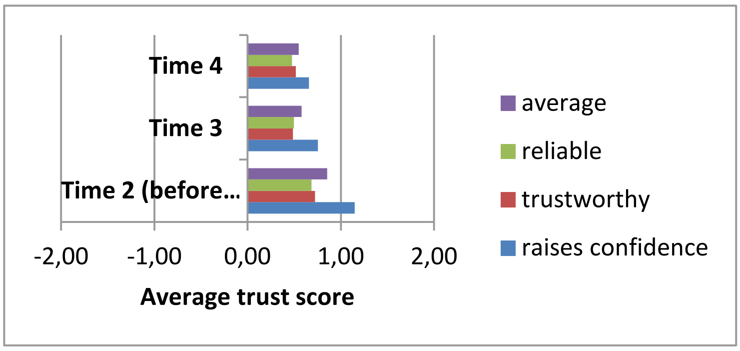
Statistical Methods

T-tests conducted to compare the trust results at time 2, time 3, and time 4.

Results

Results of the t-tests conducted to compare the trust results at time 2, time 3, and time 4 are shown in table. Significant changes are marked red.
Average trust decreases significantly from T2 (before the system use) to T3 (when system is used) with an effect size of 0.44 (Pearson’s r) as well as from T2 (before the system use) to T4 (end of FOT) with an effect size of 0.39 (Pearson’s r).
Confidence in the system decreases significantly from T2 (before the system use) to T3 (when system is used) with an effect size of 0.49 (Pearson’s r) as well as from T2 (before the system use) to T4 (end of FOT) with an effect size of 0.37 (Pearson’s r).
Even ratings of trustworthy decreases significantly from T2 (before the system use) to T3 (when system is used) with an effect size of 0.33 (Pearson’s r)
However changes of reliable ratings are not significant.

	Average trust			Raises confidence			Trustworthy			Reliable		
	df	t	p	df	t	p	df	t	p	df	t	p
T2 vs T3	100	3.22	<0.01	100	4.10	<0.001	100	2.25	<0.05	100	1.58	0.12
T3 vs T4	98	0.39	0.70	98	1.12	0.27	98	-0.53	0.60	98	0.25	0.80
T2 vs T4	98	3.21	<0.05	98	4.36	<0.001	98	1.57	0.12	98	1.81	0.07



Conclusions

Average trust in the LDW system is changing significantly over time. This is mainly based on ratings of confidence in the system which clearly decreases when system is used compared to expectations the drivers had before use. The results show that the driver had much higher trust in the LDW system than it could fulfil when used.

User practices (heuristics/rules) will change over time during the FOT

Comparison situations

For subjective indicators
T4: Evaluation of system at end of the FOT

Performance indicators (PIs)

% Frequency count of number of participants who responded to the question on user practice change.

Data

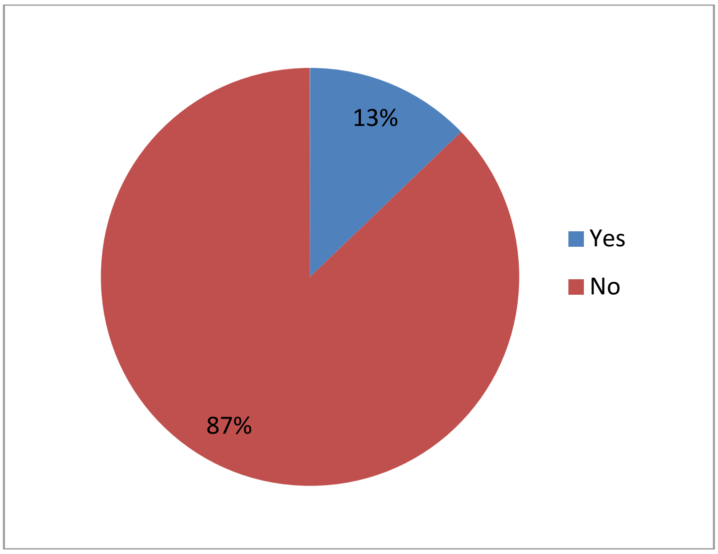
Driver's answers according to the question (user practice): "Do you use the Lane Departure Warning system differently now from the way you did when you first started using the system?" and "If yes, in what ways?" First item (LDW_upr1a_4) requires a yes/ no response. Second item (LDW_upr1b_4) is open ended.

Statistical Methods

None, descriptive

Results

Results are shown in the figure below. 117 drivers have answered the question. 13% of the drivers answered "yes" while 87% answered "no".



Conclusions

The majority of the drivers didn't use the LDW system differently at the end of the FOT from the way they did when they first started using the system. It can be stated that user practices of the LDW system didn't change significantly over time during the FOT.

Drivers will not abuse or misuse LDW

Comparison situations

T4: Evaluation of system at end of the FOT

Performance indicators (PIs)

Frequency count of number of participants who responded items under abuse/ misuse.

Data

Driver's answers according to the question: "Please indicate how often you have engaged in the following behaviours:

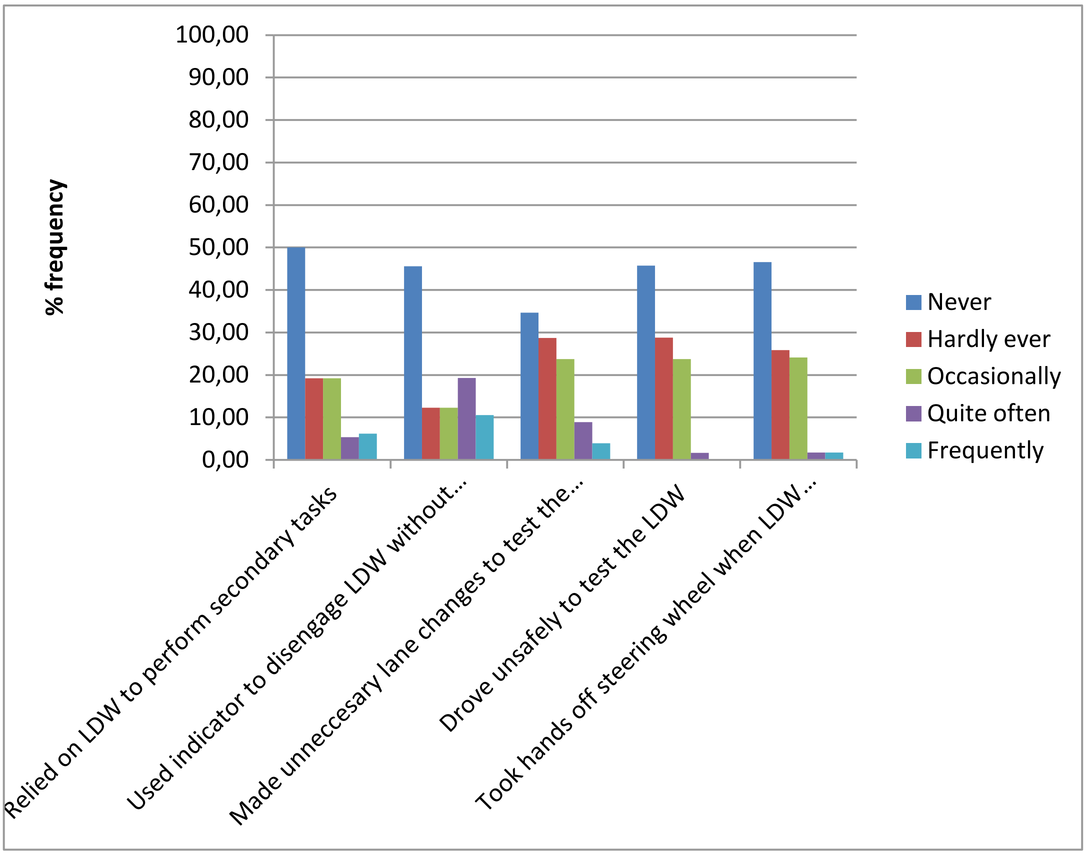
- Rely on the LDW in order to perform other tasks (e.g. eating, changing radio)
- Used the Turn Indicator to turn off the systems without checking the lane
- Made unnecessary lane changes to test the system
- Drove unsafely to test the system
- Took your hands away from the steering wheel while driving with LDW

Items for LDW_mis_1_4 are included in questions on system use and coded on a five score scale from 0 to 4: never (0), hardly ever (1), occasionally (2), quite often (3) and frequently (4).

Statistical Methods

None, frequency bar charts.

Results



Conclusions

Drivers show very little use or misuse of LDW: few concentration on secondary tasks or change to a more risky behaviour due to the usage of the system

Annex 6 Lane Departure Warning (only subjective data)

List of selected hypothesis

The following list includes all hypotheses selected for the LDW analysis:

Table 7: LDW hypothesis

LDW decreases/mitigates lateral incidents, near-crashes and accidents
LDW influences lateral driving performance
LDW increases the use of turn indicators in lane change situations
LDW increases night driving
LDW warning leads to an appropriate driver reaction
LDW is well accepted by the driver
LDW acceptance/adoption increases with LDW usage - Acceptance changes over time with system use
Certain features of the systems, in terms of usability, influence acceptance
Certain features of the systems, in terms of usefulness, influence acceptance
Trust in system changes over time with system use
Workload decreases over time with LDW system use
User practices (heuristics, rules) will change over time during the FOT
Drivers will not abuse or misuse LDW
Drivers believe that LDW influences positively their driving behaviour (with respect to specific use cases, i.e. lane change)
Perceived ease of use of LDW increases or stabilizes at high levels over time, compared to the expectation that drivers expressed at buying
Level of perceived safety of LDW increases over time, compared to the expectation that drivers expressed at buying
Drivers believe that LDW warnings are effective and relevant (as regards to specific aspects as system activation or lane departure)

LDW decreases/mitigates lateral incidents, near-crashes and accidents

Comparison situations

Subjective indicators
1. **T3a:** Evaluation of system 5 months after the beginning of the test
2. **T3b:** Evaluation of system 7 months after the beginning of the test
3. **T4:** Evaluation of system 9 months after the beginning of the test

Performance indicators (PIs)

1. System effects (factors 1 and 2)
2. Accidents in the test periods (factors 3)
3. Usefulness (factors 4 to 7)

Filtering criteria

Users in the LDW group have been considered.

Factors

1. XXX_sys_1_x - Your ability to avoid Dangerous situations, e.g. near misses
2. XXX_sys_2a_3 - XXX_sys_2a_4 - XXX_sys_2a_5 (In the last two months the LDW system avoided situations that could lead to accidents?
3. XXX_acc_4_3 - XXX_acc_4_4 - XXX_acc_4_5 If Accidents in the last 2 months =YES, were they caused by an incorrect operation in the lateral control of the vehicle, such as leaving the lane?
4. XXX_use_2_x - Please indicate whether you found the system useful in achieving the following: "Increasing safety"
5. XXX_use_2d_x - I found the LDW system capable in improving road safety significantly (% Frequency count of number of participants who responded Agree (strongly or less))
6. XXX_use_3_x - I found the LDW system helpful in case of distraction (% Frequency count of number of participants who responded Agree (strongly or less))
7. XXX_use_4_x - I found the LDW system helpful in case of falling asleep at the wheel (% Frequency count of number of participants who responded Agree (strongly or less))

Data

Subjective rating per drivers.

Statistical Methods

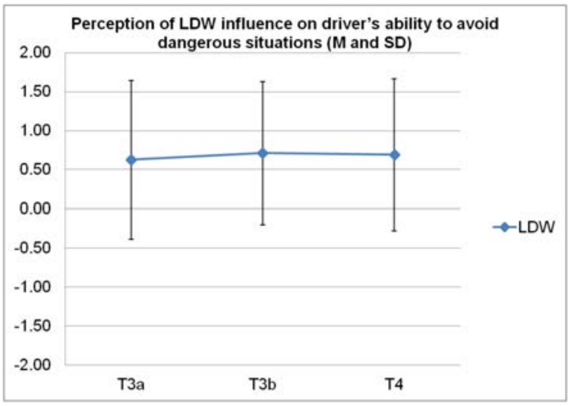
For Factor 1, repeated measures ANOVA with within factor time of rating.
For other factors:, related samples Cochran's Q tests are used.

Results

<u>Factor 1</u>
XXX_sys_1_x – Your ability to avoid Dangerous situations, e.g. near misses

Table below shows the results for the perception of LDW influence on driver's ability to avoid dangerous situations (e.g. near misses).

Group	Sub-scale	df	Error df	F	p
Experimental (w/device)	Influence on driver's ability to avoid dangerous situations	2	208	.529	0.590

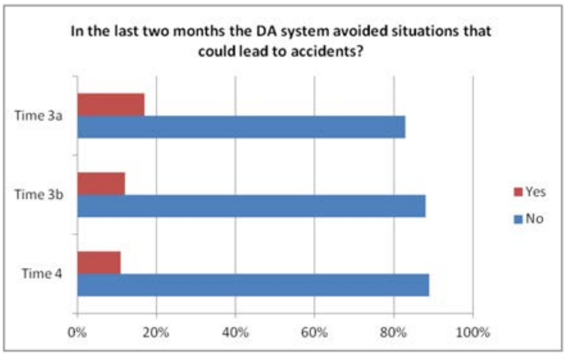


Factor 2

XXX_sys_2a_3 - XXX_sys_2a_4 - XXX_sys_2a_5 (In the last two months the LDW system avoided situations that could lead to accidents?

Table below shows the significant results for the comparison between the number of drivers answering positively to the question "In the last two months the LDW system avoided situations that could lead to accidents?" at T3a, T3b and T4.

Item	df	Cochran's Q	p
In the last two months the LDW system avoided situations that could lead to accidents	2	1.60	.449



Factor 3

XXX_acc_4_3 - XXX_acc_4_4 - XXX_acc_4_5 If Accidents in the last 2 months =YES, were they caused by an incorrect operation in the lateral control of the vehicle, such as leaving the lane?

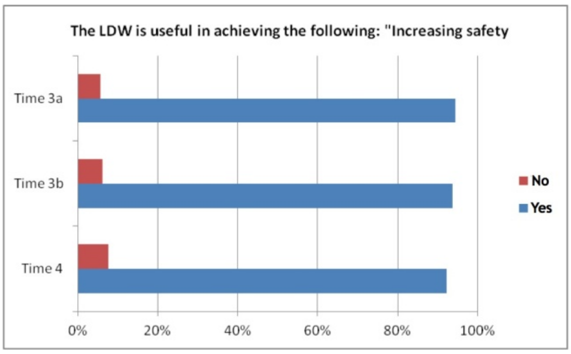
As regards the number of accidents, participants reported only two events at Time 2 and two at Time 4. Given the very low number of episodes we did not analyse this variable.

Factor 4

XXX_use_2_x - Please indicate whether you found the system useful in achieving the following: "Increasing safety"

Table below shows the significant results for the comparison between the number of drivers answering positively to the question "Please indicate whether you found the system useful in achieving the following: "Increasing safety"" at T3a, T3b and T4.

Item	df	Cochran's Q	p
The system is useful in increasing safety	2	3.00	0.223



Factors 5, 6, 7

XXX_use_2d_x - I found the LDW system capable in improving road safety significantly (% Frequency count of number of participants who responded Agree (strongly or less))

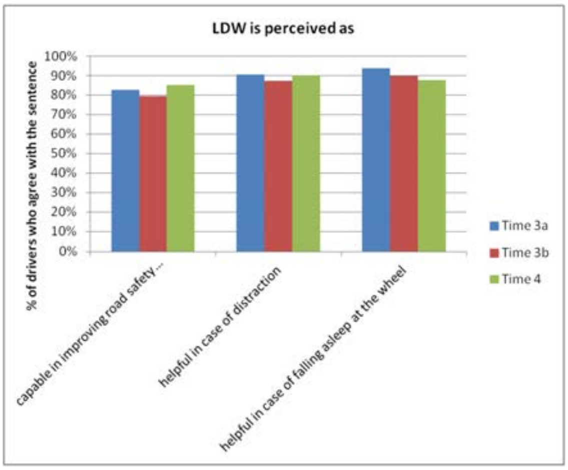
XXX_use_3_x - I found the LDW system helpful in case of distraction (% Frequency count of number of participants who responded Agree (strongly or less))

XXX_use_4_x - I found the LDW system helpful in case of falling asleep at the wheel (% Frequency count of number of participants who responded Agree (strongly or less))

Table below shows the significant results for the comparison between the number of drivers who agree (strongly or less) with three questions about the perceived effect of the LDW at Time 3a, 3b and 4. The sentences are: I found the LDW system…

- capable in improving road safety significantly.
- helpful in case of distraction.
- helpful in case of falling asleep at the wheel.

Item	df	Cochran's Q	p
The system is capable in improving road safety significantly	2	.080	.961
The system is helpful in case of distraction	2	1.882	.390
The system is helpful in case of falling asleep at the wheel	2	3.000	.223



Conclusions

The driver evaluations indicate an adequate functioning of the system as regards its help in avoiding Dangerous situations. LDW influence on the driver ability does not change along time. The LDW system does avoid situations that could lead to accidents for a part of the sample (17% at time 3a, 14% at time 3b, 11% at time 4). This perception is stable over time. During the experiment, only very few lateral accidents happened. The most part of the sample (more than 90%) found the LDW system effective in increasing the driving safety. This perception is stable over time. Even as regard the perception of road safety, most of the drivers (more than 80% at Time 4) found the LDW system able to improve it significantly. This perception is stable over time. As regards distraction, about 90% of the drivers found the LDW helpful in case of distraction. This percentage does not change significantly over time. The LDW system has been perceived as helpful in case of falling asleep at the wheel by the most part of the drivers (94% at Time 3a, 88% at Time 4).

LDW influences lateral driving performance

Comparison situations

T1: beginning of the test
T3a: 5 months after the beginning of the test
T3b: 7 months after the beginning of the test
T4: 9 months after the beginning of the test

Filtering criteria

Absolute values at times of questionnaire administration in the LDW Group (within subject) and comparison with Control Group (between subjects)

Factors

1. XXX_dri_1_x - How do you drive within the lane?
2. XXX_dri_2a_x - Do you happen to get near to the right/left side of the lane?
3. XXX_dri_3a_x - Do you happen to cut short a curve safely? (That is to overcome a line making a curve)
4. XXX_dri_4a_x - Do you happen that your car is overtaken too near by another car?
5. XXX_sys_1l_x - XXX_sys_1n_x - Please indicate how the LDW system has affected: - Your ability to keep within lane - Your ability to control the vehicle
6. XXX_dqs_1_x - How do you think you have been driving in this last period in comparison to your normal driving performance?
7. LDW_sys_1c_x - Please indicate how the LDW system has affected the following:
    a) Your attentiveness in traffic
    b) Ease of overtaking
    c) Comfort of the driving task
    d) Enjoyment of the driving task
    e) Your ability to avoid dangerous situations (e.g. near misses)
    f) Your ability to keep within the lane
    g) Your ability to obey road rules
    h) Your ability to control the vehicle
    i) With the LDW SWITCHED-ON, the usage of turn indicators
    j) The accuracy in the use of turn indicators in lane changing (Apart from system is switched-on or switched-off)

Performance indicators (PIs)

1. Driving behaviour within the lane (factors 1 to 4)
2. System effect (factor 5 and 7)
3. Driving Quality Scale (factor 6)

Data

Subjective rating per drivers.

Statistical Methods

1. Marginal homogeneity test for Factor 1
2. Mixed ANOVA for Factor 2, 3, 4, 6
3. Repeated measures ANOVA for Factor 5

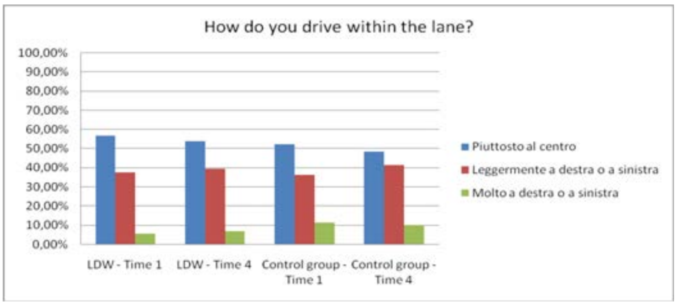
Results

Factor 1

XXX_dri_1_x - How do you drive within the lane?

Table below shows the results for the comparison between the number of drivers from control and LDW groups reporting to drive at different position within the lane answering to the question “How do you drive within the lane?” at T1 and T4. Looking at marginal homogeneity test, no differences emerged between T1 and T4 neither for the LDW and the control group.

Group	Item	Marginal homogeneity	p
LDW	How do you drive within the lane?	55.00	.250
Control	How do you drive within the lane?	148.00	.770

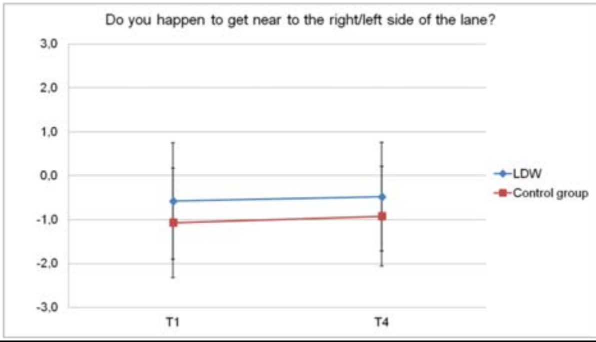


Factor 2

XXX_dri_2a_x - Do you happen to get near to the right/left side of the lane?

Table below shows the results of Mixed ANOVA used to evaluate differences in the frequency of studied behaviour (getting near to the right/left side of the lane) between LDW and control group. Means and standard deviations of the studied variable in the two groups at T1 and T4 are shown in figure 6.

Factor	df	Error df	F	p
Condition	1	358	15.47	<0.001
Time	1	358	3.06	.08
Time * Condition	1	358	.14	.71

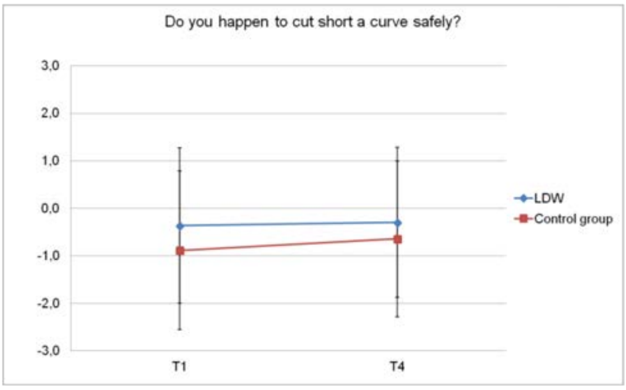


Factor 3

XXX_dri_3a_x - Do you happen to cut short a curve safely? (That is to overcome a line making a curve)

Table below shows the results of Mixed ANOVA used to evaluate differences in the frequency of studied behaviour (cutting curves short) between LDW and control group. Means and standard deviations of the studied variable in the two groups at T1 and T4 are shown in figure XXX.

Factor	df	Error df	F	p
Condition	1	355	30.39	.007
Time	1	355	3.09	.08
Time * Condition	1	355	1.03	.31

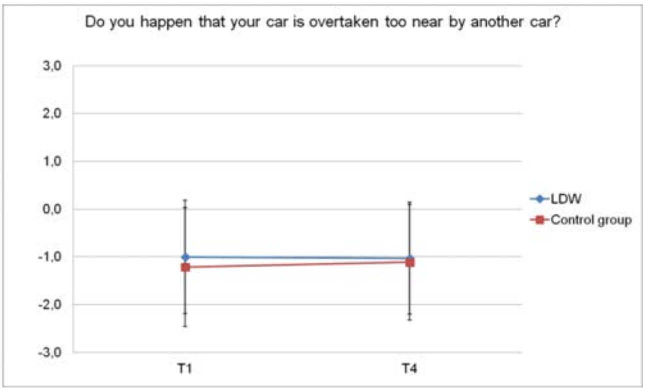


Factor 4

XXX_dri_4a_x - Do you happen that your car is overtaken too near by another car?

Table 8 shows the results of Mixed ANOVA used to evaluate differences in the frequency of studied behaviour (car overtaken to near by another car) between LDW and control group. Means and standard deviations of the studied variable in the two groups at T1 and T4 are shown in figure bellow. No differences between LDW and Control groups were found with respect to change in the frequency of the events.

Factor	df	Error df	F	p
Condition	1	352	30.39	.007
Time	1	352	2.56	.11
Time * Condition	1	352	.15	.70

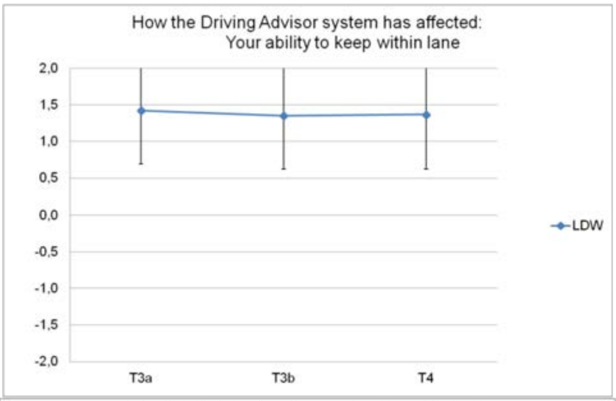


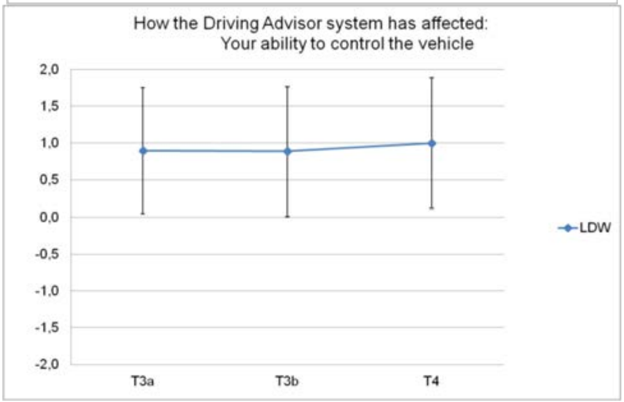
Factor 5

XXX_sys_1l_x - XXX_sys_1n_x - Please indicate how the LDW system has affected: Your ability to keep within lane (l)

The following table shows the results of Repeated Measures ANOVA used to evaluate differences in the perception of the influence of the LDW on ability to drive within lane and to control the vehicle at T1 and T4. Means and standard deviations of the studied variables at T3a, T3b, and T4 are shown in the following two figures. No significant changes emerged.

Group	Variable	df	Error df	F	p
LDW	Ability to keep within lane	2	226	.55	.58
LDW	Ability to control the vehicle	2	214	1.06	.35



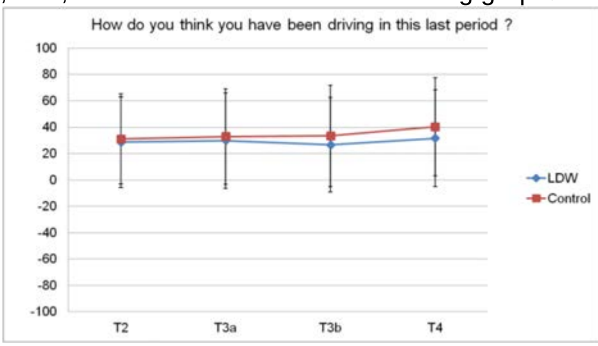


Factor 6

XXX_dqs_1_x - How do you think you have been driving in this last period in comparison to your normal driving performance? -100 represents "I have driven very badly" and +100 represents "I have driven very well"

Table below shows the results of Mixed ANOVA used to evaluate differences in self-assigned rating on driving performance in the last period between LDW and control group at T1 and T4. Changes over time are not significantly different between LDW and Control group. Means and standard deviations of the studied variable in the two groups at T1, T3a, T3b, and T4 are shown in the following graph.

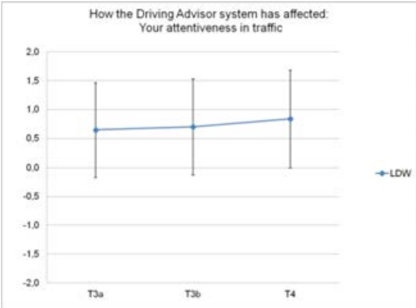
Factor	df	Error df	F	p
Condition	1	339	1.76	.19
Time	1	339	12.73	<.001
Time * Condition	1	339	1.29	.26

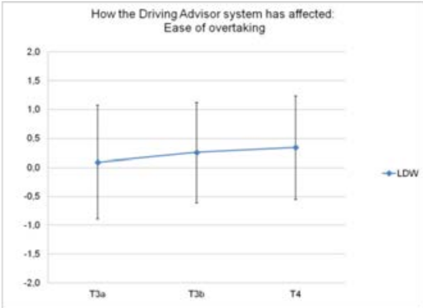


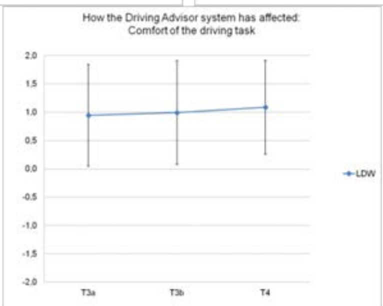
Factor 7

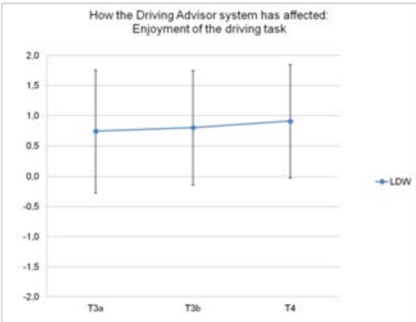
Table below shows the results of the Repeated measures ANOVA conducted on the perception of LDW system effects on driving experience. All the perceptions of system effect are stable over time, except for the perception of influence on the usage of tyurn indicators when the LDW is switched on. This perception significantly increased along time. Means and standard deviations of the studied variables T3a, T3b, and T4 are shown in figures 11 to YYY .

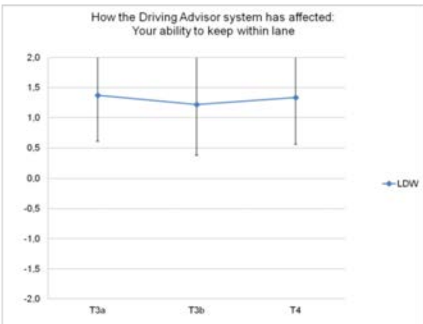
Group	Sub-scale	df	Error df	F	p
LDW	Attentiveness in traffic	2	220	2.38	.10
LDW	Ease of overtaking	2	202	2.70	.07
LDW	Comfort of the driving task was positive	2	232	1.10	.34
LDW	Enjoyment of the driving task	2	220	2.46	.09
LDW	Influence on driver’s ability to avoid dangerous situations	2	208	.529	.59
LDW	Ability to keep within lane	2	226	.55	.58
LDW	Ability to obey road rules	2	206	1.52	.22
LDW	Ability to control the vehicle	2	214	1.06	.35
LDW	Usage of turn indicators (with the LDW switched on)	2	230	5.24	.006
LDW	Use of indicators in lane changing (apart from system is switched on or switched off)	2	228	.31	.73

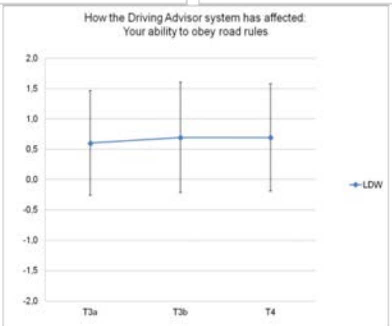


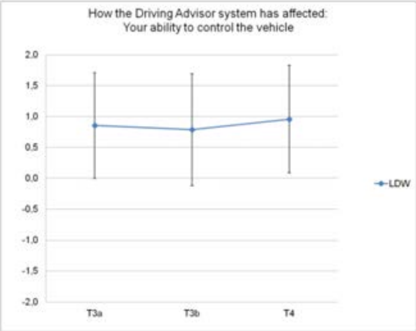


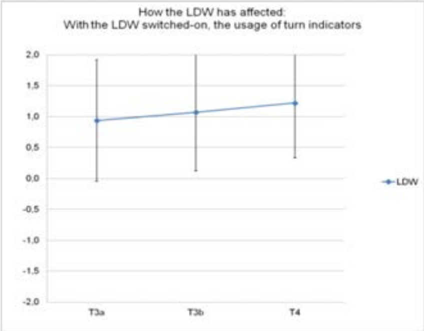


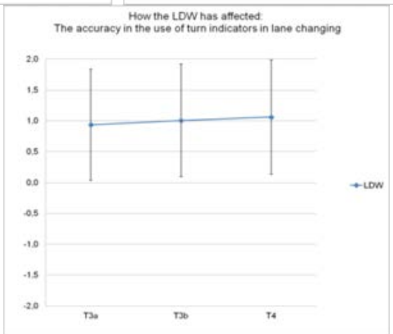







How the Driving Advisor system has affected:
Your ability to control the vehicle
2,0
1,5
1,0
0,5
0,0
-0,5
-1,0
-1,5
-2,0
T3a
T3b
T4
LDW


How the LDW has affected:
With the LDW switched-on, the usage of turn indicators
2,0
1,5
1,0
0,5
0,0
-0,5
-1,0
-1,5
-2,0
T3a
T3b
T4
LDW


How the LDW has affected:
The accuracy in the use of turn indicators in lane changing
2,0
1,5
1,0
0,5
0,0
-0,5
-1,0
-1,5
-2,0
T3a
T3b
T4
LDW

Conclusions

- As regards the driving position within the lane, it does not seem that the LDW influences it, even when comparing the LDW with the control group.
- As regards driving near to the right/left side of the lane, both LDW and control group report a low frequency of this behaviour. This behaviour is slightly more frequent in the LDW group, but it does not change over time, for either group.
- With respect to cutting curves , both LDW and control group report a low frequency of this behaviour. This behaviour is slightly less frequent in the control group ($F(1,355)=7.34$, $p < .01$), but it does not change over time, for either group ($F(1,355)=3.09$, $p = .08$).
- With respect to the reported frequency of this event (car overtaken too near by another car), both LDW and control group report a low values. This event is equally frequent in both groups and it does not change over time, for either group.
- Drivers report that the system positively affected both their ability to keep within the lane and to control the vehicle. This perception does not change over time.
- The driving performance seems not to be significantly affected by the LDW system use. Both experimental and control groups refer to have driven better than usual during the experimentation time, and the driving performance improved over time, for both groups.
- As regard the other considered system effects we found data analyses showed that:
  - Attentiveness in traffic: Respondents reported a moderate influence of the LDW on their behaviour, that do not change over time
  - Ease of overtaking: Drivers reported a low positive influence of the LDW on their behaviour, that do not significantly change over time .
  - Comfort of the driving task: Reported influence of LDW on this perception was positive This influence did not change over time.
  - Enjoyment of the driving task: The influence of LDW was positive and did not change over time.
  - Ability to avoid dangerous situations: participants perceived a moderate influence of LDW. The reported influence did not change significantly over time.
  - Ability to keep within lane: Respondents reported a quite high perceived influence of the LDW. This perception did not change over time.
  - Ability to obey road rules: drivers perceived a positive influence of the LDW. This influence did not vary over time.
  - Ability to control the vehicle: participants perceived that this ability has been positively quite highly affected by the use of the LDW. This influence did not vary over time.
  - Usage of turn indicators (with the LDW switched on): Respondents recognized a positive effect of the LDW on this behaviour. This influence significantly increased over time.
  - Accuracy in the use of indicators in lane changing (apart from system is switched on or switched off): Even with regards to this perception respondents perceived a relevant positive contribution of the LDW. The perceived influence of the LDW did not change over time.

LDW increases the use of turn indicators in lane change situations

Comparison situations

Absolute values at times of questionnaire administration in the LDW Group (within subject) and comparison with Control Group (between subjects)

Filtering criteria

Users in the LDW group and in Control Group have been considered.

Factors

1. XXX_dri_5_x - How often do you use the turn indicators
   a. to point out a lane change?
   b. to point out a turn?
   c. in roundabouts?
2. XXX_sys_1_x - Please indicate how the LDW system has affected the following:
   d. With the LDW SWITCHED-ON, the usage of turn indicators
   e. The accuracy in the use of turn indicators in lane changing (Apart from system is switched-on or switched-off)

Performance indicators (PIs)

1. Driving in lane positioning
2. System effect

Data

Subjective ratings

Statistical Methods

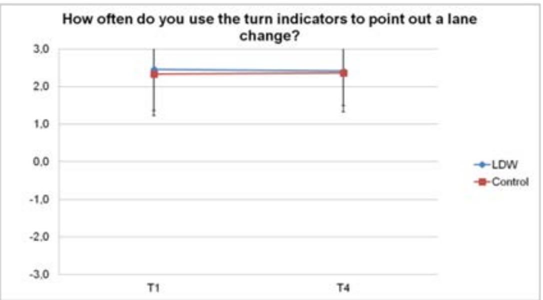
For factor 1: Mixed ANOVA
For factor 2: Repeated Measures ANOVA

Results

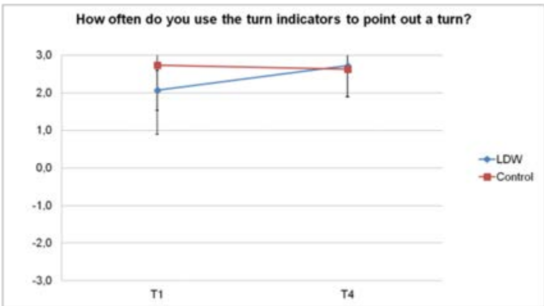
<u>Factor 1</u>
XXX_dri_5_x - How often do you use the turn indicators
a. to point out a lane change?
b. to point out a turn?
c. in roundabouts?

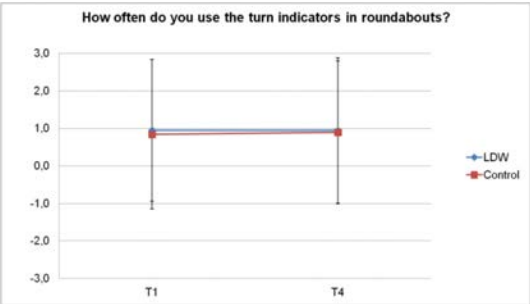
Following tables show the results of Mixed ANOVA used to evaluate differences in the frequency of studied behaviours between LDW and control group. Means and standard deviations of the variables in the two groups at T1 and T4 are shown in the following figures. No significant differences between LDW and Control groups were found with respect to change in the frequency of the behaviours, except for the use of turn indicators to indicate turns. As can be seen in the figure, the frequency of this behaviour increased in the LDW group from T1 to T4, while staying stable in the Control group.

Factor	df	Error df	F	p
Condition	1	357	.77	.38
Time	1	357	.01	.92
Time * Condition	1	357	.36	.55



Factor	df	Error df	F	p
Condition	1	356	12.39	<.001
Time	1	356	13.60	<.002
Time * Condition	1	356	26.81	<.003
Factor	**df**	**Error df**	**F**	**p**
Condition	1	357	.89	.70
Time	1	357	.05	.83
Time * Condition	1	357	.09	.76





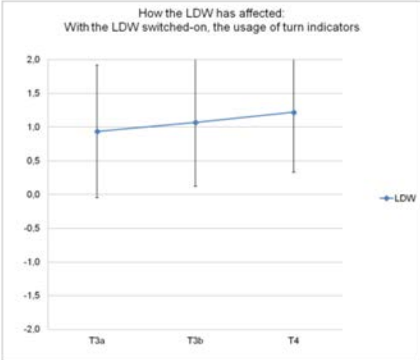
Factor 2

XXX_sys_1_x - Please indicate how the LDW system has affected the following:

a. With the LDW SWITCHED-ON, the usage of turn indicators
b. The accuracy in the use of turn indicators in lane changing (Apart from system is switched-on or witched-off)

Next table shows the results of the Repeated measures ANOVA conducted on the perception of LDW system effects on driving behaviours related to the usage of turn indicators. As regards the usage of turn indicators with the LDW switched on, we found that it significantly increased from time 3a to Time 4. In contrast, the perception of influence of the LDW on the use of turn indicators in lane changing (apart from system is switched on or switched off) was stable over time. Means and standard deviations of the studied variables T3a, T3b, and T4 are shown in the figures.

Group	Sub-scale	df	Error df	F	p
LDW	Usage of turn indicators (with the LDW switched on)	2	230	5.24	.006*
LDW	Use of indicators in lane changing (apart from system is switched on or switched off)	2	228	.31	.73



Conclusions

- Respondents, both from LDW and experimental group reported that they did not change use frequency of turn indicators in roundabouts or to indicate a lane change, while from T1 to T4 LDW drivers increased significantly the use frequency of turn indicators to indicate turns.
- Respondents recognized a positive effect of the LDW on the usage of turn indicators (with the LDW switched on). This influence increased over time. Even with regards to the accuracy in the use of indicators in lane changing (apart from system is switched on or switched off) drivers perceived a relevant positive contribution of the LDW. The perceived influence of the LDW did not change over time.

LDW increases night driving

Comparison situations

T3a: 5 months after the beginning of the test
T3b: 7 months after the beginning of the test
T4: 9 months after the beginning of the test

Filtering criteria

Only users in the LDW group have been considered.

Factors

1. XXX_pat_1a_x - Have your travel patterns changed in any way since driving with the system?
2. XXX_pat_3_x - Part of the day
3. XXX_use_1_x - Please indicate, where or when you found the LDW system most useful

Performance indicators (PIs)

1. Driving in lane positioning
2. System effect
3. Usefulness

Data

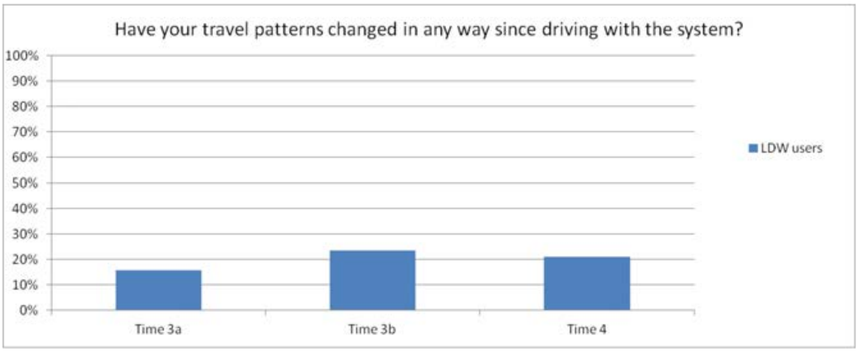
Subjective rating per drivers.

Statistical Methods

1. Descriptive statistics (percentage frequency) for Factor 1, 2 and 3

Results

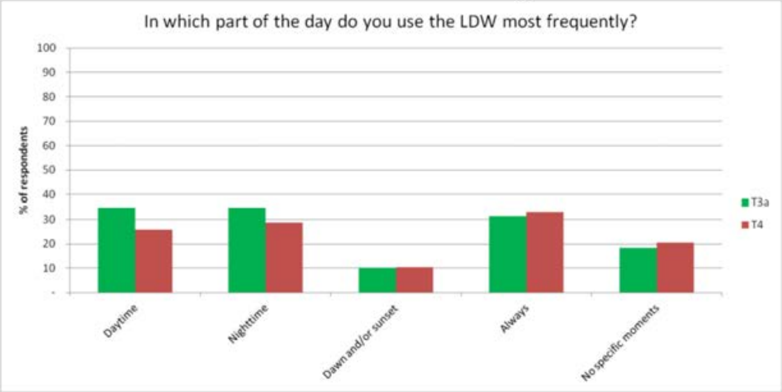
Factor 1
XXX_pat_1a_x - Have your travel patterns changed in any way since driving with the system?
Both at T3a and T4 a relevant percentage of the drivers reported that their travel patterns changed since driving with the LDW (T3a: 15.7%; T3b: 23.5%; T4: 20.9%)



Factor 2

XXX_pat_3_x - In which part of the day do you use the LDW most frequently?

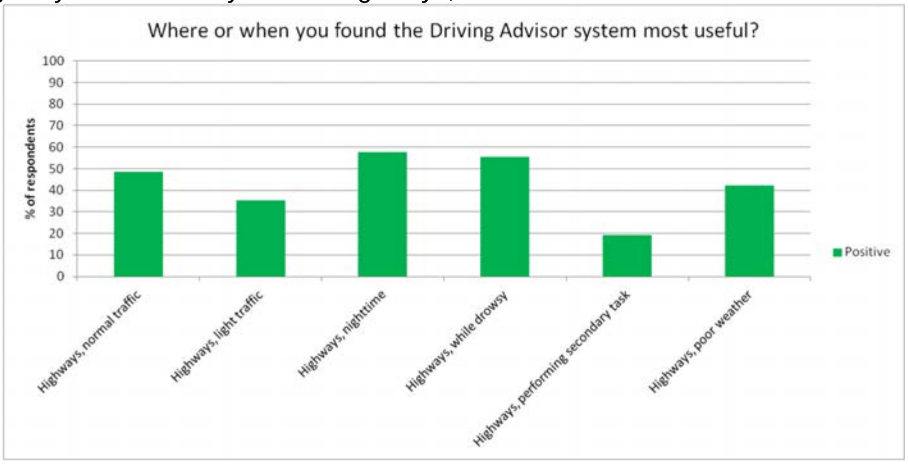
As regards the part of the day, more than 30% of the respondents reported to use the LDW at T4 always. About 30% of them use it more frequently during the night. About 20% of the respondents did report to use it in no specific moments. Frequencies reported at both T3a and T4 are reported in the following figures. From T3a to T4 no relevant differences emerged.



Factor 3

XXX_use_1_x Please indicate, where or when you found the LDW system most useful.

The following graph depicts the percentages of drivers who found the LDW most useful in different situations at T4. The situations in which drivers found the LDW most useful are: on highways during nighttime, on highways while drowsy and on highways, with normal traffic.



Conclusions

- At the end of the test (T4) about 20 % of the drivers reported that their travel patterns changed since driving with the LDW.
- More than 30% of the respondents reported to always use the LDW, while about 30% of them use it more frequently during the night. No relevant time-related changes emerged regarding the frequency of differences about the part of the day in which drivers use the LDW more frequently.
- The more important features of the LDW system influencing acceptability are the perceived usefulness of the system while driving on highways: in normal traffic, at night time, while drowsy and with poor weather. Conversely the less relevant feature is the usefulness perceived driving on highways performing secondary tasks.

LDW warning leads to an appropriate driver reaction (Usage - U3)

Comparison situations

T3a: 5 months after the beginning of the test
T3b: 7 months after the beginning of the test
T4: 9 months after the beginning of the test

Filtering criteria

Users in the LDW group have been considered.

Factors

1. XXX_sys_1_x - Your ability to avoid dangerous situations (e.g. near misses)
2. XXX_tru_1a_x - Were there any situations where you did not trust the LDW system?

Performance indicators (PIs)

1. System effect
2. Trust

Data

Subjective rating per drivers.

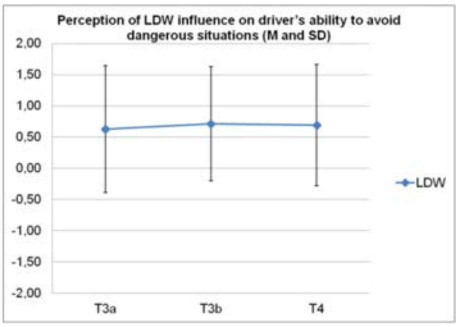
Statistical Methods

1. For factor 1 Repeated Measures ANOVA
2. For factor 2 percentage frequency of drivers who did not trust LDW in some situations.

Results

Factor 1
XXX_sys_1_x - Your ability to avoid Dangerous situations, e.g. near misses
The following table shows the results of the RM ANOVA conducted on the perception of LDW influence on driver's ability to avoid dangerous situations (e.g. near misses). No significant changes over time emerged.

Group	Sub-scale	df	Error df	F	p
Experimental (w/device)	Influence on driver's ability to avoid dangerous situations	2	208	.529	0.590



Factor 2

XXX_tru_1a_x - Were there any situations where you did not trust the LDW system?

The following Figure depicts the percentages of respondents who did not trust the LDW in some situations. Overall, the percentages are low (< 20%) from T3a to T4.

Conclusions

- The driver evaluations indicate an adequate functioning of the system as regards its help in avoiding Dangerous situations. LDW influence on the driver ability does not change over time.
- Only al low percentage of the drivers experimented situations in which they did not trust the LDW.

LDW is well accepted by the driver

Comparison situations

T1: beginning of the test
T3a: 5 months after the beginning of the test
T3b: 7 months after the beginning of the test
T4: 9 months after the beginning of the test

Filtering criteria

Users in the LDW group have been considered.

Factors

1. VdL scale - Essentially the Van der Laan (VdL) scale, with additional items.
2. XXX_ef_3a_x - Does the coming in action of the LDW seem adequate to you or not?
3. XXX_ef_4a_x - Do you find the minimum functioning speed of the LDW system (i.e. 65 km/h) appropriate?
4. XXX_st_6a_x - The LDW system functioning peeves me on certain occasion

Performance indicators (PIs)

1. Acceptance VdL (Usefulness and Satisfaction) for Factor 1
2. Effectiveness (for Factor 2 and 3)

Data

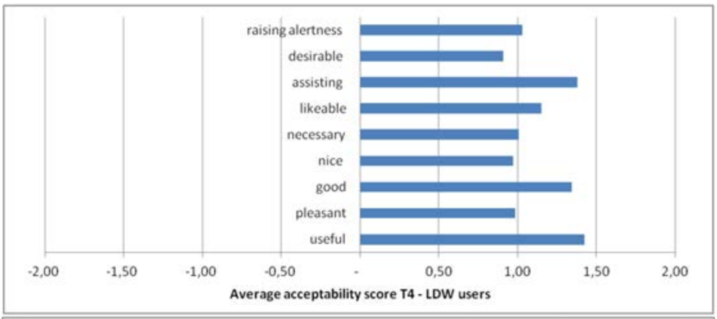
Subjective rating per drivers.

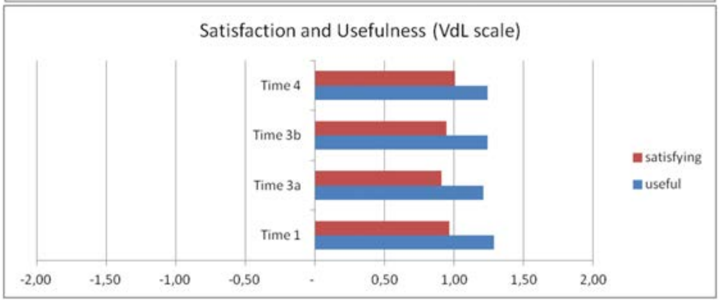
Statistical Methods

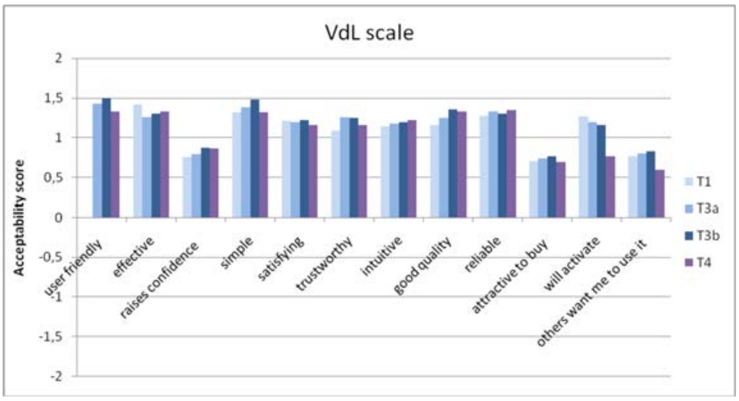
1. Average scores computed for all the features included in the Van der Laan scale at T4
2. Average scores computed for the Satisfaction and Usefulness subscales (from the VdL scale, computed at Times 1, 3a, 3b, and 4)
3. Average scores computed for the the features included in the Van der Laan scale (computed at Times 1, 3a, 3b, and 4)
4. Descriptive statistics (percentage frequency) for Factors 2, 3 and 4

Results

Factor 1
VdL scale - Essentially the Van der Laan (VdL) scale, with additional items
Following figures shows the average acceptability scores at T4, the levels of Satisfaction and Usefuleness computed at T1, T3a, T3b and T4 from the items of the VdL scale, and the changes in the single features investigated by the VdL from T1 to T4.
1. VdL scale - Essentially the Van der Laan (VdL) scale, with additional items.



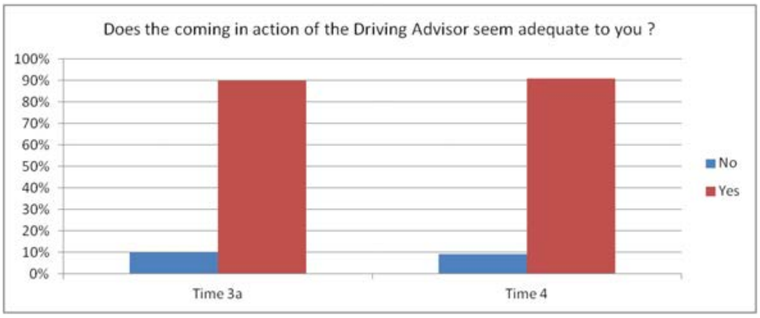




Factor 2

XXX_ef_3a_x - Does the coming in action of the LDW seem adequate to you or not?

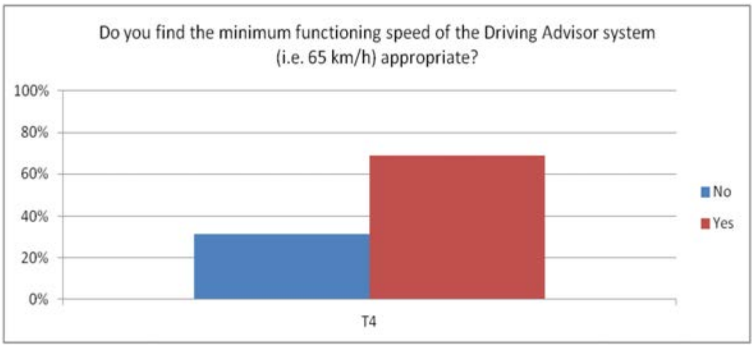
The following figure depicts the percentage frequency of answers to the question about the perceived adequacy of the coming in action of LDW, computed at T3a and T4. The majority of the respondents (about 90%) found that the coming in action of the system was adequate.



Factor 3

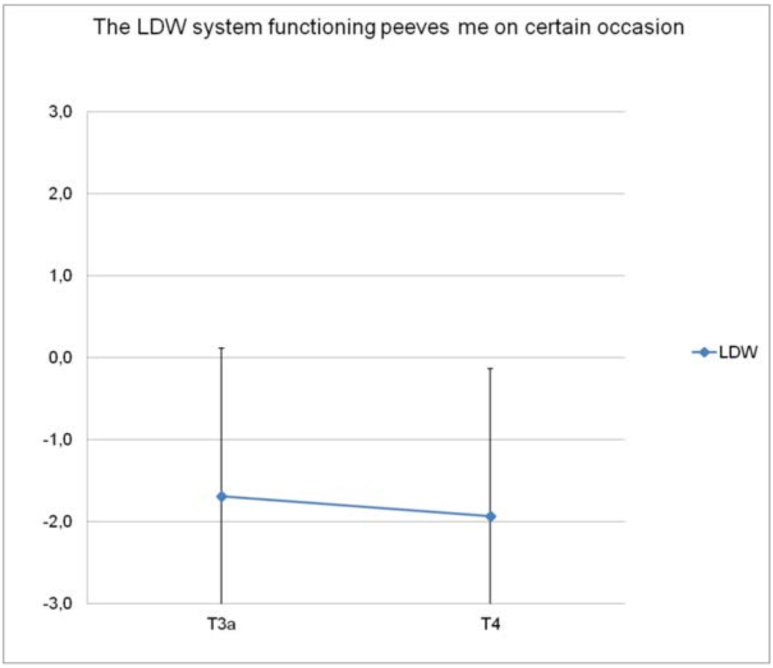
XXX_ef_4a_x - Do you find the minimum functioning speed of the LDW system (i.e. 65 km/h) appropriate?

The next graph shows the answer of the drivers with respect to the appropriateness of the minimum functioning speed of the system. For about 70% of the respondents the minimum functioning speed of the LDW was adequate.



<u>Factor 4</u>
XXX_st_6a_x - The LDW system functioning peeves me on certain occasion
The table below shows the results of the Repeated Measures ANOVA conducted on the level of accordance to the affirmation "The LDW system functioning peeves me on certain occasion". The level of accordance with this sentence was low both at T3a and at T4, and it did not change significantly along time. The following figure shows M and SD of the item at T3a and T4.

Group	Variable	df	Error df	F	p
LDW	The LDW system functioning peeves me on certain occasion	1	114	2.29	.13



Conclusions

- The acceptability of the LDW system is high for all the considered features. The characteristics which are more frequently associated with the system regard the "assisting" function, the usefulness, and the perception of the system as "good". The less frequent characteristics are the desirableness and the perception of the system as "nice" and "pleasant". As regard the composite scales of the VdL questionnaire, drivers found the system very useful and satisfying, with a prevalence of the former. This perception does not significantly vary over time. With respect to the other VdL items, drivers reported a positive perception for all the investigated aspects. The more appealing are the user friendliness, the ease of use ("simple"), the "good quality" and the "reliability", while they have a less positive attitude towards the "attraction to buy", the request by others to use the system and the confidence improvement.

- The coming in action of the system is perceived as adequate by the most part of the sample (about 90%) and this perception is stable over time.
- With respect to the minimum functioning speed of the system, a large part of the sample (69%) found it to be appropriate.
- The functioning of the LDW system is not perceived as peeving by the drivers. This perception is stable over time.

LDW acceptance/adoption increases with LDW usage - Acceptance changes over time with system use

Comparison situations

Subjective indicators

- **T1:** beginning of the test
- **T3a:** 5 months after the beginning of the test
- **T3b:** 7 months after the beginning of the test
- **T4:** 9 months after the beginning of the test

Filtering criteria

Users in the LDW group have been considered.

Factors

VdL scale - Essentially the Van der Laan (VdL) scale.

Performance indicators (PIs)

Acceptance VdL (Usefulness and Satisfaction) for Factor 1

Data

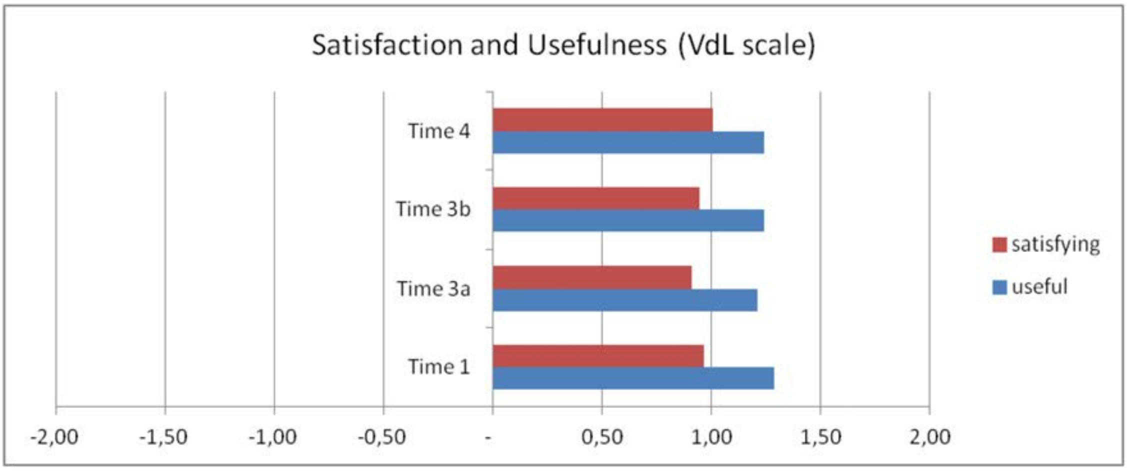
Subjective ratings.

Statistical Methods

Average scores computed for the Satisfaction and Usefulness subscales (from the VdL scale, computed at Times 1, 3a, 3b, and 4)

Results

<u>Factor 1</u>
VdL subscales (Satisfaction and Usefulness)
The figure below shows the average the levels of Satisfaction and Usefuleness computed at T1, T3a, T3b and T4 from the items of the VdL scale. As can be seen no relevant changes were found in the Satisfaction and Usefulness associated with the LDW from T1 to T4.



Conclusions

- As regard the composite scales of the VdL questionnaire, drivers found the system very useful and satisfying, with a prevalence of the former. These perceptions do not significantly vary over time.

Certain features of the systems, in terms of usability, influence acceptance

Comparison situations

T4: 9 months after the beginning of the test

Filtering criteria

Only users in the LDW group have been considered.

Factors

XXX_eas_1_x - Here think about how easy it was to use the system – were the system controls and warnings easy to understand?

Performance indicators (PIs)

Ease of use

Data

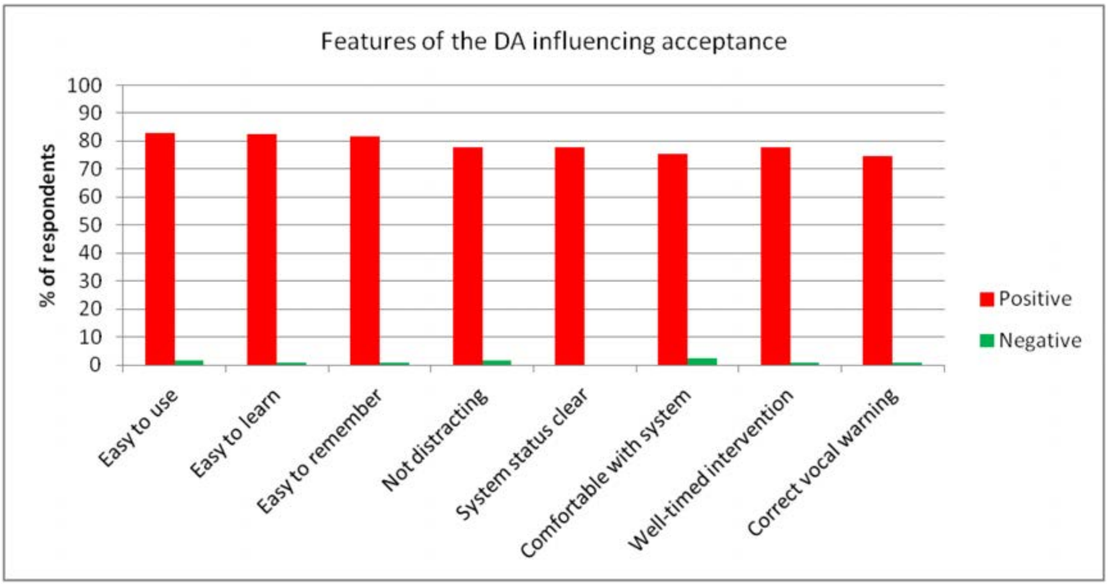
Each participant is considered separately, such that if a participant scored the system positively on the VdL (>0) then those items that score high on usability were deemed to have impacted on that score. Conversely, if a participant score the system negatively on the VdL (<0) then there would be certain items relating to usability that would contribute to this.

Statistical Methods

Percentage frequency of the drivers' positive and negative evaluations of Ease of Use items are presented

Results

The following graph depicts the LDW characteristics related to Ease of Use which impacted on the acceptance of the system by the drivers.



Conclusions

All the investigated features seem to positively contribute to the positive perception of the LDW system both in terms of Usefulness and Satisfaction. There are no relevant differences among the features.

Certain features of the systems, in terms of usefulness, influence acceptance

Comparison situations

T3a: 5 months after the beginning of the test
T3b: 7 months after the beginning of the test
T4: 9 months after the beginning of the test

Filtering criteria

Only users in the LDW group have been considered.

Factors

1. XXX_use_1_x Please indicate, where or when you found the LDW system most useful.
2. XXX_use_5_x - When I am tired, the LDW warnings enhance?
3. XXX_use_6_x - Does the LDW system provide me unuseful information? That is warnings provided on the steering wheel are not necessary?

Performance indicators (PIs)

Usefulness (Factors 1, 2 and 3)

Data

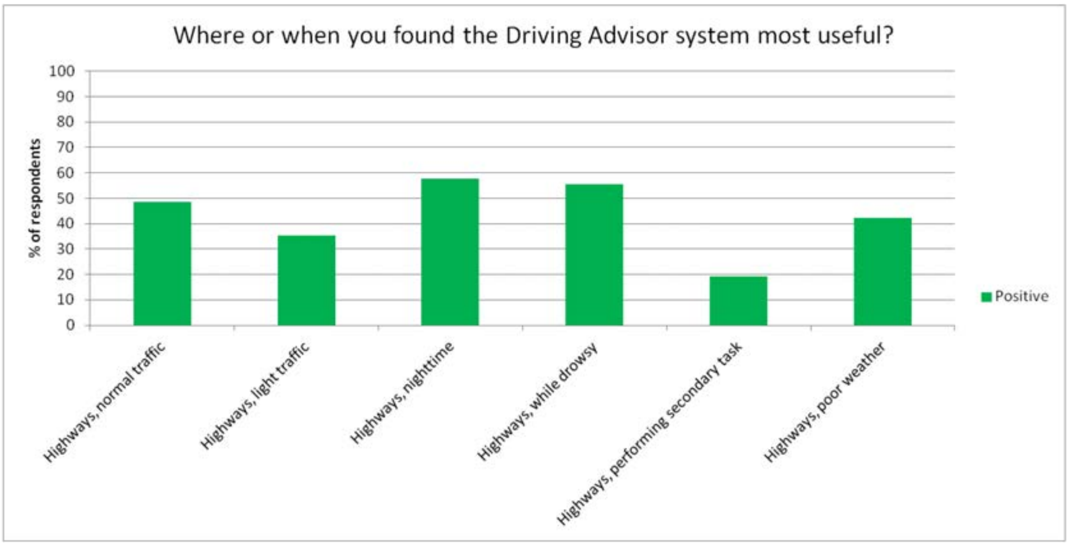
Subjective ratings.

Statistical Methods

Descriptive statistics (percentage frequency) for Factors 1, 2 and 3

Results

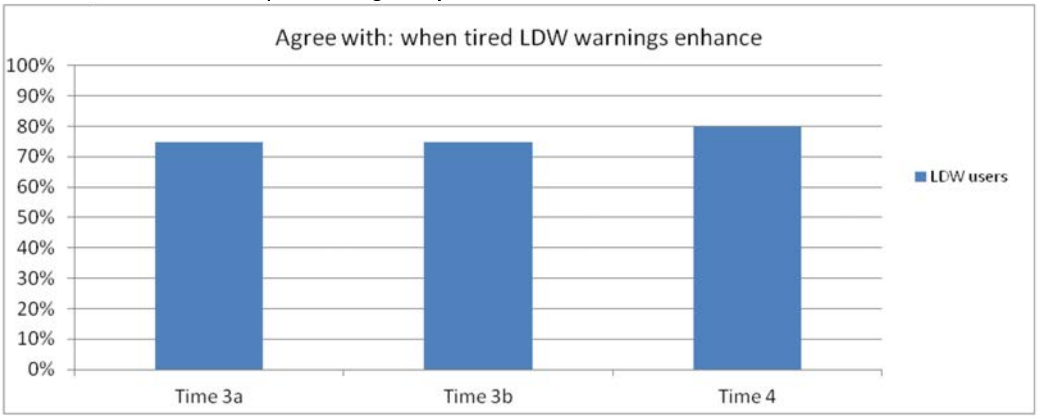
Factor 1
XXX_use_1_x Please indicate, where or when you found the LDW system most useful.
The following graph depicts the percentages of drivers who found the LDW most useful in different situations at T4. The situations in which drivers found the LDW most useful are: on highways during nighttime, on highways while drowsy and on highways, with normal traffic.



Factor 2

XXX_use_5_x - When I am tired, the LDW warnings enhance?

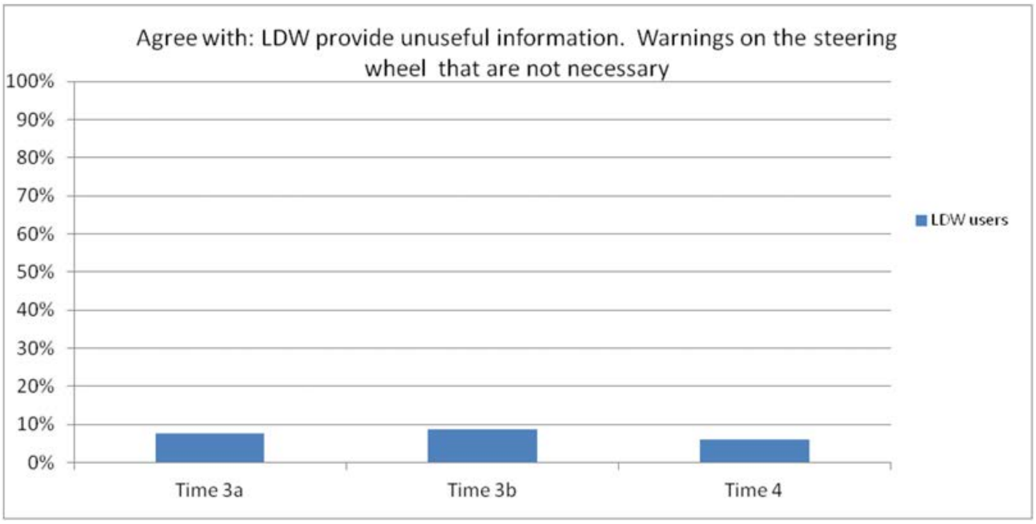
The next graph shows the percentage of respondents who agreed with the item "When I am tired, the LDW warnings enhance" at Times 3a, 3b, and 4. As shown, the percentages do not relevantly vary from T3a to T4, and at T4 the percentage of positive answers is about 80%.



Factor 3

XXX_use_6_x - Does the LDW system provide me unuseful information? That is warnings provided on the steering wheel are not necessary?

The following figure shows the percentage of drivers of cars equipped with LDW who found the system provided unuseful information (non necessary warnings) at Times 3a, 3b and 4. The percentage is low (< 10%) from T3a to T4 and no relevant differences emerged.



Conclusions

- The most important features of the LDW system influencing acceptability are the perceived usefulness of the system while driving on highways: in normal traffic, at night time, while drowsy and with poor weather. Conversely the less relevant feature is the usefulness perceived driving on highways performing secondary tasks.
- With respect to the functioning of the LDW system when drivers are tired, as expected respondents from the experimental group reported that the system warnings increased in those situations (M =1.74, SD =1.39 at Time 4). Even this perception did not change over time.
- As regards possible problems experienced with the LDW system, drivers reported that they did not find the LDW reporting useless information frequently. This perception of well-functioning was stable over time.

Trust in system changes over time with system use

Comparison situations

T1: beginning of the test
T3a: 5 months after the beginning of the test
T3b: 7 months after the beginning of the test
T4: 9 months after the beginning of the test

Filtering criteria

Only users in the LDW group have been considered.

Factors

Items under: XXX_ac_1_x (ILD_tr_x_x) Raises confidence, Trustworthy, Reliable

Performance indicators (PIs)

Trust in the system

Data

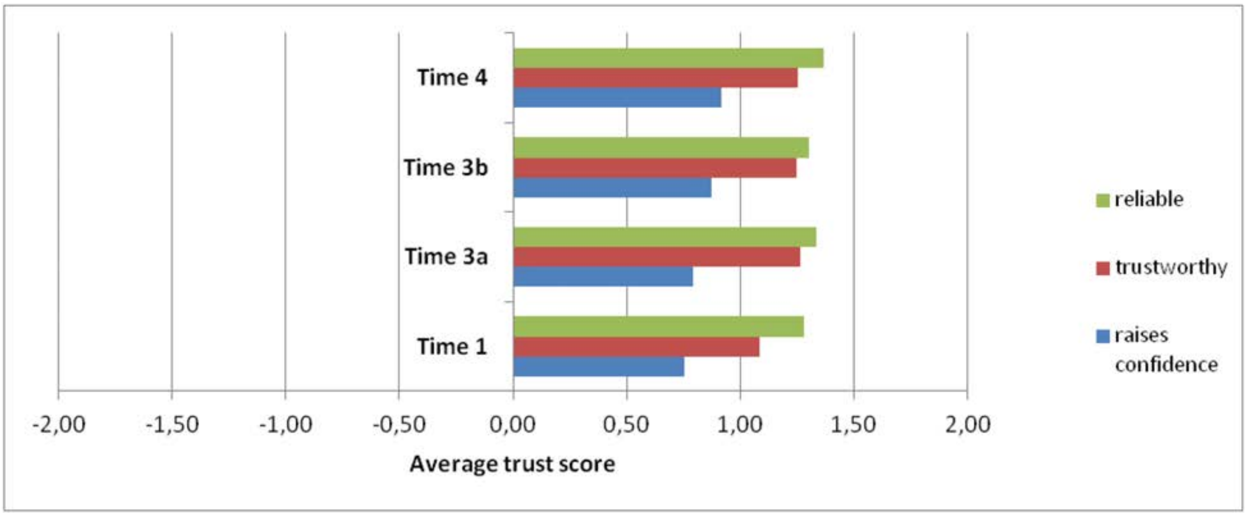
Subjective ratings.

Statistical Methods

Comparison of averages scores computed for the items referring to reliability, trustworthiness, and confidence raise at Times 1, 3a, 3b, and 4)

Results

The figure below shows the trend of the levels of reliability, trustworthiness, and confidence raise for drivers with cars equipped with LDW. As can be seen the evaluation are positive at all the times.



Conclusions

As The perceptions of three considered features (Raises confidence, Trustworthy, Reliable) of the LDW system are high and stable at all the time points. The “confidence raising” has the lower level, while reliability and trustworthiness have higher levels.

Workload decreases over time with LDW system use

Comparison situations

T2: 3 months after the beginning of the test
T3a: 5 months after the beginning of the test
T3b: 7 months after the beginning of the test
T4: 9 months after the beginning of the test

Filtering criteria

Users in the LDW group and in Control Group have been considered.

Factors

ILD_mw_1_x how much effort it took for you to drive in those situations

Performance indicators (PIs)

Workload (RSME scale)

Data

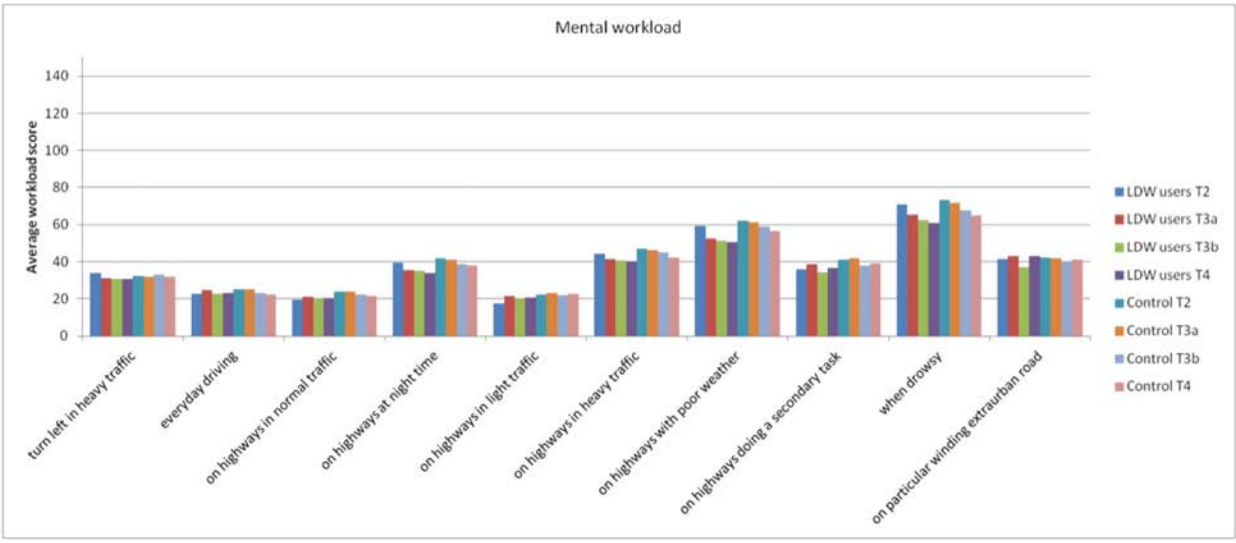
Subjective ratings

Statistical Methods

Average workload scores are presented, comparing the LDW and Control groups

Results

<u>Factor 1</u>
Workload (RSME scale)
The graph shown below depicts the trends in the perception of workload associated to different situations in the LDW and in Control groups at T2, T3a, T3b and T4.



Conclusions

The mental workload perceived by test participants from LDW and control group was quite similar for all the considered situations. No relevantly different trends (for the LDW and Control groups) emerged.

User practices (heuristics, rules) will change over time during the FOT

Comparison situations

Subjective indicators

T4: 9 months after the beginning of the test

Filtering criteria

Only users in the LDW group have been considered.

Factors

XXX_upr_1a_4 - Do you use the LDW system differently now from the way you did when you first started using the system?

Performance indicators (PIs)

User practice

Data

Subjective ratings.

Statistical Methods

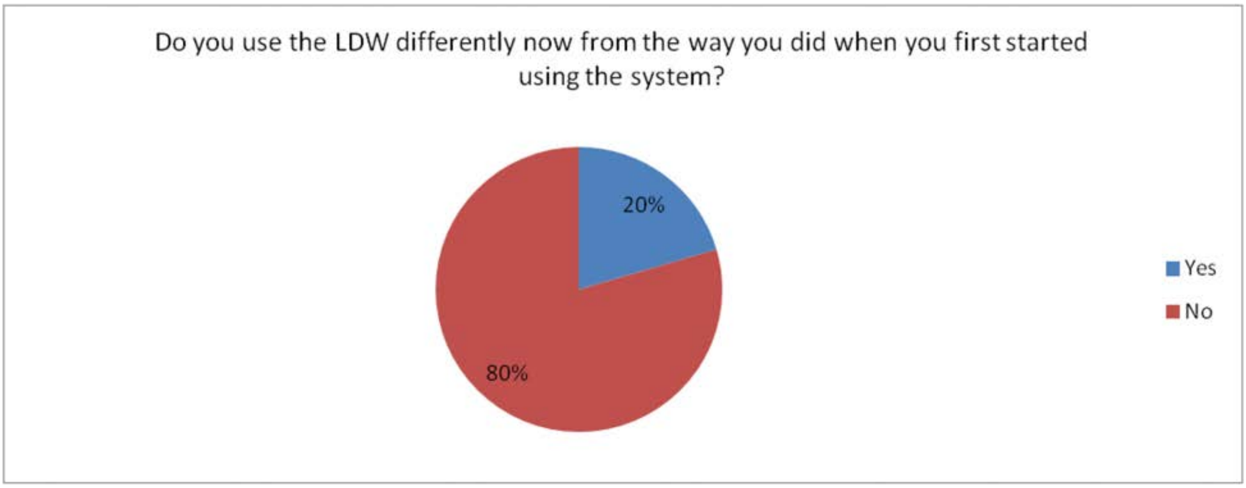
Descriptive statistics (percentage frequency) for Factor 1

Results

Factor 1

XXX_upr_1a_4 - Do you use the LDW system differently now from the way you did when you first started using the system?

The pie chart shown below depicts the percentage of drivers from the LDW group at T4 who use the LDW differently from the way they did when they started using the system.



Conclusions

About 20% of the drivers from the LDW group at the end of the test had changed the way they use the system.

Drivers will not abuse or misuse LDW

Comparison situations

T4: 9 months after the beginning of the test

Filtering criteria

Only users in the LDW group have been considered.

Factors

XXX_mis_1_4 - Please indicate how often you have engaged in the following behaviours.

Performance indicators (PIs)

Misuse

Data

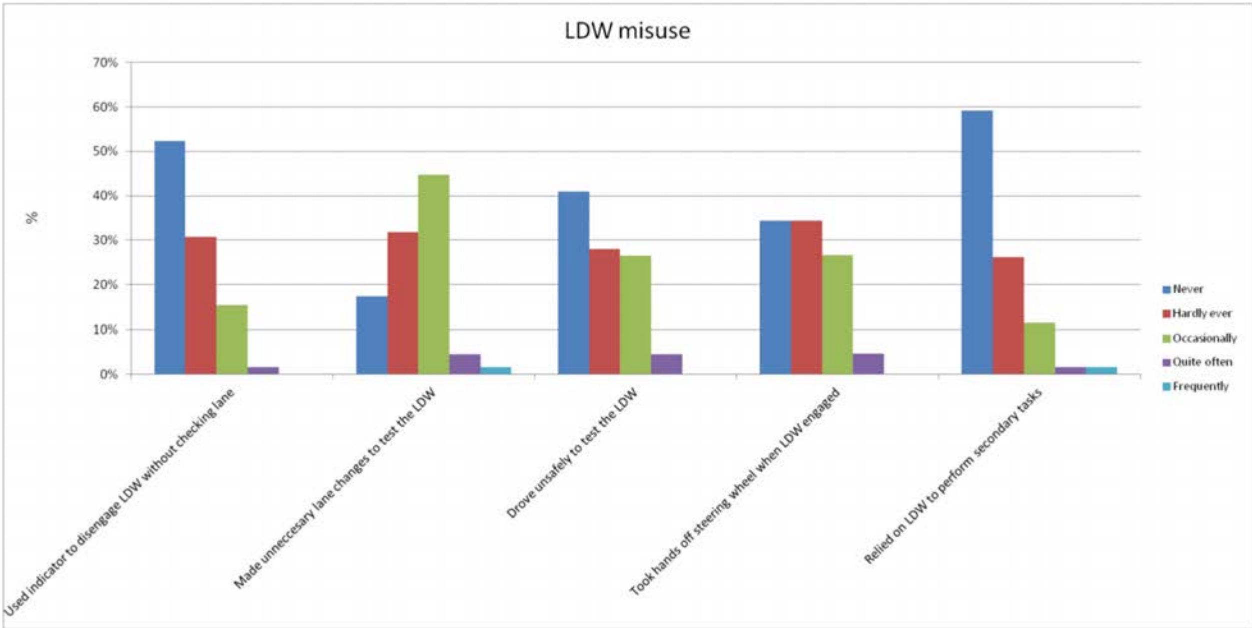
Subjective ratings

Statistical Methods

Percentage frequencies of response categories to all the misuse-related items at T4 are presented

Results

<u>Factor 1</u>
XXX_mis_1_4 - Please indicate how often you have engaged in the following behaviours
The chart below depicts the frequency of answers to the items related to misuse behaviours of LDW system.



Conclusions

With respect to LDW system misuse, none of the studied behaviours was enacted frequently. The most frequent behaviour is “making unnecessary lane changes” and taking hands off steering wheel”. Probably these behaviours are done in order to test the system. The less frequent is “relying on LDW to perform secondary tasks”.

Drivers believe that LDW influences positively their driving behaviour (with respect to specific use cases, i.e. lane change)

Comparison situations

T3a: 5 months after the beginning of the test
T3b: 7 months after the beginning of the test
T4: 9 months after the beginning of the test

Filtering criteria

Only users in the LDW group have been considered.

Factors

XXX_sys_3a_x - Does the LDW encumber or obstruct you in some driving situations? If yes, in which ones?

Performance indicators (PIs)

System effect

Data

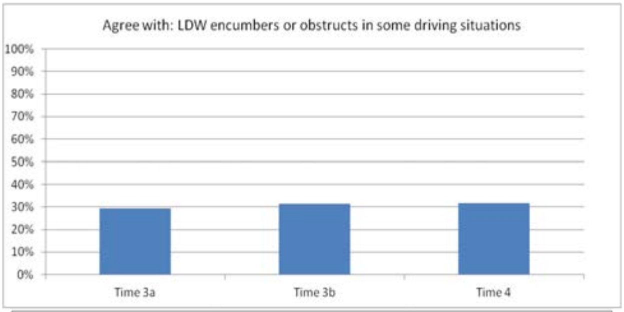
Subjective ratings

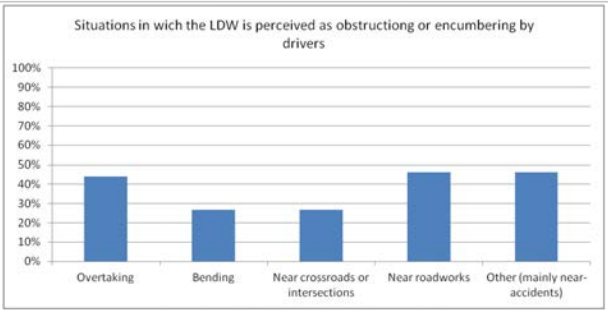
Statistical Methods

Percentage frequencies

Results

Factor 1
XXX_sys_3a_x - Does the LDW system encumber or obstruct you in some driving situations? If yes, in which ones?
The following chart depicts the percentage frequency of drivers who experienced the LDW as being encumbering or obstructing in some situations, at T3a, T3b and T4. As can be seen the percentage is about 30% in the 3 considered times and does not vary over time. Drivers who answered positively to this question were then asked about in which situations they found the LDW obstructing. The percentage frequency of answers is shown in the following figure. The most frequently reported situations were ‘Near road works’, ‘During overtaking’ and ‘Other’.





Conclusions

With respect to obstruction caused by the system we found out that a minority of the sample thinks that the LDW can encumbers or obstruct the driver in some driving situations. This percentage (about 30%) does not vary over time. The most cited situations are ‘Near road works’ and ‘Overtaking’.

Perceived ease of use of LDW increases or stabilizes at high levels over time, compared to the expectation that drivers expressed at buying

Comparison situations

T3a: 5 months after the beginning of the test
T3b: 7 months after the beginning of the test
T4: 9 months after the beginning of the test

Filtering criteria

Only users in the LDW group have been considered.

Factors

ILD_eas_1_xxx - how user friendly you found the LDW system:

1. The system was easy to use.
2. It was easy to learn how to use the system.
3. It was easy to remember how to use the system.
4. Using the system did not distract me from other driving activities.
5. It was easy to understand system status.
6. I felt comfortable with the system.
7. The intervention of the LDW system seems well-timed.
8. The "HANDS OFF" indication seems correctly provided.

Performance indicators (PIs)

Ease of use

Data

Subjective ratings

Statistical Methods

Repeated measures ANOVA with within factor time of rating.

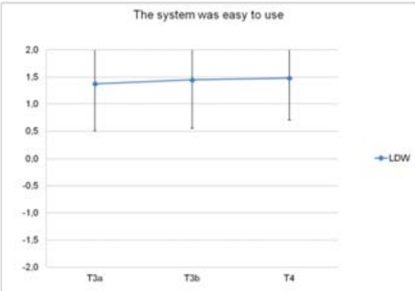
Results

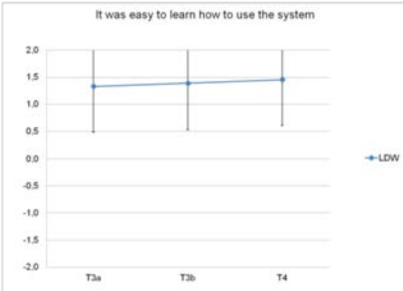
<u>Factor 1</u>
ILD_eas_1_xxx - how user friendly you found the LDW system:

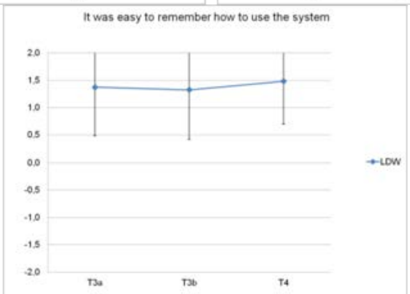
a. The system was easy to use.
b. It was easy to learn how to use the system.
c. It was easy to remember how to use the system.
d. Using the system did not distract me from other driving activities.
e. It was easy to understand system status.
f. I felt comfortable with the system.
g. The intervention of the LDW system seems well-timed.
h. The "HANDS OFF" indication seems correctly provided.

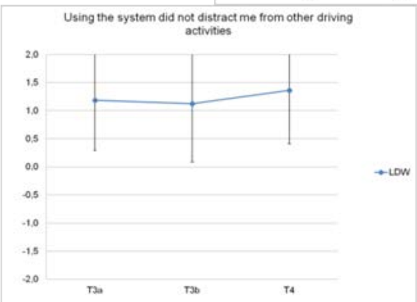
The following table shows the results of the RM ANOVA conducted on the LDW users to investigate whether their perception of user friendliness of the LDW changed over time. Of all the investigated friendliness aspects, the only one which significantly changed during the test was the one related to the possible distraction from other activities due to the use of LDW. Drivers at T4 were less prone to be distracted from other activities by the LDW than before. Following graphs show mean values and standard deviations at T3a, T3b and T4 for all the studied items.

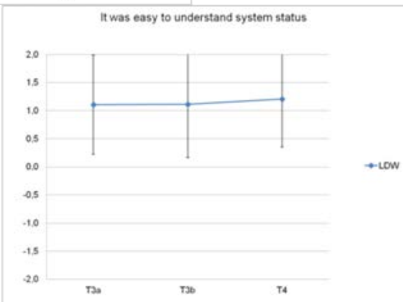
Group	Sub-scale	df	Error f	F	p
LDW	a. The system was easy to use.	2	240	1.23	.29
LDW	b. It was easy to learn how to use the system.	2	242	1.43	.24
LDW	c. It was easy to remember how to use the system.	2	240	2.66	.07
LDW	d. Using the system did not distract me from other driving activities.	2	236	3.70	.03
LDW	e. It was easy to understand system status.	2	240	.89	.41
LDW	f. I felt comfortable with the system.	2	236	.30	.74
LDW	g. The intervention of the LDW system seems well-timed.	2	242	1.10	.34
LDW	h. The "HANDS OFF" indication seems correctly provided.	2	204	1.82	.17

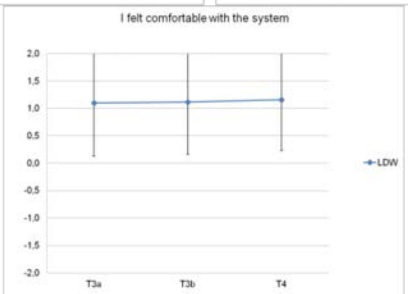


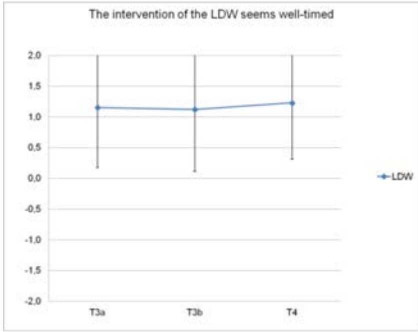


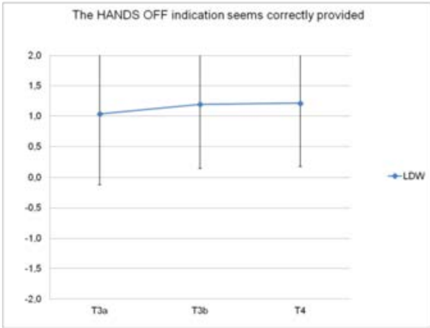












Conclusions

- As regards ease of use, LDW system is perceived positively (M =1.48, SD =.78 at Time his perception does not vary over time .
- Even considering the functioning learning, drivers who used LDW found easy to learn how to use the system (M =1.33, SD =.85 at Time 3a; M =1.45, SD =.84 at Time 4). This perception was stable over time.
- Similarly to what we found about ease of learning, drivers reported that it was easy to remember how to use the system (M =1.48, SD =.79 at Time 4). This perception was stable over time.
- Another investigated feature was the possible distraction linked to the LDW system use. Drivers reported that they generally did not find the system distracting from other driving activities (M =1.36, SD =.95 at Time 4). This perception did not vary over time.
- The ease of use was confirmed with respect to the ease of understanding the system status, that was quite high among drivers equipped with the LDW system (M =1.21, SD =.86 at Time 4). This perception stayed stable over time.
- In addition to the ease of use, drivers even felt highly comfortable with the system (M =1.16, SD =.93 at Time 4). This perception too did not change over time.
- With respect to the interventions timing, drivers reported that perceived the LDW system interventions well-timed (M =1.23, SD =.92 at Time 4) and this perception was stable over time.
- According to drivers, even the HANDS OFF indication was correctly provided by the LDW system (M =1.21, SD =1.04 at Time 4) and this perception was stable over time.

Level of perceived safety of LDW increases over time, compared to the expectation that drivers expressed at buying

During the baseline period users were asked not to use the system. About 13% of LDW group sample users joined the project as a result of buying a new car. They were asked to fill the first questionnaire in before experiencing the system. According to response rates, data collected and the questionnaire arrangement, it is not possible to assess users' expectations about impact of LDW on safety as expressed at buying.
For workload assessment, please refer to hypothesis "LDW decreases/mitigates lateral incidents, near-crashes and accidents (Safety - S1)" and " LDW influences lateral driving performance (Safety - S4)"

Drivers believe that LDW warnings are effective and relevant (as regards to specific aspects as system activation or lane departure)

Comparison situations

T3a: 5 months after the beginning of the test
T3b: 7 months after the beginning of the test
T4: 9 months after the beginning of the test

Filtering criteria

Only users in the LDW group have been considered.

Factors

1. XXX_ef_1_x – (Item from VdL scale) Do you find the LDW is effective?
2. XXX_ef_3a_x - Does the coming in action of the LDW seem adequate to you or not? If the intervention does NOT seem adequate to you, please point out the motivation
3. XXX_ef_4a_x - Do you find the minimum functioning speed of the LDW (i.e. 65 km/h) appropriate?

Performance indicators (PIs)

1. For factor 1: Acceptability
2. For factors 2 and 3: Usability

Data

Subjective ratings

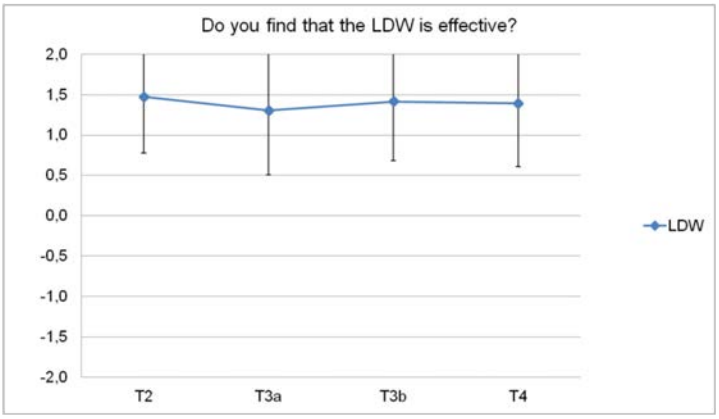
Statistical Methods

1. For factor 1: Repeated Measures ANOVA
2. For factors 2 and 3: Percentage frequencies

Results

Factor 1
XXX_ef_1_x – (Item from VdL scale) Do you find that the LDW is effective?
The following table shows the results of the RM ANOVA conducted on the item about effectiveness from the VdL scale. Result of the analysis is not significant, thus the high level of perceived effectiveness perceived by drivers as regards the LDW did not change from the start to the end of the test. Responses are also shown in the next graph, as M and SD.

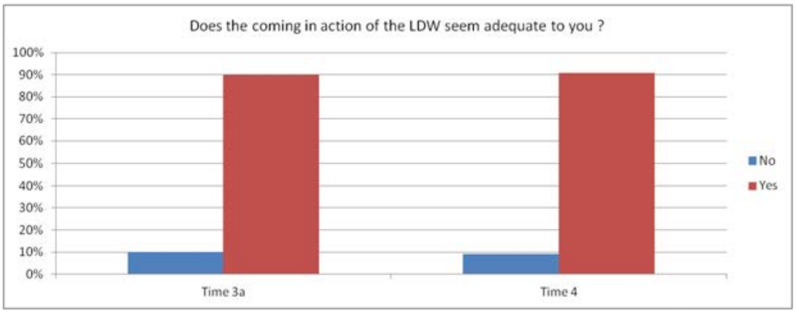
Group	Item	df	Error df	F	p
LDW	Do you fintd that the LDW is effective?	3	351	2.03	.11



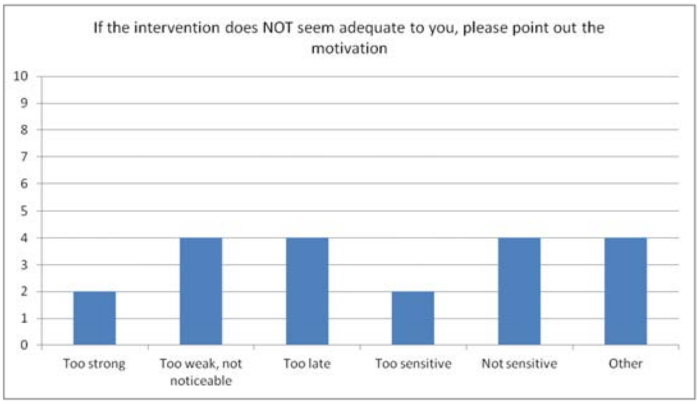
Factor 2

XXX_ef_3a_x - Does the coming in action of the LDW seem adequate to you or not? If the intervention does NOT seem adequate to you, please point out the motivation.

The following figure depicts the percentage frequency of answers to the question about the perceived adequacy of the coming in action of LDW, computed at T3a and T4. The majority of the respondents (about 90%) found that the coming in action of the system was adequate.



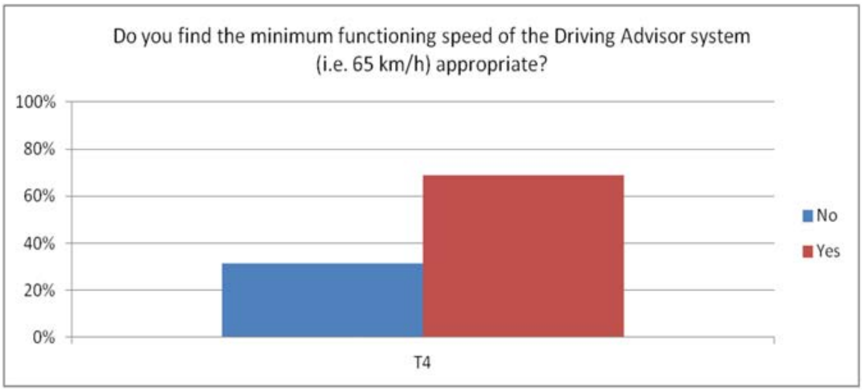
The next graph depicts the motivations expressed by drivers who did not found adequate the coming in action of the LDW. Given the very low number of drivers who found the coming in action of the system non adequate (*N*=12) the graph shows the *N*s and not the percentages.



Factor 3

XXX_ef_4a_x - Do you find the minimum functioning speed of the LDW system (i.e. 65 km/h) appropriate?

The next graph shows the answer of the drivers with respect to the appropriateness of the minimum functioning speed of the system. For about 70% of the respondents the minimum functioning speed of the LDW was adequate.



Conclusions

- The level of effectiveness perceived by drivers as regards the LDW is quite high and it did not change from the start to the end of the test.
- The coming in action of the system is perceived as adequate by the most part of the sample (about 90%) and this perception is stable over time.
- With respect to the minimum functioning speed of the system, a large part of the sample (69%) found it to be appropriate.

Annex 7 Curve Speed Warning (CSW)

List of selected hypothesis

The list of the CSW hypothesis is the following one:

Table 8: List of CSW hypothesis

Acceptance changes over time with system use
Certain features the systems, in terms of usefulness, influence user acceptance
Certain features of the systems, in terms of usability influence acceptance
Trust in system changes over time with system use
User practices (heuristics/rules) will change over time during the FOT

Acceptance changes over time with system use

Comparison situations

1. **T2:** Evaluation of system before use
2. **T4:** Evaluation of system after end of condition

Performance indicators (PIs)

1. Subjective rating of acceptance on van der Laan scale (subscales regarding to satisfying and useful: raising alertness, desirable, assisting, likeable, necessary, nice, good, pleasant, and useful)
2. Subjective rating of additionally acceptability items (social pressure, intended to use, attractive to buy, reliable, competent, intuitive, trustworthy, satisfying, simple, raises confidence, effective)

Data

Acceptance changes over time with system use.
Item: Please indicate how appealing you find the ACC system by ticking the box that most accurately expresses your feeling on each line. (Useful- Useless; Pleasant- Unpleasant; Good- Bad;Nice-Annoying; Necessary- Superfluous; Likeable- Irritating;Assisting- Worthless; Desirable-Undesirable;Raising alertness- Sleep-inducing).

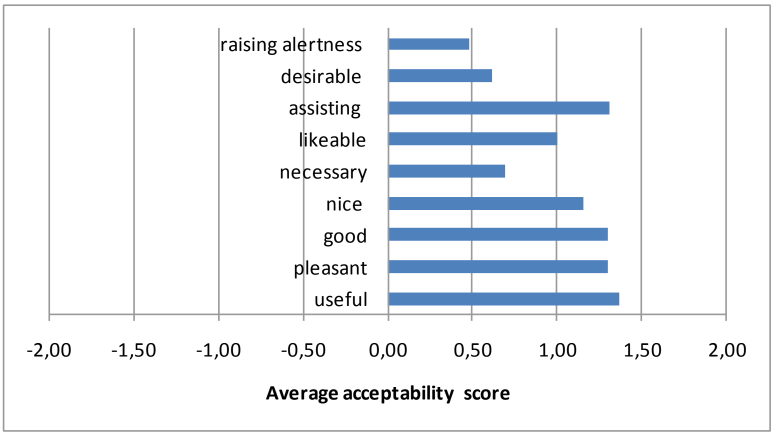
Statistical Methods

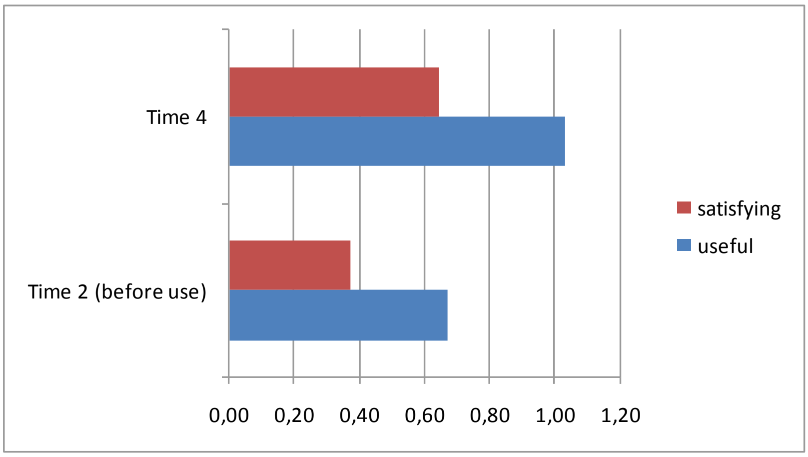
Wilcoxon Signed Rank Test **useful** and **satisfaction**: T2 vs T4

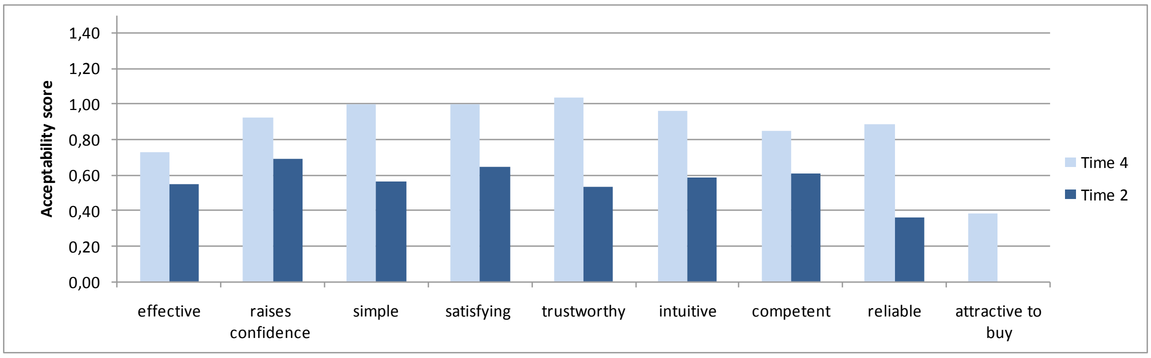
	Median		N	Z	Amp. Sig (2-tailed).
Useful	T2	,40	27	-2,178	,029
	T4	,60			
Satisfaction	T2	,40	34	-2,217	,027
	T4	,80			

A Wilcoxon Signed Rank Test showed there are statistically difference with an increase in useful scores, z=-2,178,p<.05, with a medium effect (r=0,30). The median of T2 decrease from 0,40 to 0,60 (T4). Moreover, there are a statistically difference in satisfaction with an increase from T2 (Md=0,40) to T4 (Md=0,80), z=-2,217,p<.05, with a medium effect (r=0,27).

Results







Conclusions

Average acceptability scores are all positives. Useful, assisting, good and pleasant are the adjectives with highest values (around 1,5 points) meanwhile raising alertness and necessary had the lowest.
Regarding changes over time for the satisfying and useful criteria, it was appreciated that usefulness perception increases over the time although these differences are not statistically significant. With regards to satisfaction, the bar graph that it decreases over time. The differences are also statistically significant. Then it seems that drivers are less pleased with the system over the time.
With reference to acceptability scores, the values increase between the two times for the 9 adjectives used to assess the satisfactoriness of drivers using ACC. Moreover the drivers would like find the CSW attractive to buy.

Certain features the systems, in terms of usefulness, influence user acceptance

Comparison situations

T4: Percentage of positive answers about how certain features of the systems have influence acceptance

Performance indicators (PIs)

Subjective rating of perceived usefulness

Factors

1. Type of the route (highway, urban road, rural road)
2. Familiarity roads (familiar vs. unfamiliar)
3. Traffic (normal, light, heavy)
4. Weather conditions

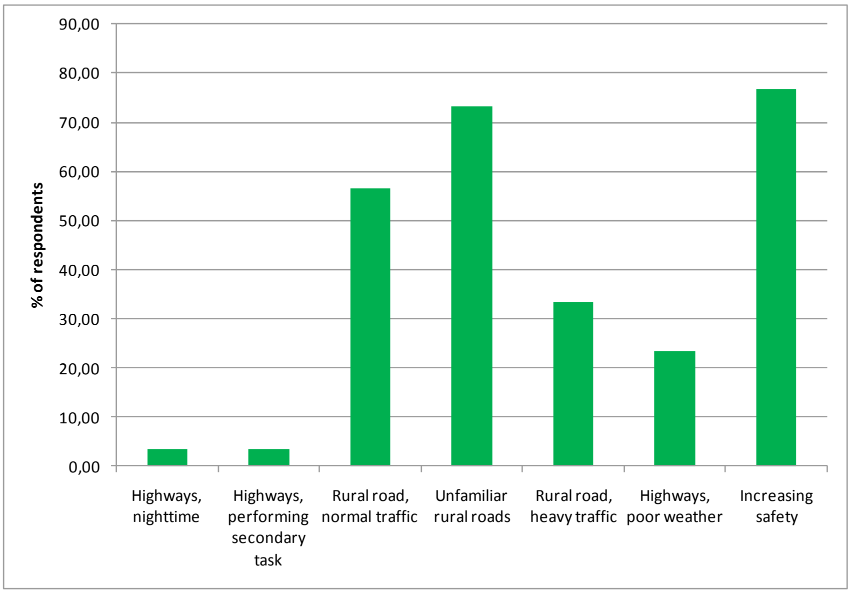
Data

Item: Usefulness relates to the extent to which the system meets your own personal needs. Here, try to think about where or when you found the CSW system was in meeting your needs (e.g., to save you money, to save you time, to increase your safety, to help you avoid traffic fines, etc.): On highways is normal traffic; On highways at night-time; On a highway whilst performing another task (e.g. eating); On a highway in heavy traffic; On a rural road in normal traffic; On unfamiliar rural roads; On rural roads in heavy traffic; On highways in adverse weather conditions (fog/heavy rain);Increasing safety. The answers were affirmative (yes) or negative (no).

Statistical Methods

None

Results



Conclusions

In relation to subjective usefulness influence acceptance after the system usage in the FOT, the highest values are for “Increasing safety” (77%); “Unfamiliar rural roads” (73%) and “Rural road normal traffic” (56%) and the lowest for “Highways night time” and “Highways, performing secondary tasks”, both with only (3%).

Therefore, it seems that the subjective influence is more positive when they drive in safe conditions in rural roads (except when the traffic is heavy). The lowest values corresponded when the participants drive on highways.

Certain features of the systems, in terms of usability influence acceptance

Comparison situations

T4: Subjective ratings vs. value indicating no misuse

Performance indicators (PIs)

Subjective rating of is perceived ease of use (Easy to use, easy to learn, easy to remember, not distracting, system status clear, comfortable with system)

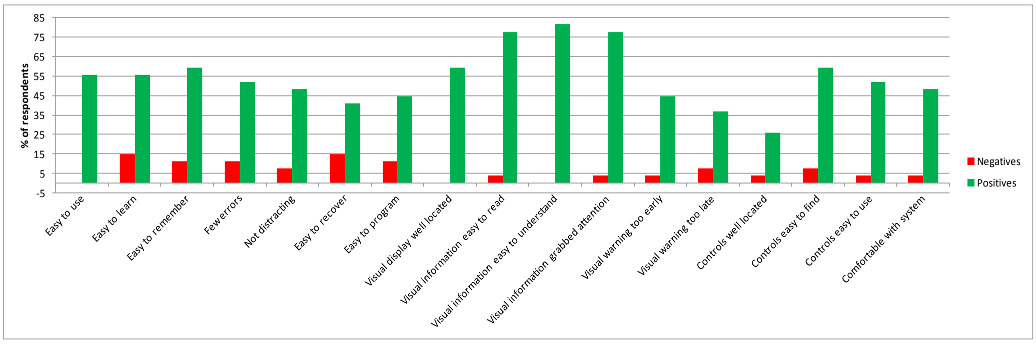
Data

The next series of questions are designed to get a feel a how user friendly you found the CSW system. Here think about how easy it was to use the system – were the system controls, displays, warnings easy to understand? **(“**The system was easy to use”, “It was easy to learn how to use the system”,” It was easy to remember how to use the system”, “Using the system did not distract me from other driving activities”, “It was easy to recover if I made an error using the system”, “It was easy to program the system to do what I wanted it to do”, “The visual display was well located”, “The visual information was easy to read”, “The visual information was easy to understand”, “The visual information grabbed my attention”, “The visual warnings were too early”, “The visual warnings were too late”, “The controls were well located”, “The controls were easy to find”, “The controls were easy to use”, “I felt comfortable with the system”. The possible answers were “Strongly disagree=1- strongly agree=5”.

Statistical Methods

None

Results



Conclusions

In relation to subjective usefulness influence acceptance after the system usage in the FOT, the highest values are for “Visual information easy to understand” (81%), “Visual information easy to read” and “Visual information grabbed attention” (both with a percentage of 77%).

The items with lowest values are “Visual warning too late” (37%) and “Controls well located” (25%). In any case, most of the bars have percentages between 45%-60%.
All items, except “Easy to use”, “Visual display well located” and “Visual information easy to understand”, have negative values, but these scores are lowest to respect the positive values. The items with highest negatives values, “Easy to learn” and “Easy to recover” (both with a percentage of 15 %) it represents a smaller percentage in to the sample.

Trust in system changes over time with system use

Comparison situations

1. **T2:** Expectance in system; evaluation before usage
2. **T4:** Evaluation of system after end of condition

Performance indicators (PIs)

Subjective rating of trust on van der Laan scale (subscales reliable, trustworthy & raises confidence)

Data

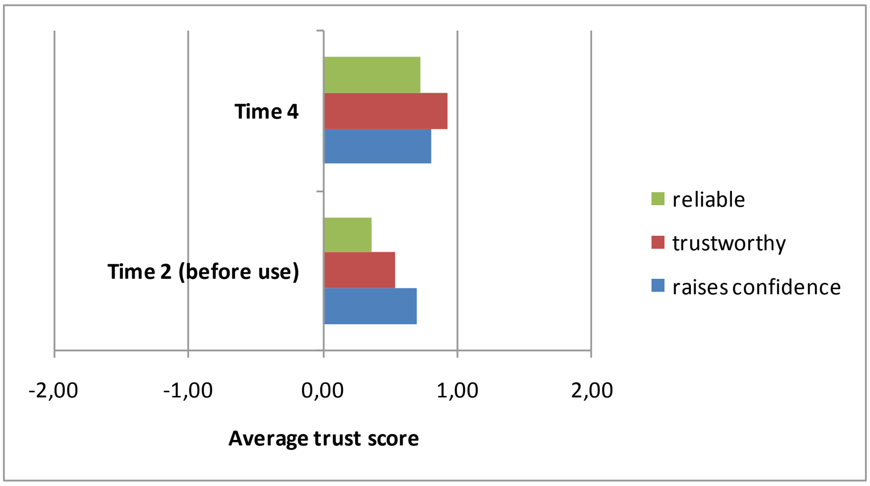
Item: Please indicate how appealing you find the CSW system by ticking the box that most accurately expresses your feeling on each line. Please leave blank if you have not experienced the system. (“Raises confidence- Creates uncertainty”, “Trustworthy- Untrustworthy” and “Reliable- Unreliable”).

Statistical Methods

	Median		N	Z	Amp. Sig (2-tailed).
Raises confidence	T2	1,00	24	-1,355	,175
	T4	1,00			
Trustworthy	T2	1,00	24	-2,399	,016
	T4	1,00			
Reliable	T2	1,00	24	-1,979	,048
	T4	1,00			

A Wilcoxon Signed Rank Test revealed there are statistically significant differences in trustworthy and reliable scores with an increase in useful scores, z=-1,355,p<.05, with a medium effect (r=0,33). Moreover, there are a statistically significant difference in reliable indicator with an increase in values, z=-1,979,p<.05, with a medium effect (r=0,29). The other variable (raises confidence) didn’t show a statistically significant difference.

Results



Conclusions

Average scores for reliable, trustworthy and raises confidence are all positive. The differences among the two times T2 and T4 are remarkable, in fact, the participants trusted more in the system after the system usage in the FOT. For trustworthy and reliable items, the differences are statistically significant.

User practices (heuristics/rules) will change over time during the FOT

Comparison situations

T4: User practices heuristics/rules will change over time during FOT vs. user practices won't change

Performance indicators (PIs)

Subjective rating of frequency of number of participants who responded Yes

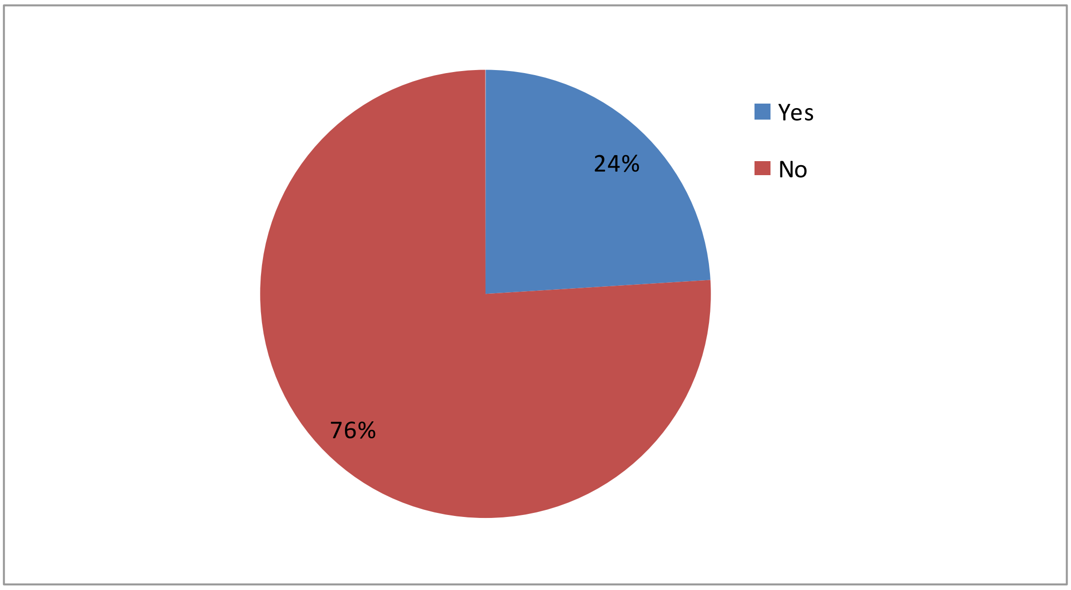
Data

Participants in FOT answered if the used the ACC system differently after use the system from the way you did when you first started using the system. And if the answer were positive, they should explain in what ways.

Statistical Methods

None

Results



Conclusions

Most of drivers (76% of sample) answered that they didn't change their user practices over time during the FOT meanwhile 24% did.

Annex 8 Navigation System

List of selected hypothesis

The following table is the list of the selected hypothesis for Navigation system.

Table 9: Navigation System selected hypothesis

Navigation systems decrease incidents while approaching decision points
Navigation systems decrease proportion of time with close following distance
Navigation systems decrease lane keeping errors
Navigation systems decrease number of hard brakings per hour
Navigation systems decrease number of hard accelerations
Navigation systems increase journey efficiency based on surrogate measures
Navigation systems decrease fuel consumption
Navigation systems increase the time spent on secondary tasks
Navigation systems increase compliance with traffic rules
Navigation system handling mainly occurs in low demanding situation
Navigation system handling increases active compensation by the driver
Navigation system handling doesn't decrease safety based on surrogate measures
Navigation systems decrease driver load at intersections
Navigation system increase perceived driving comfort
Acceptance and trust of navigation system will increase over time
Navigation systems decrease driver workload over time with function use
Drivers will not abuse or misuse navigation systems
The type of the navigation system affects interaction with the system

Navigation systems decrease incidents while approaching decision points

Comparison situations

1. **Baseline**: All baseline trips
2. **Treatment – built-in**: All trips in condition built-in navigation system with routing function active
3. **Treatment – mobile**: All trips in condition mobile navigation system with routing function active

Filtering criteria

1. Trip length > 1km
2. On intersection

Factors

1. Road type (rural and urban)
2. Familiarity (familiar, unfamiliar) in combination with road type

Performance indicators (PIs)

1. Distance events per intersection crossed
2. Lateral events per intersection crossed
3. Longitudinal events per intersection crossed
4. All incidents per intersection crossed

Data

All of the available data in DB divided *per driver*.

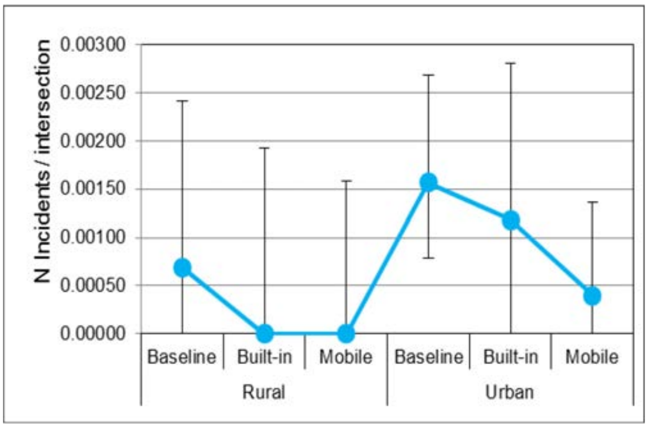
Statistical Methods

Friedman ANOVA comparing baseline, treatment built-in and treatment mobile. Independent testing per situational condition (familiarity * road type). For post-hoc testing, Wilcoxon signed rank tests are used.

Results

Familiarity	PI	Rural			Urban		
		N / df	Chi2	p	N / df	Chi2	p
Overall	Distance	83 / 2	3.55		85 / 2	25.69	<0.001
	Lateral	83 / 2	6.95	<0.05	85 / 2	27.98	<0.001
	Longitudinal	83 / 2	3.40		85 / 2	7.23	<0.05
	All	83 / 2	1.33		85 / 2	32.15	<0.001
Familiar	Distance	84 / 2	7.80	<0.05	86 / 2	22.52	<0.001
	Lateral	84 / 2	15.38	<0.001	86 / 2	41.06	<0.001
	Longitudinal	84 / 2	4.86	0.088	86 / 2	10.44	<0.01
	All	84 / 2	8.16	<0.05	86 / 2	35.41	<0.001
Unfamiliar	Distance	49 / 2	0.91		50 / 2	4.04	
	Lateral	49 / 2	0.40		50 / 2	1.42	
	Longitudinal	49 / 2	1.00		50 / 2	0.40	
	All	49 / 2	0.42		50 / 2	3.29	

PI	Road type	Baseline		Built-in		Mobile	
		m	sd	m	sd	m	sd
Overall	Rural	0.0020	0.0038	0.0016	0.0029	0.0019	0.0069
	Urban	0.0023	0.0027	0.0020	0.0028	0.0017	0.0057
Familiar	Rural	0.0019	0.0037	0.0018	0.0040	0.0015	0.0067
	Urban	0.0022	0.0025	0.0020	0.0026	0.0020	0.0072
Unfamiliar	Rural	0.0035	0.0152	0.0017	0.0064	0.0010	0.0026
	Urban	0.0019	0.0054	0.0008	0.0017	0.0005	0.0010



Conclusions

With active navigation system, there are fewer incidents at intersections on familiar routes than in baseline condition. For unfamiliar routes, there is no effect of condition.

Navigation systems decrease proportion of time with close following distance

Comparison situations

1. **Baseline**: All baseline trips
2. **Treatment – built-in**: All trips in condition built-in navigation system with routing function active
3. **Treatment – mobile**: All trips in condition mobile navigation system with routing function active

Performance indicators (PIs)

1. Proportion of critical THW
2. Proportion of critical TTC

Filtering criteria

1. Trip length > 1km
2. Car-follow situation
3. v > 0.5 km/h

Factors

1. Road type (highway, rural, urban).
2. Familiarity (familiar, unfamiliar) in combination with road type

Data

All of the available data in DB divided *per driver*.

Statistical Methods

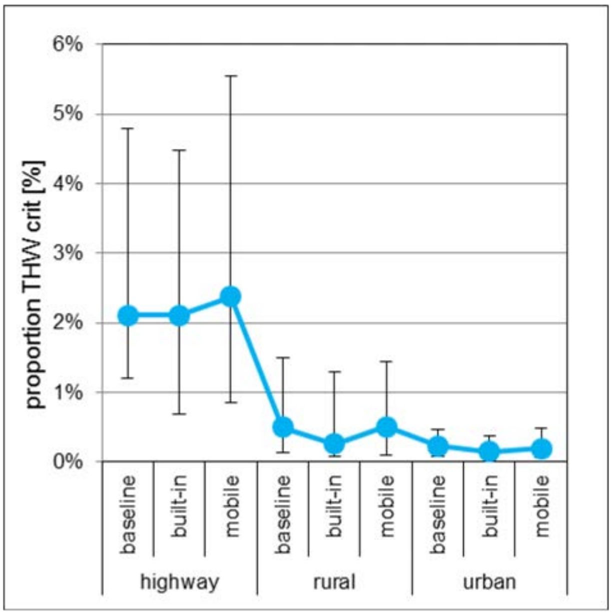
Friedman ANOVA with within factor condition. For post-hoc testing, Wilcoxon signed rank tests are used.

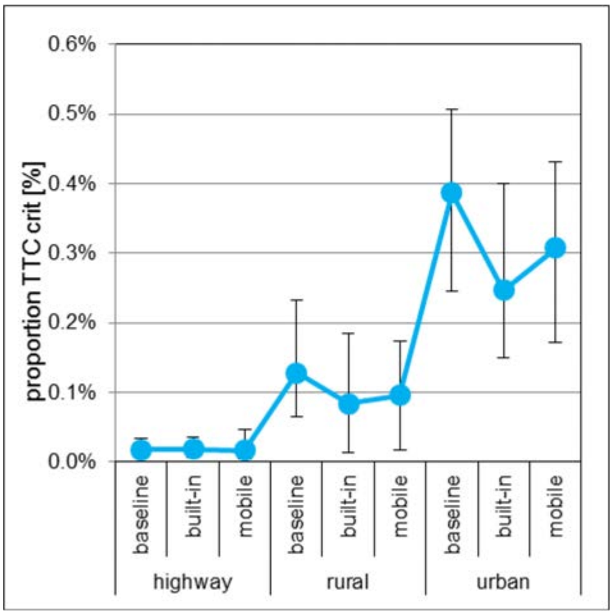
Results

Post-hoc tests show that in urban areas the proportion of critical TTC is reduced for both types of navigation systems as compared to baseline. This effect is based on familiar trips only. On rural roads, the proportion of critical TTC is reduced for both navigation systems. Again, there is no difference between the two types of system. If we split the data based on familiarity, there is a tendency for familiar trips and no effect for unfamiliar trips.
For the proportion of critical THW, there is a significant decrease with the built-in device and a tendency for the mobile device in urban areas. Splitting based on familiarity gives a significant decrease for both HMI-solutions on familiar trips. On unfamiliar trips there is a tendency that the proportion of critical THW is reduced with the built-in navigation system on urban and rural roads.

PI	Sit	Highway			Rural			Urban		
		N / df	Chi2	p	N / df	Chi2	p	N / df	Chi2	p
% THW crit	All	85 / 2	0.61		86 / 2	1.60		87 / 2	10.36	<0.01
	Fam	82 / 2	2.99		83 / 2	1.93		85 / 2	11.23	<0.01
	unfam	46 / 2	1.00		48 / 2	7.72	<0.05	52 / 2	4.70	0.096
% TTC crit	All	85 / 2	0.55		86 / 2	15.93	<0.001	87 / 2	19.13	<0.001
	Fam	82 / 2	2.58		83 / 2	5.46	0.065	85 / 2	16.73	<0.001
	unfam	46 / 2	2.58		48 / 2	1.29		52 / 2	1.01	

PI	Road type	Baseline		Built-in		Mobile	
		m	sd	m	sd	m	sd
Proportion THW crit	Highway	3.98%	5.42%	4.07%	6.03%	4.64%	6.07%
	Rural	1.09%	1.71%	1.16%	2.06%	1.28%	2.44%
	Urban	0.45%	1.18%	0.40%	0.98%	0.48%	1.12%
Proportion TTC crit	Highway	0.03%	0.05%	0.04%	0.05%	0.05%	0.09%
	Rural	0.19%	0.19%	0.19%	0.67%	0.16%	0.29%
	Urban	0.42%	0.25%	0.33%	0.28%	0.37%	0.30%





Conclusions

In urban areas and on rural roads, less close following distances occur while a navigation system is used. There is no consistent difference between the two HMI-solutions.

Navigation systems decrease lane keeping errors

Comparison situations

1. **Baseline**: All baseline trips
2. **Treatment – built-in**: All trips in condition built-in navigation system with routing function active
3. **Treatment – mobile**: All trips in condition mobile navigation system with routing function active

Performance indicators (PIs)

1. Proportion of critical TTC
2. Number of lane exceedances / hour

Filtering criteria

1. Trip length > 1km
2. Lane position detected
3. v > 0.5 km/h

Factors

1. Road type (highway, rural, urban).
2. Familiarity (familiar, unfamiliar) in combination with road type

Data

All of the available data in DB divided *per driver*.

Statistical Methods

Friedman ANOVA with within factor condition. For post-hoc testing, Wilcoxon signed rank tests are used.

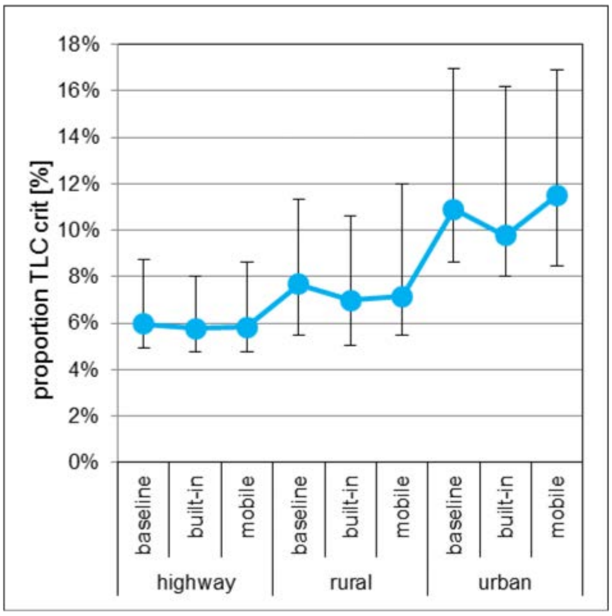
Results

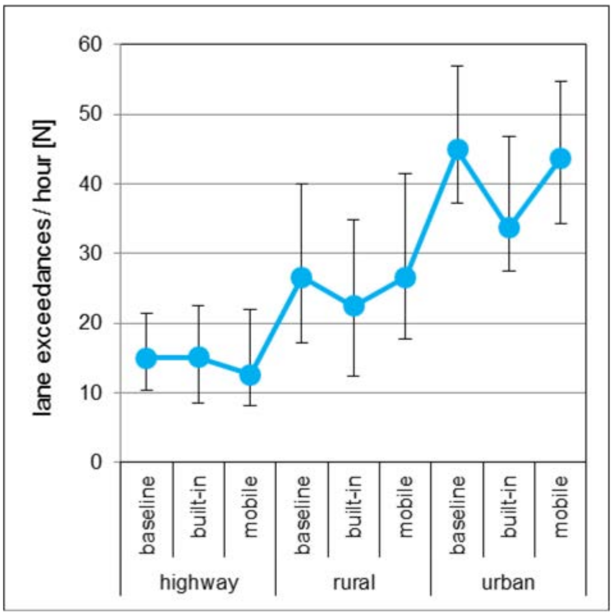
Post-hoc tests show that in urban areas the proportion of critical TLC is reduced with the built-in navigation system compared to baseline. This effect can be found for unfamiliar but not for familiar trips. Furthermore, in urban areas the frequency of lane exceedances is reduced with the built-in navigation system compared to baseline and compared to the mobile device. If we split by familiarity, the frequency of lane exceedances is lower with the built-in device compared to the two other conditions on familiar and unfamiliar trips.

Table 10: Results

PI	Sit	Highway			Rural			Urban		
		N / df	Chi2	p	N / df	Chi2	p	N / df	Chi2	p
% TLC crit	All	84 / 2	0.31		85 / 2	3.98		86 / 2	7.07	<0.05
	Fam	83 / 2	0.46		83 / 2	0.10		85 / 2	4.05	
	unfam	45 / 2	0.84		49 / 2	0.65		52 / 2	14.12	<0.001
Lane exc/h	All	84 / 2	4.17		85 / 2	1.34		86 / 2	21.21	<0.001
	Fam	83 / 2	1.62		83 / 2	6.54	<0.05	85 / 2	21.15	<0.001
	unfam	45 / 2	0.84		49 / 2	1.68		52 / 2	6.60	<0.05

PI	Road type	Baseline		Built-in		Mobile	
		m	sd	m	sd	m	sd
Proportion TLC crit	Highway	6.8%	2.7%	6.7%	2.9%	7.0%	3.0%
	Rural	8.9%	4.4%	8.2%	4.0%	8.6%	4.3%
	Urban	12.9%	4.8%	12.2%	5.1%	12.7%	4.8%
Lane exceedances / h	Highway	16.6	9.0	16.3	9.9	15.5	9.9
	Rural	30.9	24.3	26.0	20.4	30.9	20.6
	Urban	47.2	17.6	38.4	20.0	44.6	16.7





Conclusions

With the built-in navigation system, lane keeping performance in urban areas is improved compared to baseline condition. There is no clear effect for the mobile device.

Navigation systems decrease number of hard brakings per hour

Comparison situations

1. **Baseline**: All baseline trips
2. **Treatment – built-in**: All trips in condition built-in navigation system with routing function active
3. **Treatment – mobile**: All trips in condition mobile navigation system with routing function active

Performance indicators (PIs)

1. Number of hard brakings per hour

Filtering criteria

1. Trip length > 1km
2. v > 0.5 km/h

Factors

1. Road type (highway, rural, urban).
2. Familiarity (familiar, unfamiliar) in combination with road type

Data

All of the available data in DB divided *per driver*.

Statistical Methods

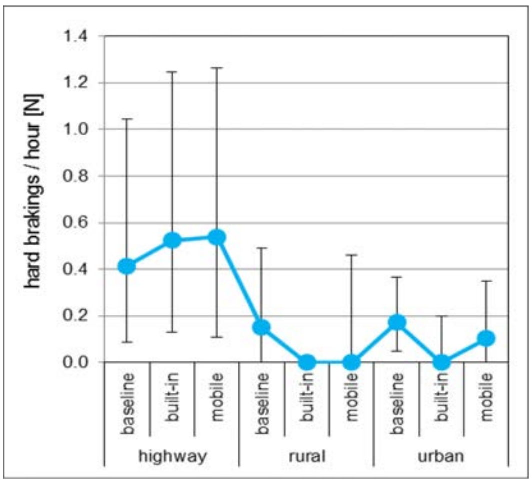
Friedman ANOVA with within factor condition. For post-hoc testing, Wilcoxon signed rank tests are used.

Results

Post-hoc tests show that on urban and rural roads the number of hard brakings is reduced while using the built-in navigation system compared to baseline condition. This effect can also be found for familiar trips only.

	Highway			Rural			Urban		
	N / df	Chi2	p	N / df	Chi2	p	N / df	Chi2	p
Overall	85 / 2	2.98		86 / 2	10.35	<0.01	87 / 2	11.93	<0.01
Familiar	84 / 2	1.79		85 / 2	14.32	<0.01	86 / 2	18.63	<0.01
Unfamiliar	46 / 2	0.65		50 / 2	5.09	0.078	53 / 2	4.43	0.109

Road	Baseline		Built-in		Mobile	
	m	sd	m	sd	m	sd
highway	0.934	1.883	1.010	1.610	1.253	2.663
rural	0.402	0.732	0.335	0.828	0.517	1.352
urban	0.274	0.319	0.239	0.528	0.283	0.544



Conclusions

With the built-in navigation system, the number of hard brakings is reduced on rural roads and in urban areas. There is no influence of the mobile device on the number of hard brakings.

Navigation systems decrease number of hard accelerations

Comparison situations

1. **Baseline**: All baseline trips
2. **Treatment – built-in**: All trips in condition built-in navigation system with routing function active
3. **Treatment – mobile**: All trips in condition mobile navigation system with routing function active

Performance indicators (PIs)

1. Number of hard accelerations/ hour

Filtering criteria

1. Trip length > 1km
2. v > 0.5 km/h

Factors

Road type (highway, rural, urban).

Data

All of the available data in DB divided *per driver*.

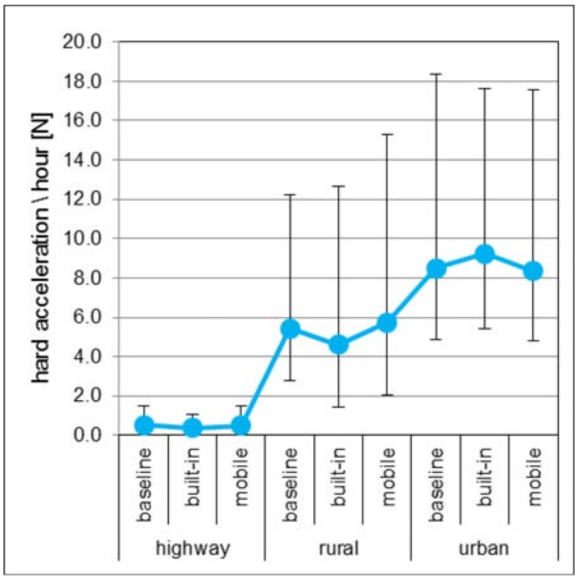
Statistical Methods

Friedman ANOVA with within factor condition. For post-hoc testing, Wilcoxon signed rank tests are used.

Results

	Highway			Rural			Urban		
	N / df	**Chi2**	**p**	**N / df**	**Chi2**	**p**	**N / df**	**Chi2**	**p**
Acceleration / h	85 / 2	5.75	0.57	86 / 2	0.87		87 / 2	2.78	

Road	Baseline		Built-in		Mobile	
	m	sd	m	sd	m	sd
highway	1.193	2.351	1.041	3.078	1.118	1.972
rural	9.388	11.199	8.580	9.673	10.626	14.276
urban	13.640	15.096	13.446	12.697	12.821	12.898



Conclusions

The frequency of hard accelerations does not change with navigation system usage.

Navigation systems increase journey efficiency based on surrogate measures

Comparison situations

1. **Baseline**: All baseline trips
2. **Treatment – built-in**: All trips in condition built-in navigation system with routing function active
3. **Treatment – mobile**: All trips in condition mobile navigation system with routing function active

Performance indicators (PIs)

1. Relative trip length: Based on start- and end-GPS-position, estimated trip length is derived from Google Maps. The difference between the measured trip length and the estimated trip length is calculated in percent of the estimated length.
2. Relative trip duration: Based on start- and end-GPS-position, estimated trip duration is derived from Google Maps. The difference between the measured trip duration and the estimated trip duration is calculated in percent of the estimated length.
3. Proportion of time spent in congestion on highways.

Filtering criteria

1. Overall: Trip length > 1km
2. For PI 1 and 2: Absolut difference between estimated and measured trip length is < 100%
3. For PI 3: Roadtype is highway

Data

All of the available data in DB divided *per driver*.

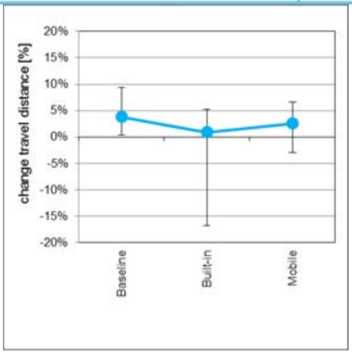
Statistical Methods

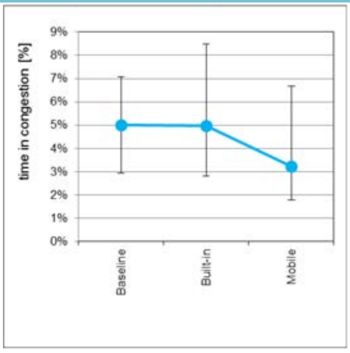
PI1, PI2 & PI3: Repeated measures ANOVA with within factor condition. For post-hoc-testing, Bonferroni tests are used..

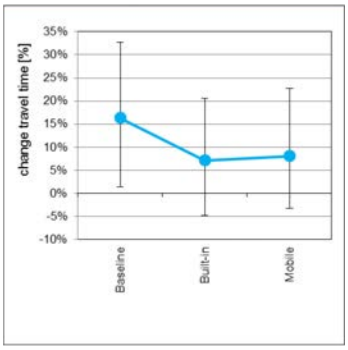
Results

PI	Effect	df	Error df	F	p
Relative trip length	Condition	2	168	6.02	<0.01
Relative trip duration	Condition	2	168	5.56	<0.01
Time spent in congestion	Condition	2	168	1.24	

PI	Baseline		Built-in		Mobile	
	m	sd	m	sd	m	sd
Relative trip length	0.0060	0.1542	-0.0618	0.2192	-0.0273	0.1947
Relative trip duration	0.1704	0.2608	0.0763	0.3472	0.1001	0.2777
Time spent in congestion	0.057	0.040	0.074	0.082	0.055	0.069







Conclusions

Navigation systems reduce relative travel time. For the built-in device, also a decrease in relative travel distance can be found. Since this is mainly a function of the used navigation algorithm, the difference between the HMI-solutions cannot be attributed to the used HMI-concept. The proportion of time spent in congestion on highways is not influenced by the usage of a navigation system.

Navigation systems decrease fuel consumption

Comparison situations

1. **Baseline**: All baseline trips
2. **Treatment – built-in**: All trips in condition built-in navigation system with routing function active
3. **Treatment – mobile**: All trips in condition mobile navigation system with routing function active

Performance indicators (PIs)

1. Mean fuel consumption [l/100 km]

Filtering criteria

1. Trip length > 1km
2. Engine on

Factors

Road type (highway, rural, urban)

Data

All of the available data in DB divided *per driver*.

Statistical Methods

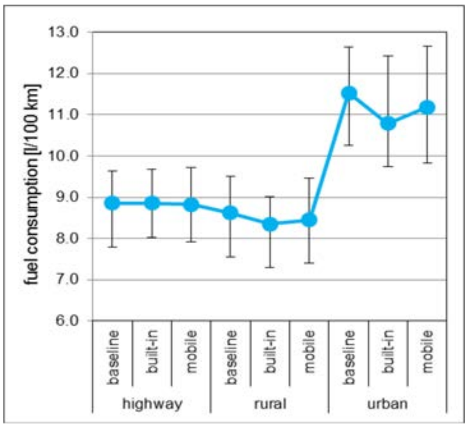
Repeated measures ANOVA with within factor condition. For post-hoc-testing, Bonferroni tests are used.

Results

Post hoc tests show that on urban roads fuel consumption while driving with the built-in navigation system is reduced compared to baseline and compared to driving with the mobile device.

Road type	Effect	df	Error df	F	p
Rural	Condition	2	170	2.69	0.071
Urban	Condition	2	172	10.66	<0.001

Road type	Baseline		Built-in		Mobile	
	m	sd	m	sd	m	sd
Highway	8.8	1.3	8.9	1.4	8.9	1.5
Rural	8.5	1.3	8.3	1.2	8.4	1.6
Urban	11.6	1.6	11.1	1.8	11.3	1.8



Conclusions

On urban roads, fuel consumption is reduced by 4.4% while driving with the built-in navigation system. Furthermore, there is a tendency for a similar effect on rural roads.

Navigation systems increase the time spent on secondary tasks

Comparison situations

1. **Baseline**: All baseline trips
2. **Treatment – built-in**: All trips in condition built-in navigation system with routing function active
3. **Treatment – mobile**: All trips in condition mobile navigation system with routing function active

Filtering criteria

1. Trip length > 1km

Factors

1. Road type (highway, rural, urban)
2. Familiarity
3. Passenger seat occupied

Performance indicators (PIs)

1. Proportion of time during which interaction with secondary tasks was measured via CAN-signals (e.g. hands-free telephoning)

Chunking

None.

Data

All of the available data in DB divided *per driver*.

Statistical Methods

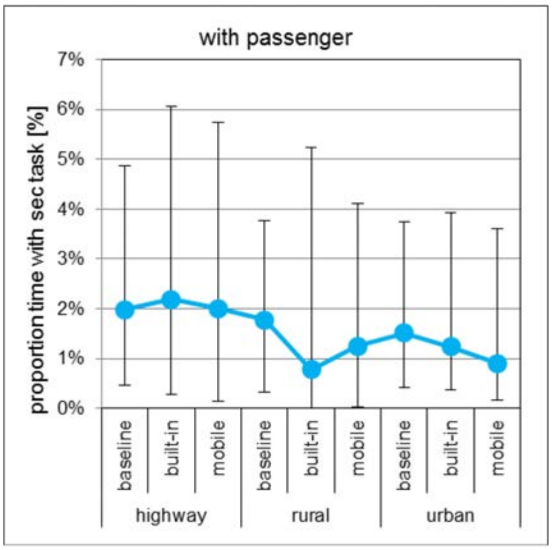
Friedman ANOVA comparing baseline, treatment built-in and treatment mobile. Independent tests are used per situational condition (familiarity * road type). For post-hoc testing, Wilcoxon signed rank tests are used.

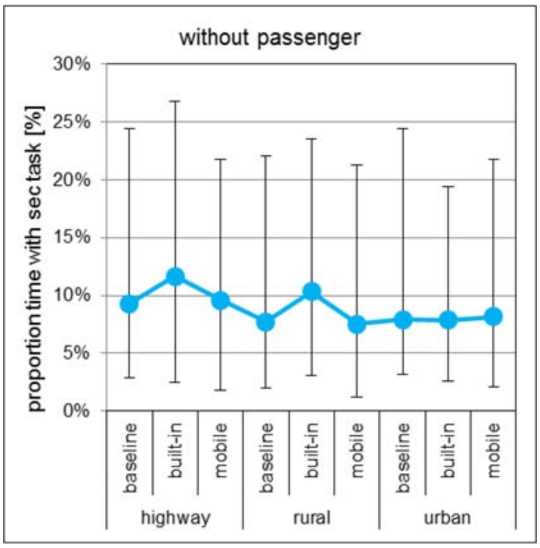
Results

In urban areas on familiar routes, there is a tendency that the proportion of time engaging in a secondary task is lower with the mobile as compared to the built-in navigation system. On highways without a passenger being present the proportion of time engaging in a secondary task is lower with the mobile as compared to the built-in navigation system. On rural roads with a passenger present, the proportion of time is lower with the mobile device compared to baseline driving.

	Highway			Rural			Urban		
	N / df	Chi2	p	N / df	Chi2	p	N / df	Chi2	p
No passenger	82 / 2	9.07	<0.05	83 / 2	2.19		86 / 2	3.33	
Passenger	68 / 2	0.63		72 / 2	7.73	<0.05	72 / 2	0.27	
Familiar	84 / 2	2.67		85 / 2	2.39		86 / 2	5.88	0.053
Unfamiliar	46 / 2	2.50		50 / 2	0.20		53 / 2	0.30	

Situation	Road type	Baseline		Built-in		Mobile	
		m	sd	m	sd	m	sd
No passenger	Highway	15%	16%	17%	17%	15%	16%
	Rural	14%	14%	15%	17%	13%	15%
	Urban	14%	13%	13%	15%	13%	13%
Passenger	Highway	4%	7%	6%	13%	5%	9%
	Rural	3%	4%	5%	12%	4%	6%
	Urban	3%	5%	5%	14%	3%	6%
Familiar	Highway	13%	12%	14%	14%	13%	14%
	Rural	11%	10%	13%	13%	11%	13%
	Urban	10%	10%	13%	13%	10%	10%
Unfamiliar	Highway	12%	16%	11%	12%	14%	18%
	Rural	9%	12%	12%	14%	11%	16%
	Urban	10%	12%	10%	13%	8%	11%





Conclusions

Overall, there is no clear influence of navigation system usage on the proportion of time engaging in a secondary task. In three situational categories, the proportion of time with a secondary task is lower when driving with the mobile device.

Navigation systems increase compliance with traffic rules

Comparison situations

1. **Baseline**: All baseline trips
2. **Treatment – built-in**: All trips in condition built-in navigation system with routing function active
3. **Treatment – mobile**: All trips in condition mobile navigation system with routing function active

Filtering criteria

1. Trip length > 1km

Factors

1. Road type (highway, rural, urban)
2. Direction of turning for PI2 (left vs. right)

Performance indicators (PIs)

1. Proportion of time speeding
2. Proportion of turning at intersections with using turn indicator
3. Subjective evaluation of change caused by navigation system (-2=decreased significantly, 0 = no change, 2 = increased significantly)

Data

All of the available data in DB divided *per driver*.

Statistical Methods

For objective PIs, Friedman ANOVA comparing baseline, treatment built-in and treatment mobile are used. Independent testing per situational condition. For post-hoc testing, Wilcoxon signed rank tests are used. For subjective PIs, multiple t-tests comparing ratings against 0 = no change.

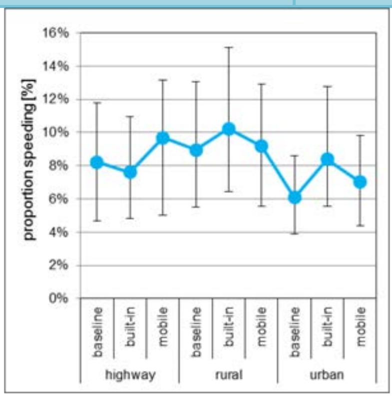
Results

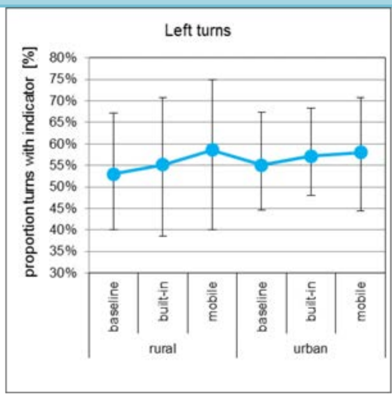
In urban areas, the proportion of time spent speeding is higher in the condition built-in navigation system than in the condition with the mobile device. In both conditions with navigation system usage, more speeding occurs than in baseline condition. For both, left and right turns there is a tendency that the turn indicator is used more often if drivers use a navigation system.

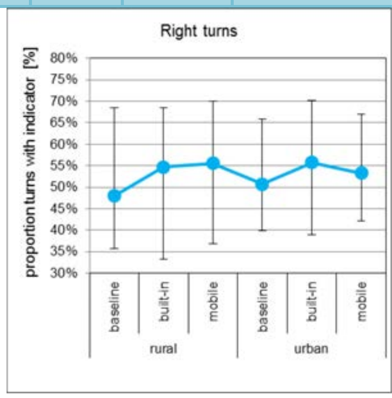
	Highway			Rural			Urban		
	N / df	Chi2	p	N / df	Chi2	p	N / df	Chi2	p
Speeding	85 / 2	4.52		86 / 2	1.14		87 / 2	15.10	<0.001
Left turns				77 / 2	0.34		87 / 2	5.68	0.058
Right turns				82 / 2	2.25		87 / 2	4.78	0.092

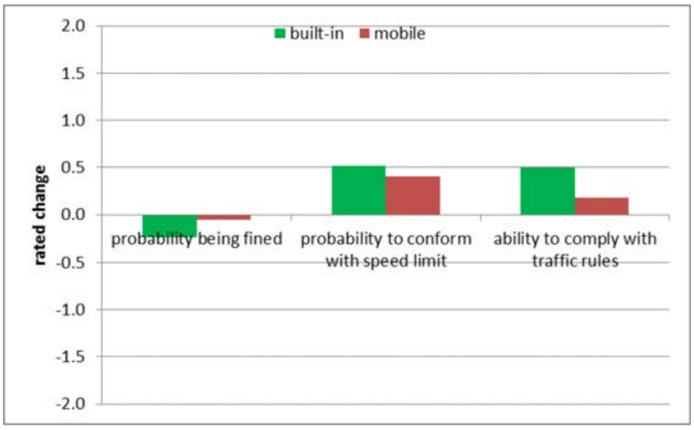
PI	Road type	Baseline		Built-in		Mobile	
		m	sd	m	sd	m	sd
Speeding	Highway	9%	7%	9%	6%	10%	6%
	Rural	10%	10%	14%	17%	13%	26%
	Urban	7%	4%	10%	8%	8%	6%
% indicating left turns	Rural	53%	18%	55%	23%	58%	25%
	Urban	56%	15%	58%	16%	59%	18%
% indicating right turns	Rural	50%	22%	52%	26%	55%	25%
	Urban	51%	17%	55%	17%	54%	18%

Type of navigation system	Item	df	t	p
Built-in device	Probability being fined	104	-4.74	<0.001
	Probability to conform with speed limit	107	6.06	<0.001
	Ability to comply with traffic rules	107	6.38	<0.001
Mobile device	Probability to conform with speed limit	108	5.32	<0.001
	Ability to comply with traffic rules	108	2.68	<0.01









4.1.1.1 Conclusions

The subjective evaluation and results obtained with objective driving data partly contradict each other: Drivers state that both navigation systems helped them to comply with the speed limit, with objective data an increase of speeding can be found for both navigation systems in urban areas. The result for the proportion of turning at intersections with using the turn indicator is more in line with the subjective evaluation of the drivers. Both PIs indicate that navigation systems help the drivers to comply with traffic rules.

All in all, it is difficult to decide whether the hypothesis is true or has to be rejected.

Navigation system handling mainly occurs in low demanding situation

Comparison situations

1. **Situation 1: Input to navigation system in the following situations:** standstill, driving on urban roads, rural roads or on highway
2. **Situation 2: Input to navigation system in the following situations:** standstill, v < 10km/h, driving on urban roads, driving on rural roads, driving on highways with v < 110km/h, driving on highways with 110km/h < v < 160km/h, driving on highways with v > 160km/h

Filtering criteria

1. Input to navigation system longer than 5 seconds

Factors

1. Type of navigation system: built-in vs. mobile

Performance indicators (PIs)

1. Quotient of proportion of system inputs in situations x / proportion of measurement time in situation x;
   For statistical evaluation, quotients are transformed into even spaced values between -1 and 1 by using the following formula: x >=1: y = x-1; x<1: y = 1-(1(1/x)

Data

All of the available data in DB divided *per driver*.

Statistical Methods

Repeated measures ANOVA with within factors situation and condition. For post-hoc-testing, Bonferroni tests are used. With repeated t-test comparing against zero, it is tested whether system handling is preferred or avoided in a situation.

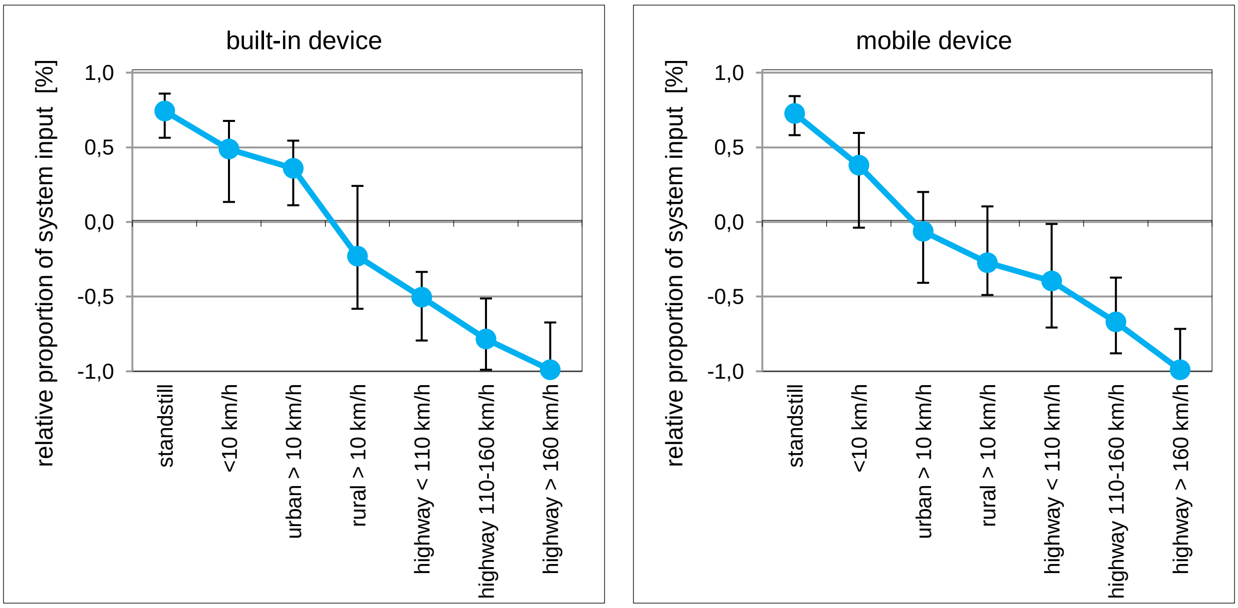
Results

Results are displayed in the following tables. For situation 1, post-hoc tests show that all situational categories differ from each other. Interaction is due to the fact that the two systems differ on urban roads. Here, more inputs are made with the built-in compared to the mobile navigation system. For situation 2, post-hoc tests show that all situational categories differ from each other. Standstill is preferred most for system inputs, followed by v < 10km/h, followed by rural roads, followed by urban areas. On highways, the least system inputs are made. Here, the proportion of system inputs in relation to time spent in the situational category declines with rising speed. Interaction is due to the fact that the two systems differ on urban roads. Here, more inputs are made with the built-in compared to the mobile navigation system.

PI	Effect	df	Error df	F	p
Situation 1	Situation	3	252	233.9	<0.001
	Situation * Condition	3	252	12.9	<0.001
Situation 2	Condition	6	468	264.4	<0.001
	Situation * Condition	6	468	8.48	<0.001

	Standstill	Urban	Rural	Highway
Built-in	+	+	-	-
Mobile	+		-	-

	Standstill	<10km/h	Urban	Rural	Highway <110km/h	Highway 110-160km/h	Highway >160km/h
Built-in	+	+	+	-	-	-	-
Mobile	+	+	-	-	-	-	-



Conclusions

Drivers prefer low demanding driving situations like standing or speed below 10km/h for making inputs to a navigation system. The only difference between the two HMI-solutions can be found in urban areas. Here, a higher proportion of inputs are made with the built-in compared to the mobile device.

Navigation system handling increases active compensation by the driver

Comparison situations

1. **Before system input:** Period directly prior to system input; same duration as following system input
2. **During system input:** Input to navigation system
3. **After system input:** Period directly after system input; same duration as preceding system input

Filtering criteria

1. Input to navigation system longer than 5 seconds
2. m(v) during system input > 0.5 km/h

Factors

1. Type of navigation system: built-in vs. mobile
2. Road type: highway vs. rural vs. urban

Performance indicators (PIs)

1. Change of speed during interval (v_{end}-v_{start}) [km/h]
2. Mean of mean time-head-way during interval [sec]
3. Mean of standard deviation of lane position during interval [m]

Chunking

- Calculation of indicators per system input.
- Unweighted aggregation for each driver (each system input counts equally). Robust indicators like median or 90% interval are used to aggregate across system inputs.
- Calculation of sdlp: continuous calculation of standard deviation of lane position in moving time window of x seconds; PI is calculated as mean of continuous sdlp in analysed time period

Data

All of the available data in DB divided *per driver*.

Statistical Methods

For THW, repeated measures ANOVA with within factors time and condition are used. For sdlp, repeated measures ANOVA with within factor time are used. For post-hoc-testing, Bonferroni tests are used. For the change in speed (diff(v)), it is tested with repeated t-tests against zero.

Results

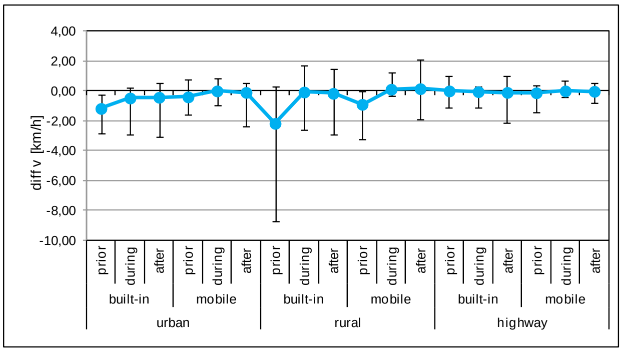
Post hoc tests show that with the mobile device sdlp increases during system inputs on urban roads and on highways. On highways, the increase in sdlp endures also during the period directly after the system input. On urban roads, THW increases during system inputs for both systems. On rural roads a tendency can be found for the same effect. Furthermore, on rural roads THW in the time during and close to a system input is higher for the built-in than for the mobile device. On rural and urban roads, drivers reduce speed directly before making a system input while driving with the built-in device. For the mobile device, the reduction of speed can only be found on rural roads.

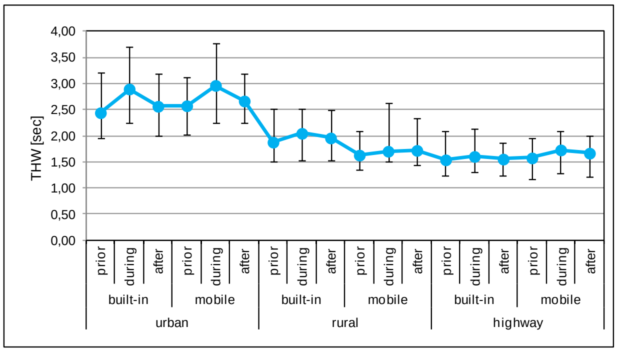
PI	Roadtype	Effect	df	Error df	F	p
THW	Rural	Time	2	126	2.57	0.080
		Condition	1	63	5.19	<0.05
	Urban	Time	2	154	12.99	<0.001

System	Roadtype	Effect	df	Error df	F	p
Mobile	Urban	Time	2	92	6.69	<0.01
Mobile	Highway	Time	2	146	6.90	<0.01

System	Highway			Rural			Urban		
	prior	during	post	prior	during	post	prior	during	post
Built-in			-	-			-	-	
Mobile				-		+			-

PI	Road	Condition	prior		during		after	
			m	sd	m	sd	m	sd
Diff(v)	Urban	Built-in	-1.78	4.48	-1.76	6.75	-1.51	6.94
		mobile	-0.47	5.16	-0.34	3.09	-1.04	3.83
	Rural	Built-in	-4.19	14.55	1.86	19.08	-1.45	20.40
		mobile	-2.94	5.66	0.50	3.23	1.10	7.56
	Highway	Built-in	-0.16	11.12	-0.36	10.30	-1.66	8.84
		mobile	-1.68	10.20	0.29	4.22	0.91	7.78
THW	Urban	Built-in	2.70	1.36	3.29	1.53	2.83	1.28
		mobile	2.72	0.97	3.24	1.43	2.82	1.08
	Rural	Built-in	2.22	1.26	2.23	1.09	2.24	1.26
		mobile	1.81	0.72	2.14	1.03	1.94	0.75
	Highway	Built-in	1.79	0.87	1.94	1.61	1.70	0.93
		mobile	1.67	0.75	1.86	0.96	1.69	0.64
sdlp	Urban	Built-in	0.228	0.173	0.287	0.147	0.258	0.133
		mobile	0.183	0.161	0.261	0.142	0.204	0.153
	Rural	Built-in	0.353	0.164	0.349	0.181	0.334	0.165
		mobile	0.300	0.159	0.334	0.136	0.306	0.148
	Highway	Built-in	0.315	0.124	0.317	0.124	0.316	0.125
		mobile	0.292	0.145	0.325	0.130	0.312	0.147





Conclusions

On urban and rural roads, for both HMI-solutions compensatory behaviour can be found regarding distance to the lead vehicle and on rural roads also regarding speed. On urban roads, speed is also reduced directly prior to making system inputs to the built-in navigation system.

Navigation system handling doesn't decrease safety based on surrogate measures

Comparison situations

1. **Before system input:** Period directly prior to system input; same duration as following system input
2. **During system input:** Input to navigation system
3. **After system input:** Period directly after system input; same duration as preceding system input

Filtering criteria

1. Input to navigation system longer than 5 seconds
2. m(v) during system input > 0.5 km/h
3. For indicators relating to distance: car follow situation
4. For indicators relating to lane keeping: stable lane tracking

Factors

1. Type of navigation system: built-in vs. mobile
2. Road type: highway vs. rural vs. urban

Performance indicators (PIs)

1. 90% interval of proportion time with critical THW
2. 90% interval of proportion time with critical TTC
3. 75% interval of proportion time with critical TLC
4. 75% interval of number of lane exceedances per hour

Chunking

- Calculation of indicators per system input.
- Unweighted aggregation for each driver (each system input counts equally). Robust indicators like median or 90% interval are used to aggregate across system inputs.

Data

All of the available data in DB divided *per driver*.

Statistical Methods

Friedman ANOVA comparing prior, during and after the system inputs. Independent testing per situational condition (condition * road type). For post-hoc testing, Wilcoxon signed rank tests are used.

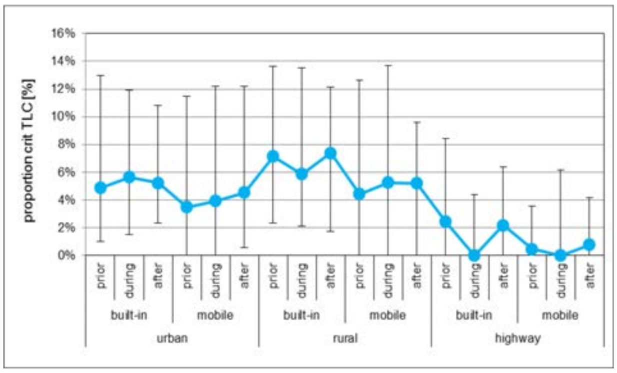
Results

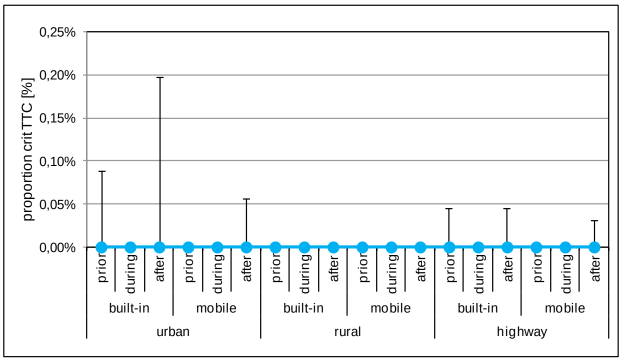
For highways, post-hoc tests show that with the built-in navigation system the proportion of critical THW is smaller during the system input than directly after the system input. The proportion of critical TTC is smaller during the system input compared to directly before and after. With the mobile device, the proportion of time with a critical distance is smaller during the system input compared to before

and after for both indicators. In urban areas, the proportion of time with a critical TTC is smaller during system inputs compared to directly before and after for both types of system.
Driving on highways with the built-in navigation system, the proportion of time with a critical TLC is lower during system input than compared to directly before and after. With the mobile device, there are no effects. The time interval does not influence the frequency of lane exceedances.

PI	System	Highway			Rural			Urban		
		N / df	Chi2	p	N / df	Chi2	p	N / df	Chi2	p
THW crit	Built-in	89 / 2	6.52	<0.05	84 / 2	3.81	0.149	92 / 2	1.72	
	Mobile	86 / 2	6.34	<0.05	84 / 2	1.67		91 / 2	1.08	
TTC crit	Built-in	89 / 2	9.97	<0.01	84 / 2	4.11	0.128	92 / 2	15.18	<0.01
	Mobile	86 / 2	10.85	<0.01	84 / 2	2.82		91 / 2	15.71	<0.01
TLC crit	Built-in	86 / 2	16.48	<0.01	79 / 2	0.24		89 / 2	0.57	
	Mobile	85 / 2	2.61		80 / 2	1.24		89 / 2	2.02	
Lane exceed.	Built-in	86 / 2	4.37	0.112	79 / 2	0.85		89 / 2	2.20	
	Mobile	85 / 2	1.90		80 / 2	0.13		89 / 2	1.69	

PI	Road	Condition	prior		during		after	
			m	sd	m	sd	m	sd
THW crit	Urban	Built-in	0.09%	0.65%	0.00%	0.01%	0.29%	1.81%
		mobile	0.07%	0.60%	0.07%	0.57%	0.06%	0.53%
	Rural	Built-in	0.77%	3.56%	0.03%	0.17%	0.16%	1.16%
		mobile	1.12%	7.66%	1.48%	11.10%	1.45%	9.22%
	Highway	Built-in	6.16%	18.37%	5.95%	19.50%	7.35%	20.96%
		mobile	3.79%	12.71%	2.37%	12.55%	3.24%	12.50%
TTC crit	Urban	Built-in	0.31%	1.21%	0.10%	0.48%	0.33%	1.04%
		mobile	0.22%	1.11%	0.17%	0.98%	0.29%	1.41%
	Rural	Built-in	0.12%	0.59%	0.06%	0.42%	0.13%	0.59%
		mobile	0.11%	0.51%	0.28%	1.50%	0.30%	1.37%
	Highway	Built-in	0.13%	0.42%	0.05%	0.15%	0.19%	0.57%
		mobile	0.08%	0.25%	0.05%	0.22%	0.07%	0.25%
TLC crit	Urban	Built-in	9.1%	13.5%	9.5%	16.1%	9.6%	14.2%
		mobile	6.9%	8.4%	9.1%	19.3%	8.4%	11.0%
	Rural	Built-in	10.5%	11.5%	9.7%	12.1%	9.7%	11.4%
		mobile	10.1%	14.8%	9.1%	13.1%	8.8%	13.5%
	Highway	Built-in	5.9%	9.6%	3.9%	7.3%	4.5%	6.5%
		mobile	3.8%	9.6%	4.6%	10.9%	4.3%	8.3%
Lane exceed.	Urban	Built-in	0.004	0.014	0.008	0.030	0.008	0.027
		mobile	0.004	0.017	0.001	0.008	0.004	0.021
	Rural	Built-in	0.006	0.020	0.007	0.023	0.004	0.012
		mobile	0.006	0.025	0.004	0.019	0.006	0.021
	Highway	Built-in	0.004	0.018	0.003	0.015	0.002	0.009
		mobile	0.001	0.007	0.007	0.053	0.002	0.016





Conclusions

With all indicators, no increase in safety critical behaviour can be found for both HMI-solutions. Instead, a decrease of very close following distances is shown for both HMI solutions on highways and in urban areas. Furthermore, with the built-in navigation system a decrease of small time-to–line crossing occurs during system inputs on highways. The decreased lane keeping performance during system inputs to the mobile device (see previous hypothesis) does not result in an increase in parameters linked to lane keeping errors.

Navigation systems decrease driver load at intersections

Comparison situations

1. **Baseline**: All baseline trips
2. **Treatment – built-in**: All trips in condition built-in navigation system with routing function active
3. **Treatment – mobile**: All trips in condition mobile navigation system with routing function active

Performance indicators (PIs)

1. Subjective rating of workload on RSME-scale after condition baseline, treatment – built-in and treatment-mobile; subjective load is rated for several types of intersections
2. Mean speed while turning on intersections
3. Proportion of time driving very slowly while approaching intersection

Filtering criteria

1. Trip length > 1km
2. Rural and urban areas
3. On intersection (P2) or on approach to intersection (P3)

Factors

Road type (rural, urban)
Left vs. right turn

Chunking

For P2, mean speed is calculated per intersection. Median over all intersections is calculated per driver.

Data

All of the available data in DB divided *per driver*.

Statistical Methods

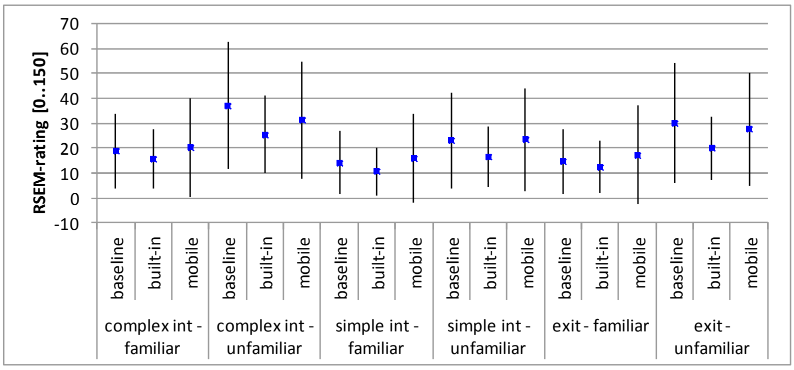
Repeated measures ANOVA with within factor condition. For post-hoc-testing, Bonferroni tests are used.

Results

For intersections on unfamiliar routes, drivers report less workload than driving with the built-in device compared to driving with the mobiles device and also compared to baseline. On familiar intersections, subjective workload is lower with the built-in navigation system compared to the mobile device.
Post-hoc tests for mean speed on intersections show that drivers drive faster with the built-in navigation system compared to baseline condition and also a tendency for higher speed while driving with the mobile device compared to baseline. Furthermore, speed on rural roads is higher than in urban areas. The interaction is due to the fact that on rural roads drivers are faster during right turns as compared to left turns. In urban areas there is no influence of turning direction. In urban areas, the proportion of time driving very slowly is lower in the two conditions with a navigation system compared

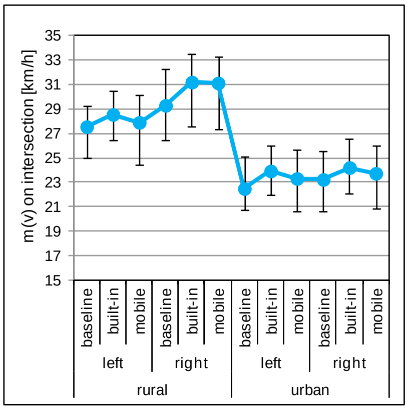
to baseline driving. On rural roads the proportion of time driving very slowly is lower with the built-in navigation system compared to the mobile device. The mobile device is the only condition for which the proportion of time driving very slowly is lower in urban areas compared to rural roads.

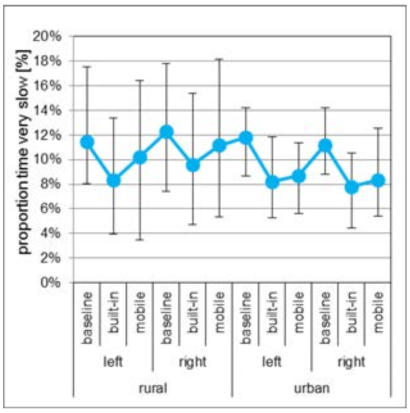
Item	df	Error df	F	p	Order of conditions
Complex intersections - familiar	2	212	4.81	<0.01	Built-in < mobile
Complex intersection unfamiliar	2	212	15.31	<0.001	Built-in < mobile < baseline
Simple intersections - familiar	2	212	6.05	<0.01	Built-in < mobile
Simple intersections - unfamiliar	2	212	8.49	<0.001	Built-in < mobile & baseline
Highway exits - familiar	2	212	4.59	<0.05	Built-in < mobile
Highway exits - unfamiliar	2	212	11.65	<0.001	Built-in < mobile & baseline



PI	Effect	df	Error df	F	p
m(v) on intersection	Condition	2	152	7.69	<0.001
	Road type	1	76	418.1	<0.001
	Turning direction	1	76	36.6	<0.001
	Road type * turning dir.	2	152	15.2	<0.001
% time very slow	Condition	2	152	10.2	<0.001
	Road type	1	76	8.1	<0.001
	Turning direction	1	76	4.23	<0.05
	Condition * road type	2	152	10.2	<0.001

PI	Road	Turning direction	Baseline		Built-in		Mobile	
			m	sd	m	sd	m	sd
m(v) on intersection	Rural	Left	26.9	4.40	28.7	4.18	27.5	5.36
		Right	29.0	4.20	30.6	4.60	30.4	6.04
	Urban	Left	22.7	2.81	23.8	3.12	23.4	3.62
		Right	23.2	3.05	24.2	3.48	23.4	3.79
% time very slow	Rural	Left	13%	7%	10%	12%	12%	12%
		Right	13%	7%	12%	11%	14%	12%
	Urban	Left	12%	4%	9%	5%	9%	5%
		Right	12%	4%	8%	5%	9%	6%





Conclusions

For intersections on unfamiliar routes, drivers report less workload than driving with the built-in device compared to baseline. The analysis of speed on respectively directly prior to intersections supports this result. Drivers are faster on intersections and spent less time driving very slowly then driving with the built-in device. Driving with the mobile device is rated as more demanding than driving with the built-in device on familiar and unfamiliar intersections. Only on complex intersections on unfamiliar routes a decrease of subjective workload can be found for the mobile device compared to baseline. In the objective parameters based on speed choice on intersections, driving with the mobile device is more similar to the built-in navigation system than to baseline driving. Still, the effects are less systematic than for the built-in navigation system.

Navigation system increase perceived driving comfort

Comparison situations

Subjective rating of change of comfort vs. expected rating for comfort is unchanged

Factors

Type of navigation system: built-in vs. mobile

Performance indicators (PIs)

Subjective rating for change of comfort between 1 = decreased comfort significantly and 5 = increased comfort significantly.

Data

Subjective rating per drivers.

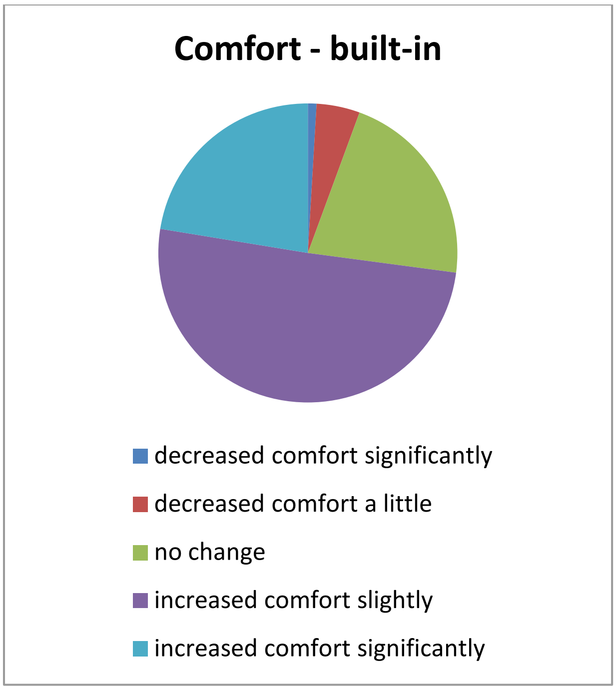
Statistical Methods

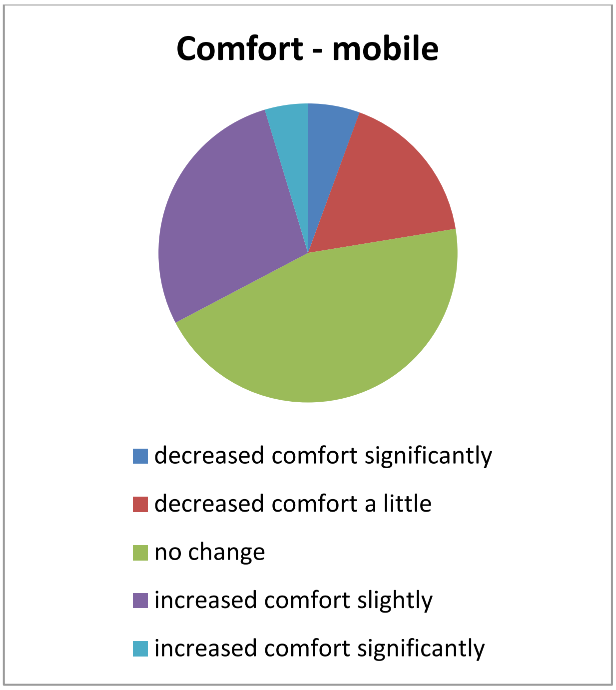
T-test comparing ratings against 3 = no change.

Results

Results are displayed in table below.

System	df	t	p
Built-in	106	10.9	<0.001





Conclusions

With the built-in device, subjective driving comfort is significantly increased. With the mobile device, there is no change of driving comfort.

Acceptance and trust of navigation system will increase over time

Comparison situations

For subjective indicators
1. **T2:** Expectance in system; evaluation before usage
2. **T3:** Evaluation of system after two weeks of usage
3. **T4:** Evaluation of system after end of condition

For objective indicator
1. 1st half of FOT
2. 2nd half of FOT

Performance indicators (PIs)

1. Subjective rating of acceptance on van der Laan scale (subscales satisfying and useful)
2. Subjective rating of trust on van der Laan scale (subscales reliable, trustworthy & raises confidence)
3. Proportion of time driving with routing function activated

Factors

Type of navigation system (built-in vs. mobile).

Data

Subjective rating per drivers.
All of the available data in DB divided *per driver*.

Statistical Methods

Repeated measures ANOVA with within factor time of rating. For post-hoc-testing, Bonferroni tests are used.

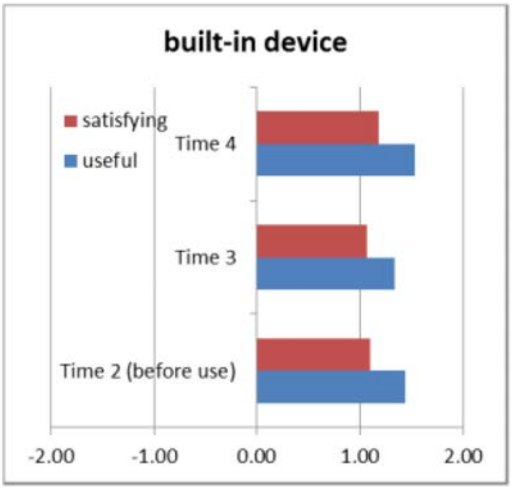
Results

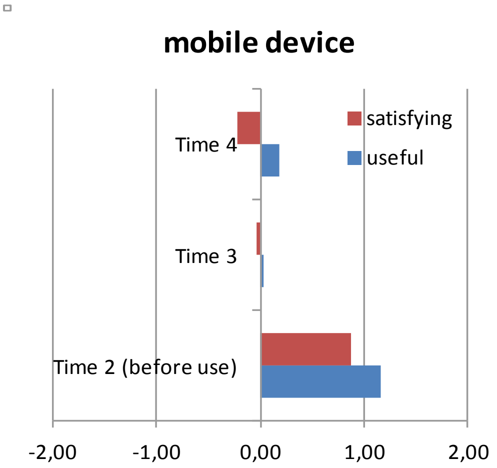
For the built-in device, rated usefulness is lower at T3 compared to T2 and T4. For the mobile device, rated usefulness and satisfaction decreases compared to the expectations expressed in T2. For the built-in device, rated reliability rises from T2 to T3. For the mobile device, subjective trust decreases on all three subscales. The evaluation of the systems is reflected in usage. The built-in navigation system is used more often than the mobile one and for the mobile system, usage declines over time.

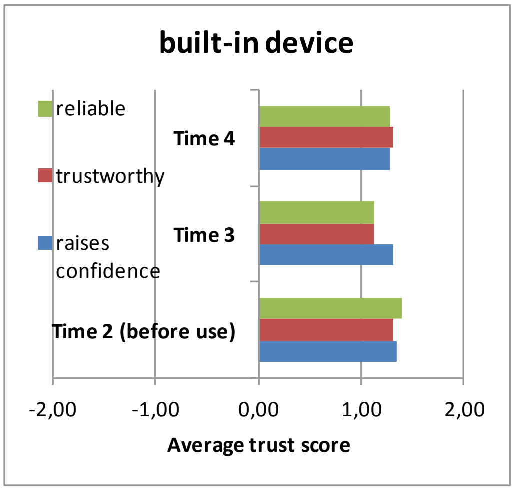
Type of navigation system	Sub-scale	df	Error df	F	p
Built-in device	Acceptance - satisfying	2	194	2.39	0.094
	Acceptance - useful	2	194	7.21	<0.001
	Trust – reliable	2	192	4.02	<0.05
Mobile device	Acceptance - satisfying	2	184	58.4	<0.001
	Acceptance - useful	2	184	72.3	<0.001
	Trust – reliable	2	186	50.91	<0.001
	Trust – trustworthy	2	186	50.42	<0.001
	Trust – raises confidence	2	186	35.54	<0.001

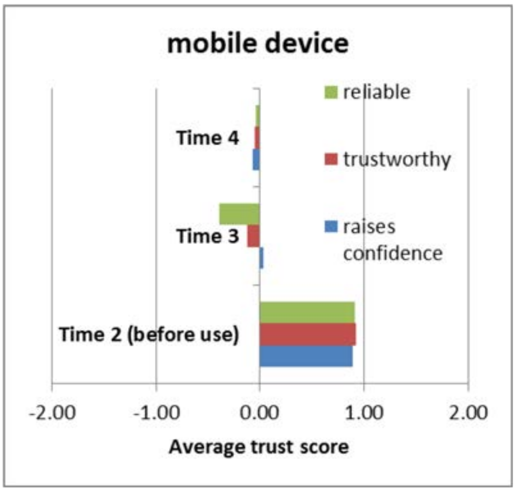
Factor	df	Error df	F	p
Condition	1	92	35.62	<0.001
Time	1	92	4.78	<0.05
Time * Condition	1	92	7.59	<0.01

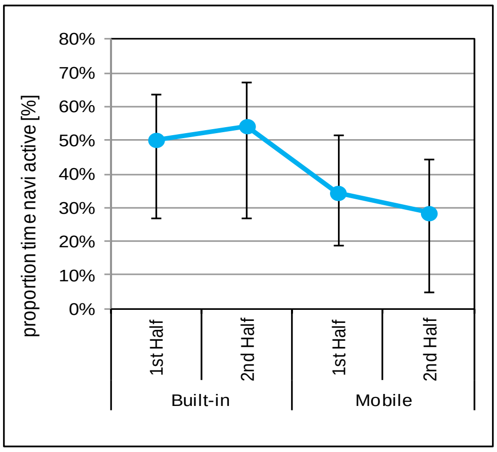
Time	Built-in		Mobile	
	m	sd	m	sd
1st half	46.8%	24.1%	35.3%	23.2%
2nd half	47.0%	25.1%	28.8%	23.6%











Conclusions

For both HMI-solutions, drivers have positive expectations at the beginning of the FOT. For the built-in navigation systems, expectations are confirmed and overall there is no change of acceptance and trust over time. For the mobile device, expectations are not fulfilled. Acceptance and trust decline after having used the system. For both systems, the proportion of time the system is used reflects the subjective evaluation of the systems. For the mobile device, usage of the system declines in the second half of the FOT-condition.

Navigation systems decrease driver workload over time with function use

Comparison situations

1. **T3:** Evaluation of system after two weeks of usage
2. **T4:** Evaluation of system after end of condition

Performance indicators (PIs)

1. Subjective rating of workload on RSME-scale for different driving situations

Factors

Type of navigation system (built-in vs. mobile).

Data

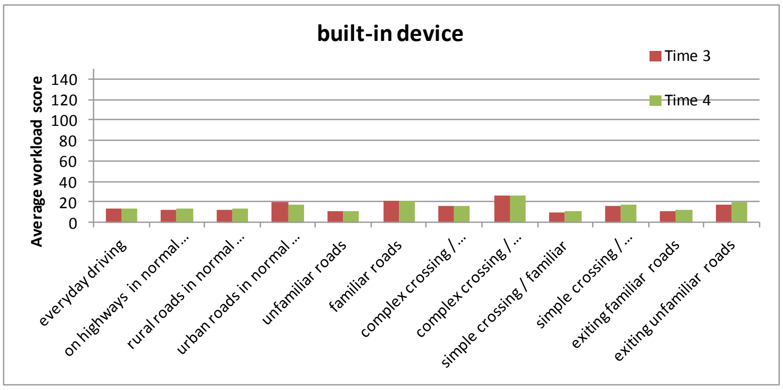
Subjective rating per drivers.
All of the available data in DB divided *per driver*.

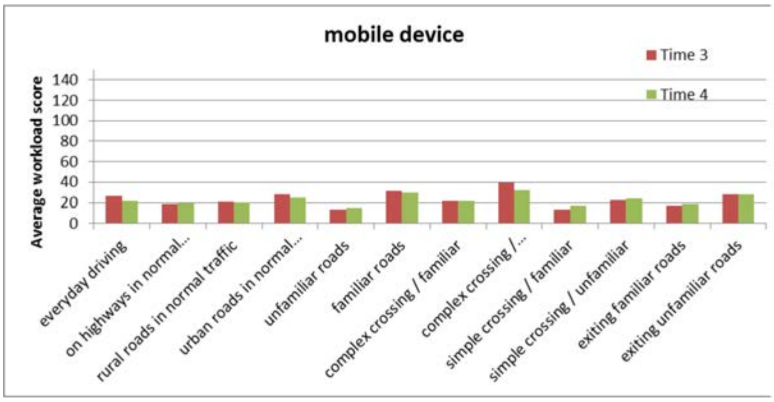
Statistical Methods

Multiple t-tests comparing the rating at T3 and T4.

Results

Type of navigation system	Item	df	t	p
Built-in device	Exiting – familiar roads	96	-2.25	<0.05
	Exiting – unfamiliar roads	98	-2.05	<0.05
	Urban roads in normal traffic	97	2.41	<0.05
	Turning left	98	-2.33	<0.05
Mobile device	Simple crossings – familiar roads	94	-2.19	<0.05





Conclusions

For both HMI-solutions there is no systematic change of workload over the period of system usage.

Drivers will not abuse or misuse navigation systems

Comparison situations

Subjective ratings vs. value indicating no misuse

Performance indicators (PIs)

Subjective rating of frequency of misuse behaviour

Factors

Type of navigation system (built-in vs. mobile).

Data

Subjective rating per drivers.

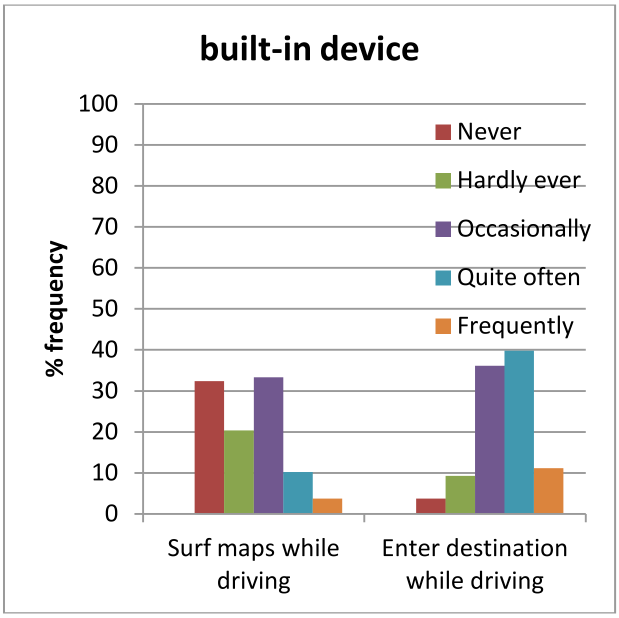
Statistical Methods

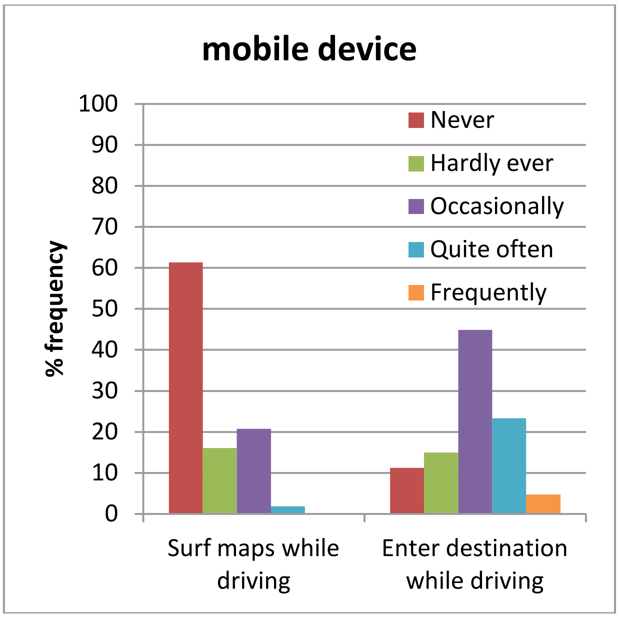
Multiple t-tests comparing the ratings against 1 = hardly ever engaging in misuse behaviour.

Results

Table below shows the significant results for the RSEM-ratings for the different workload items.

Type of navigation system	Item	df	t	p
Built-in device	Surf maps while driving	107	2.95	<0.05
	Enter destination while driving	105	-4.33	<0.001
Mobile device	Surf maps while driving	107	16.05	<0.001
	Enter destination while driving	105	1.98	<0.001





Conclusions

With the built-in navigation system drivers state that they engage in both misuse behaviours at least occasionally. With the mobile device, drivers enter destinations while driving at least occasionally but they do not surf maps while driving.

The type of the navigation system affects interaction with the system

Comparison situations

1. **Built-in navigation system**
2. **Mobile device**

Performance indicators (PIs)

1. Usage of the system
2. Evaluation of the system on different scales
    a. Usefulness of system in different situations (yes / no)
    b. Evaluation of different aspects of system (5-point Likert scale)
3. Answers to open questions

Filtering criteria

For PI1: Trip length > 1 km

Factors

For PI1:
1. Familiarity of the route (familiar vs. unfamiliar)
2. Length of the trip (<20km, 20-100km, >100km)

Data

Subjective rating per drivers.
All of the available data in DB divided *per driver*.

Statistical Methods

For PI1, multifactorial ANOVA, Bonferonni-test for post-hoc testing.
For subjective PIs, partly multiple t-tests comparing built-in and mobile device, partly chi2-tests are used.

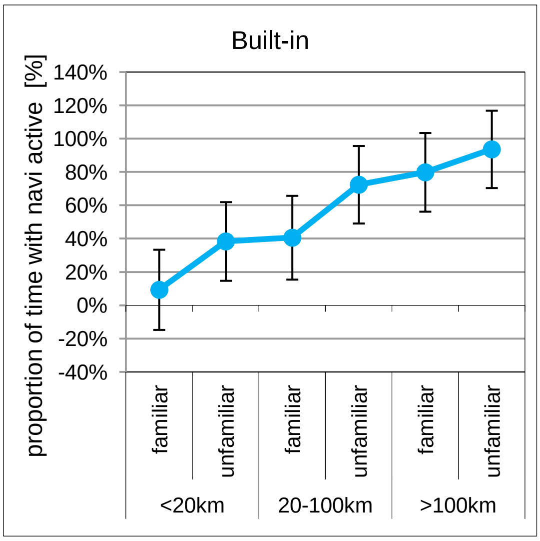
Results

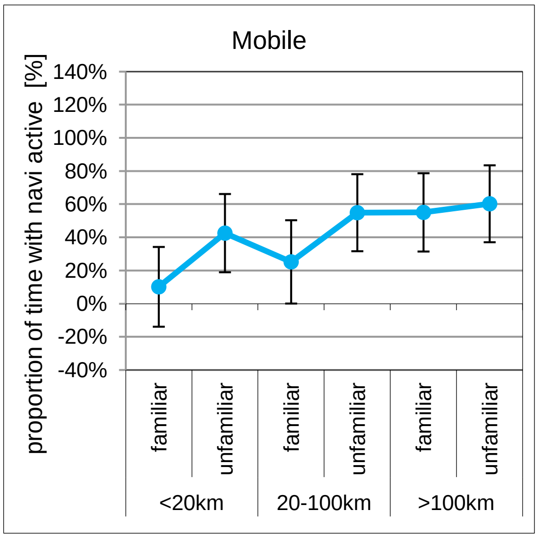
Item	df	Chi2	p
Unfamiliar roads	1	11.48	<0.001
Exiting unfamiliar highways	1	14.48	<0.001
Heavy traffic	1	26.39	<0.001
Complex crossing, unfamiliar roads	1	17.33	<0.001
Saving journey time	1	7.29	<0.01
Increasing safety	1	21.27	<0.001

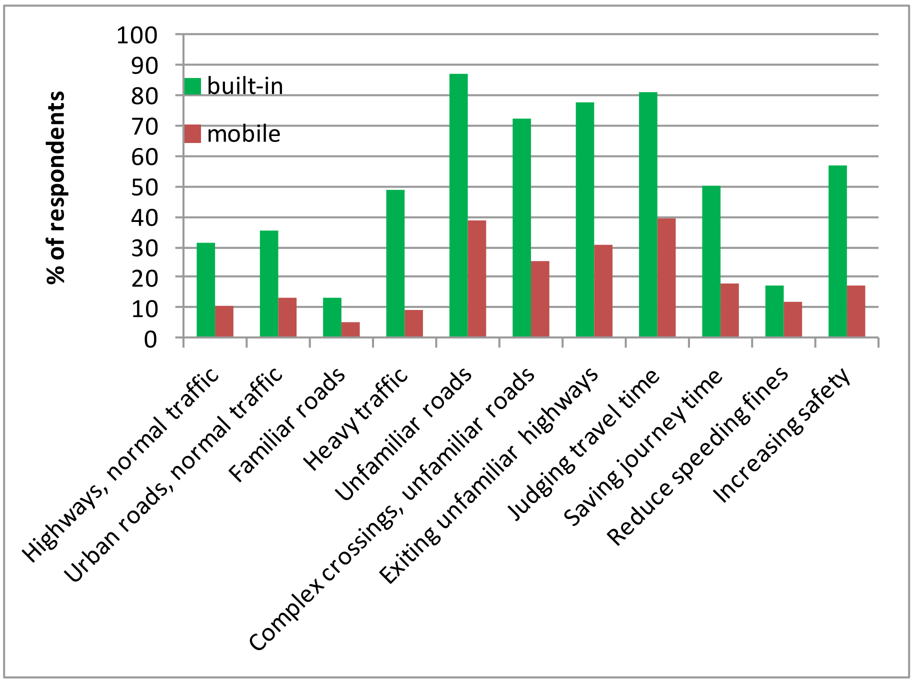
Item	df	t	p
Easy to use	104	7.17	<0.001
Easy to learn	104	7.82	<0.001
Easy to remember	104	7.54	<0.001
Few errors	104	8.16	<0.001
Not distracting	103	3.33	<0.01
Easy to recover	102	8.19	<0.001
Easy to program	103	4.86	<0.001
Visual display well located	104	11.67	<0.001
Visual information easy to read	104	10.88	<0.001
Visual information easy to understand	104	10.73	<0.001
Visual information grabbed attention	103	8.97	<0.001
Auditory information easy to hear	102	8.56	<0.001
Auditory information easy to understand	103	8.27	<0.001
Controls well located	102	11.39	<0.001
Controls easy to find	103	10.47	<0.001
Controls easy to use	102	10.33	<0.001
Comfortable with system	104	12.85	<0.001

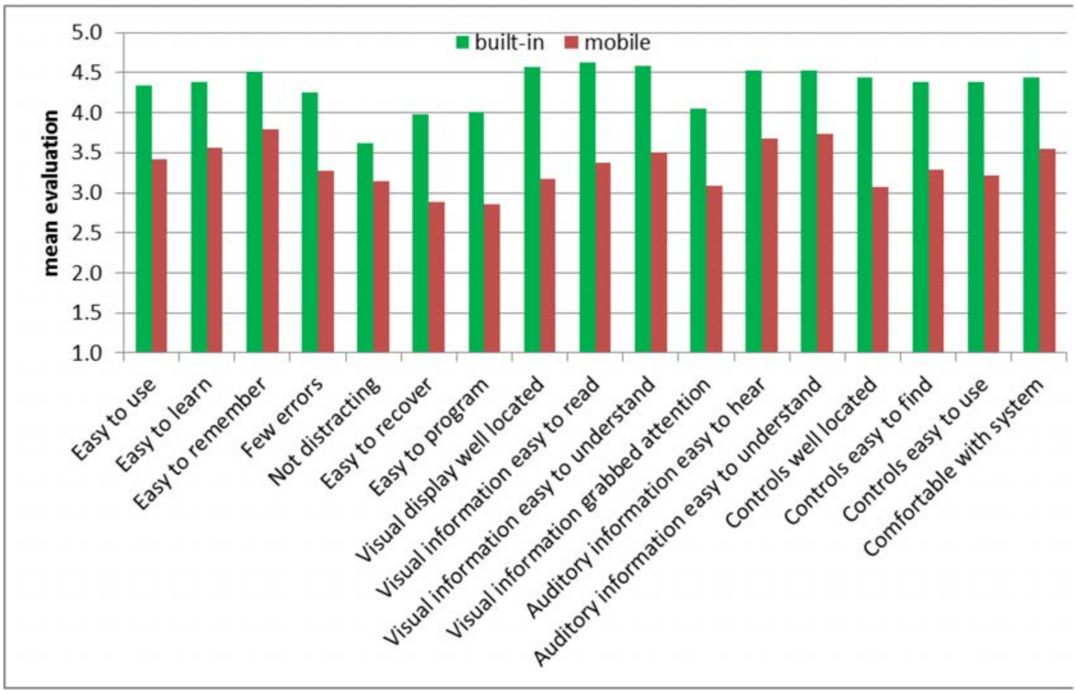
Factor	df	Error df	F	p
Condition	1	19	8.26	<0.01
Familiarity	1	19	79.71	<0.001
Trip length	2	38	62.15	<0.001
Trip length*condition	2	38	21.46	<0.001
Length*familiarity	2	38	14.68	<0.001

Familiarity	Trip length	Built-in		Mobile	
		m	sd	m	sd
Familiar	< 20 km	9.3%	12.4%	10.2%	12.9%
	20-100 km	40.6%	29.4%	25.3%	24.2%
	> 100 km	79.8%	32.4%	55.1%	38.4%
Unfamiliar	< 20 km	38.4%	34.9%	42.6%	37.0%
	20-100 km	72.4%	32.6%	54.9%	38.7%
	> 100 km	93.6%	17.4%	60.3%	40.3%


Built-in
proportion of time with navi active [%]
140%
120%
100%
80%
60%
40%
20%
0%
-20%
-40%
familiar
unfamiliar
<20km
20-100km
>100km


Mobile
proportion of time with navi active [%]
140%
120%
100%
80%
60%
40%
20%
0%
-20%
-40%
familiar
unfamiliar
<20km
20-100km
>100km


% of respondents
100
90
80
70
60
50
40
30
20
10
0
built-in
mobile
Highways, normal traffic
Urban roads, normal traffic
Familiar roads
Heavy traffic
Unfamiliar roads
Complex crossings, unfamiliar roads
Exiting unfamiliar highways
Judging travel time
Saving journey time
Reduce speeding fines
Increasing safety



Conclusions

The mobile device is used less often than the built-in device especially in situations where overall system usage is less likely (short trips, unfamiliar trips). Furthermore, system usage decreases overtime with the mobile device. The built-in device is rated as more useful than the mobile device especially in the main use cases for navigation systems (unfamiliar routes, highway exits and intersections, heavy traffic, reduction of travel times). Furthermore, the HMI of the built-in device is evaluated more positively on all aspects (display, auditory information, controls, usage and learnability, stability in case of errors). It can be concluded that the built-in device is preferred because of better system functionality and better system design. This preference is reflected in the frequency of system usage.

Annex 9 Fuel Efficiency Advisor (FEA)

List of selected hypothesis

The list of hypothesis for FEA is the following one:

Table 11:FEA list of hypothesis

FEA increases time in the "green area"
FEA decreases fuel consumption
FEA reduces idling time
FEA decreases average speed

FEA increases time in the "green area"

Comparison situations

1. **Baseline**: FEA unavailable
2. **Treatment**: FEA available

Performance indicators (PIs)

% within economy time.

Data

Data from 50 drivers: 25 with FEA available and 25 with FEA unavailable.

Statistical Methods

Independent sample t-test.

Results

No significant results were found.

Conclusions

There is no significant change in time in the green area in the treatment phase. It is important to point out that since the data obtained from FEA trucks were extremely limited (no factors could be included in the analysis) and drivers In the treatment phase were different from drivers in baseline, further analysis must be performed in order to better understand the effects of FEA on time in the "green area."

FEA decreases fuel consumption

Comparison situations

1. **Baseline**: FEA unavailable
2. **Treatment**: FEA available

Performance indicators (PIs)

Average fuel in l/100km.

Data

Data from 50 drivers: 25 with FEA available and 25 with FEA unavailable.

Statistical Methods

Independent sample t-test.

Results

No significant results were found.

Conclusions

There is no significant change in time in fuel consumption in the treatment phase. It is important to point out that since the data obtained from FEA trucks were extremely limited (no factors could be included in the analysis) and drivers In the treatment phase were different from drivers in baseline, further analysis must be performed in order to better understand the effects of FEA on fuel consumption.

FEA reduces idling time

Comparison situations

1. **Baseline**: FEA unavailable
2. **Treatment**: FEA available

Performance indicators (PIs)

Percentage of idling.

Data

Data from 50 drivers: 25 with FEA available and 25 with FEA unavailable.

Statistical Methods

Independent sample t-test.

Results

No significant results were found.

Conclusions

There is no significant change in percentage of idling In the treatment phase. It is important to point out that since the data obtained from FEA trucks were extremely limited (no factors could be included in the analysis) and drivers In the treatment phase were different from drivers in baseline, further analysis must be performed in order to better understand the effects of FEA on idling time.

FEA decreases average speed

Comparison situations

1. **Baseline**: FEA unavailable
2. **Treatment**: FEA available

Performance indicators (PIs)

Average speed in km/h.

Data

Data from 50 drivers: 25 with FEA available and 25 with FEA unavailable.

Statistical Methods

Independent sample t-test.

Results

No significant results were found.

Conclusions

There is no significant change in average speed In the treatment phase. It is important to point out that since the data obtained from FEA trucks were extremely limited (no factors could be included in the analysis) and drivers In the treatment phase were different from drivers in baseline, further analysis must be performed in order to better understand the effects of FEA on average speed.

Annex 10 Impairment Warning (IW) and Lane Departure Warning (LDW)

List of selected hypothesis

The list of selected hypothesis for IW+LDW is as follows:

Table 12: List of hypothesis for IW+LDW

IW is well accepted by the driver
Acceptance changes over time with system use
Certain features of the IW system, in terms of usability, influence acceptance
Certain features of the IW system, in terms of usefulness, influence acceptance
Trust in the IW system changes over time with system use
Drivers workload decreases over time with system use
User practices (heuristics, rules) will change over time during the FOT
Drivers will not abuse or misuse IW

IW is well accepted by the driver

Comparison situations

T4: Subjective ratings of acceptance using the Van der Laan scale. Given that this is not a well defined hypothesis (positive compared to what?), we will only present the data descriptively.

Performance indicators (PIs)

For evaluation of acceptance using the Van der Laan scale the following 9 items are rated on a scale from -2 to +2 :

- **useful**
- pleasant
- **good**
- nice
- **necessary**
- likeable
- **assisting**
- desirable
- **raising alertness**

In the Van der Laan scale, acceptance is also broken down into Usefulness and Satisfaction. The average rating of the bold items are considered to be a measure of usefulness and the average of the remaining items is a measure of satisfaction

In addition to the nine Van der Laan items, eleven additional items which also gives an indication of level of acceptance were included in the questionnaire:

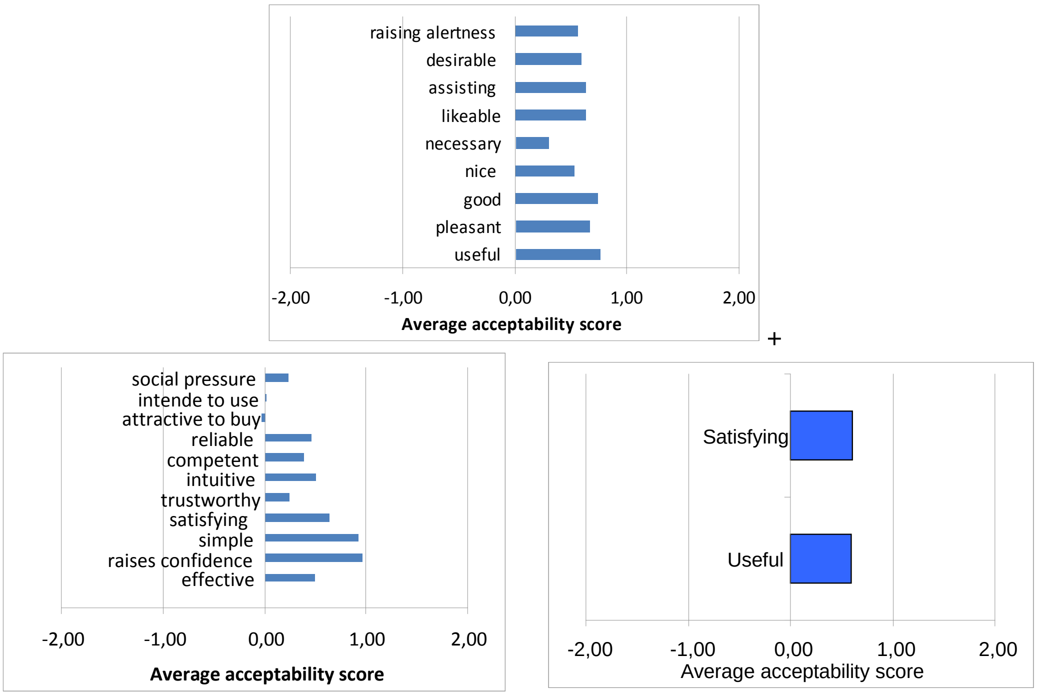
- effective
- raises confidence
- simple
- trustworthy
- intuitive
- competent
- attractive to buy
- intend to use
- social pressure
- satisfying
- reliable

These items were also rated on a scale from -2 to +2.

Data

Items under IW_ac_1_4 in the questionnaire

Results



Conclusions

Overall, the acceptance of the system is positive. Even drivers say that the system raises confidence and is simple to use they score lowest on “necessary”. This might be because the perceived necessity of this feature varies a lot among different people.

Acceptance changes over time with system use

Comparison situations

T2: Evaluation of expectations of system before they are activated in the car.
T3: Evaluation of the system once it has been thoroughly used by the drivers.
T4: Evaluation of system after Treatment period is completed.

Performance indicators (PIs)

For evaluation of acceptance using the Van der Laan scale the following 9 items are rated on a scale from -2 to +2 at different times during use.

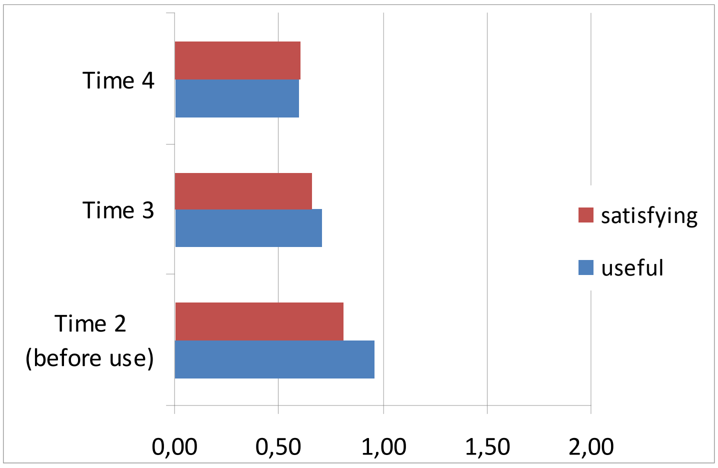
- useful
- pleasant
- good
- nice
- necessary
- likeable
- assisting
- desirable
- raising alertness

Items under IW_ac_1_2 . IW_ac_1_3 and IW_ac_1_4 in the questionnaire.

Statistical Methods

Paired T-test is conducted to compare the usefulness and satisfaction results in T3 vs T4.
As a reference, also acceptance at T2 (before use) is presented.

Results



Satisfaction		
Time	**N**	**Mean score**
T2	86	0,81
T3	86	0,65
T4	86	0,60
p value T2->T3	0,066	
p value T3->T4	0,574	

Usefulness		
Time	**N**	**Mean score**
T2	86	0,96
T3	86	0,71
T4	86	0,98
p value T2->T3	**0,011**	
p value T3->T4	0,326	

Conclusions

The expectations on usefulness of the system are significantly higher than experienced once the system is in use. During use. acceptance, in terms of usefulness and satisfaction, does not change and remains on a positive level.
There is a significant drop in usefulness between T2 and T3 which indicates that the participants' expectations of the system was not fulfilled.
No significant changes of satisfaction and usefulness over time during use (T3 to T4)

Certain features of the IW system, in terms of usability, influence acceptance

Comparison situations

T4: Subjective ratings of acceptance using the Van der Laan scale. Given that this is not a well defined hypothesis, we will only present the data descriptively.

Performance indicators (PIs)

For evaluation of acceptance 18 items under the concept of Perceived Ease of Use (usability) have been rated on a scale from -2 to +2 (Strongly disagree to Strongly agree).

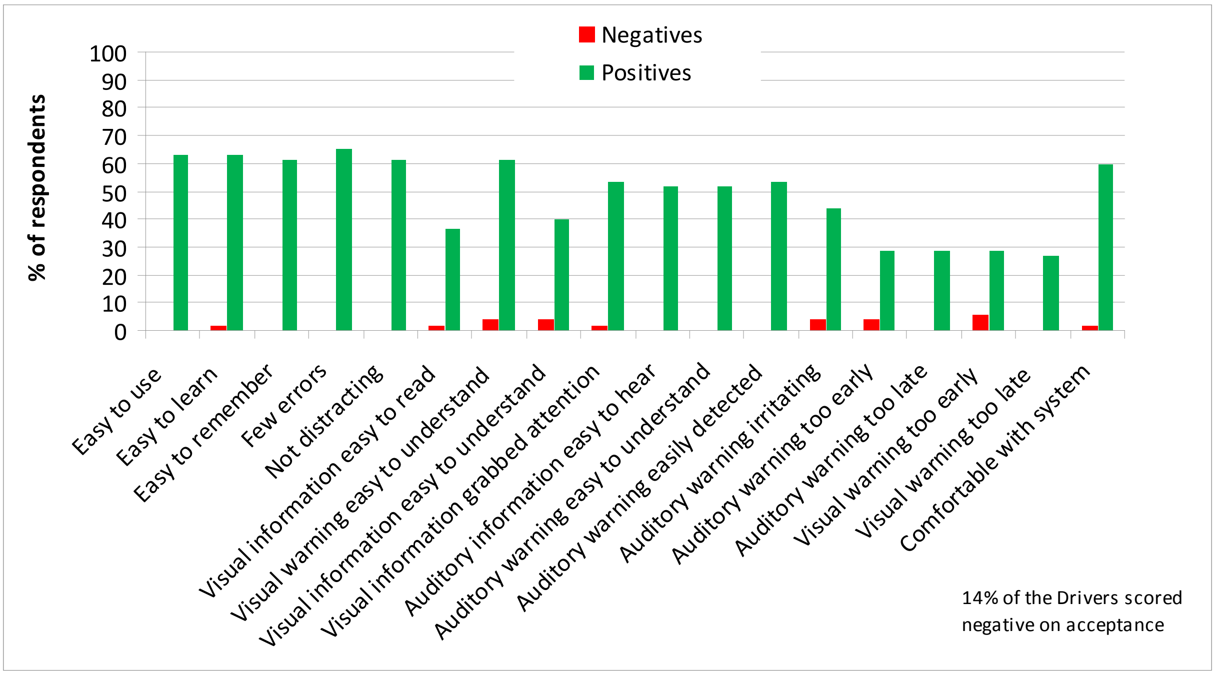
Data

Items under IW_eas_1_4 in the questionnaire

Statistical Methods

The task is to identify the usability items that influence acceptance scores
Each participant is considered separately, such that if a participant scored the system positively on the Van der Laan scale in IW8, then those scores that score high (>0) on usability were deemed to have impacted on that score. Conversely, if a participant scored the system negatively on the Van der Laan scale, then there will be certain items relating to usability that would contribute to this.

Results



Explanations of the diagram:
The height of the red bars indicates where a “negative” participant rated the system as negative on that particular item. A “negative” participant is one whose average acceptability score is negative.
The height of the green bars indicates where a “positive” participant rated the system as positive on that particular item. A “positive” participant is one whose average acceptability score is positive.

Conclusions

The 14 % drivers who scored negatively on acceptance were not satisfied with the timing of the warnings including the warning sound and the visual information on the instrument panel provided by the system which they found hard to understand. Also the positive drivers scored low on these items. 60 % of the drivers were comfortable with the system.

Certain features of the IW system, in terms of usefulness, influence acceptance

Comparison situations

T4: Drivers view of the level of usefulness of the IW system at different driving conditions. Given that this is not a well defined hypothesis we will only present the data descriptively.

Performance indicators (PIs)

6 items under the concept of Perceived Usefulness have been rated on a scale from -2 to +2 (Strongly disagree to Strongly agree). Usefulness is rated by the driver at different driving scenarios, i.e. driving on different road types under various conditions.

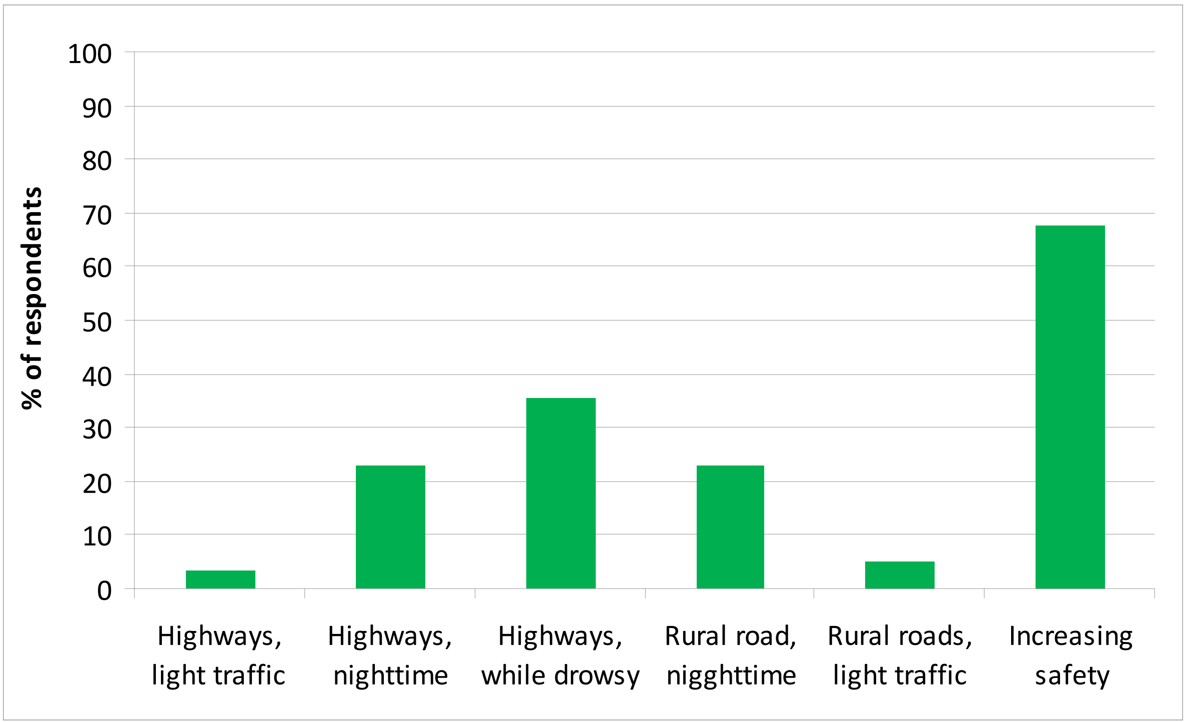
Data

Items under IW_use_1_4 in the questionnaire.

Statistical Methods

The task is to identify the usefulness items that influence the positive acceptance scores
Each participant is considered separately, such that if a participant scored the system positively on the Van der Laan scale in IW8, then those scores that score high (>0) on usability were deemed to have impacted on that score.

Results



Conclusions

Usefulness on highways in normal traffic contributed the most to positive acceptability scores. Also a relative high proportion of the respondents felt that the system increased safety.

Trust in the IW system changes over time with system use

Comparison situations

T2: Evaluation of expectations of system before it is activated in the car.
T3: Evaluation of the system once the drivers had accumulated relatively extensive experience with the system, i.e. after approximately half of the treatment period had passed..
T4: Evaluation of system after Treatment period is completed.

Performance indicators (PIs)

For evaluation of the drivers trust in the system the following 3 items are rated on a scale from +2 to - 2 at different times during use.

- Raises confidence – creates uncertainty
- Trustworthy - untrustworthy
- Reliable - unreliable

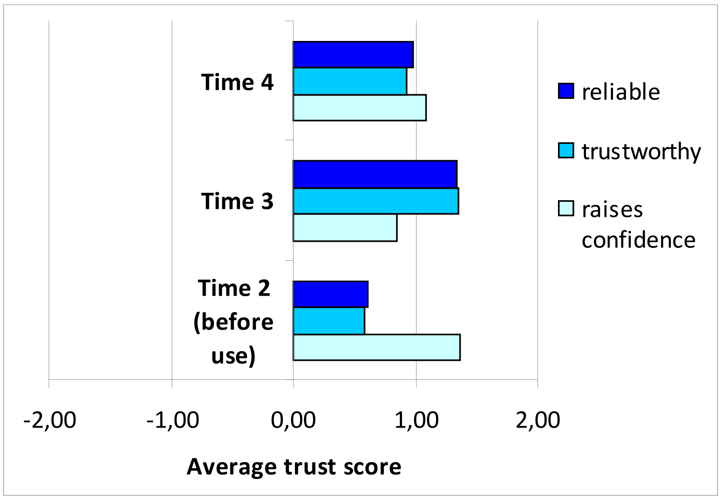
Data

Items under IW_ac_1_2. IW_ac_1_3 and IW_ac_1_4 in the questionnaire.

Statistical Methods

Paired T-test is conducted to compare the usefulness and satisfaction results in T3 vs T4.
As a reference, also acceptance at T2 (before use) is presented.

Results



Reliable		
Time	N	Mean score
T3	57	1,33
T4	57	0,98
p value	0,646	

Trustworthy		
Time	N	Mean score
T3	57	1,35
T4	57	0,92
p value	0,219	

Raises confidence		
Time	N	Mean score
T3	57	0,84
T4	57	1,09
p value	0,837	

Conclusions

Confidence in the system before use is higher than experienced during the first period of use (significant). Perceived trust and reliability does not change during use.
Trust in the system is relatively high and does not change significantly during use (T3 to T4).

Confidence in the system before use is higher than experienced during the first period of use (significant).

Drivers workload decreases over time with system use

Comparison situations

T3: Evaluation of the system once the drivers had accumulated relatively extensive experience with the system, i.e. after approximately half of the treatment period had passed..
T4: Evaluation of system after Treatment period is completed.

Performance indicators (PIs)

Level of Workload on a scale ranging from 0 to 140. 0 is no mental effort and 140 is very high mental effort.

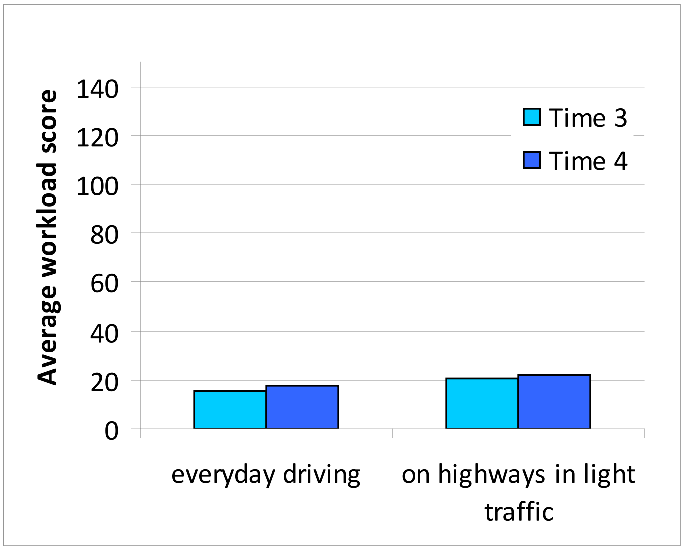
Data

Items under IW_mw_1_3 and IW_mw_1_4 in the questionnaire.

Statistical Methods

Paired T test to compare, between T3 and T4, if the drivers perception of mental workload changes over time with system use when driving in different situations.

Results



Everyday traffic		
Time	N	Mean score
T3	54	16
T4	54	18
p value	0,062	

Highways in light traffic		
Time	N	Mean score
T3	54	21
T4	54	22
p value	0,766	

Conclusions

Participants indicated very low effort experienced when driving with the IW system at everyday driving and when driving on highways in light traffic and does not change over time in use.
The drivers' perception of mental workload while driving with the IW system is very low and does not change over time with system use.

User practices (heuristics, rules) will change over time during the FOT

Comparison situations

T4: Evaluation of system after Treatment period is completed.

Performance indicators (PIs)

Drivers' view of using the system different in the end of the treatment period compared to when they first started to use the system.

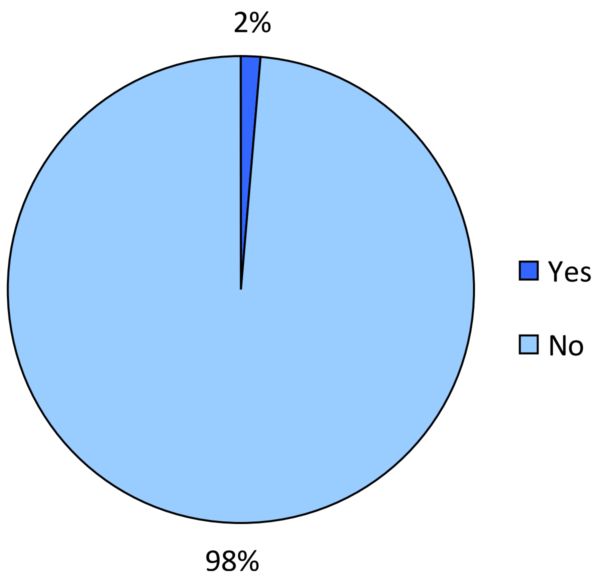
Data

Items under IW_upr_1a_4 in the questionnaire.

Statistical Methods

None. Descriptiv presentation only..

Results



Conclusions

Very few drivers (2% which in practice in this questionnaire corresponds to one driver) believes they have changed user practices over time with system use.

Drivers will not abuse or misuse IW

Comparison situations

T4: Evaluation of system after Treatment period is completed.

Performance indicators (PIs)

Question asked: Drove whilst tired, and relied on IW

Filtering criteria

None

Chunking

None

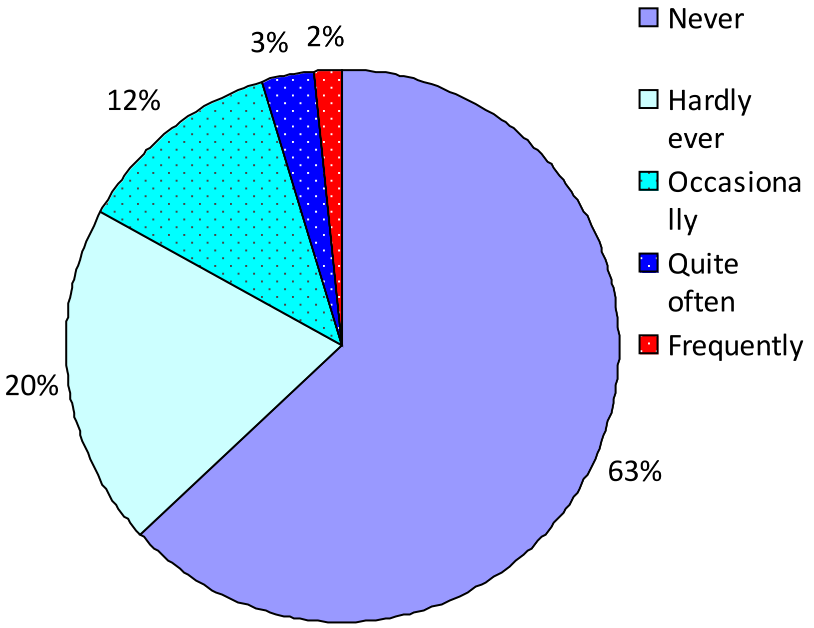
Data

Items under IW_mis_1_4 in the questionnaire.

Statistical Methods

None. Descriptive statistics only..

Results



Conclusions

17 % of the drivers report that they have driven whilst tired and relied on the IW system. 2% did frequently.

Annex 11 Glossary

ACC - Adaptive Cruise Control

ADAS - Advanced Driver Assistance System

BLIS - Blind Spot Information System

CAN - Controller Area Network

CBA - Cost-benefit Analysis

CSW - Curve Speed Warning

DAS - Data Acquisition System

FCW - Forward Collision Warning

FEA - Fuel Efficiency Advisor

FOT - Field Operational Test

GPRS - General Packet Radio Service

GPS - Global Positioning System

HMI - Human-Machine Interface

IW - Impairment Warning

LDW - Lane Departure Warning

OC - Operational Centre

OEM - Original Equipment Manufacturer

SRS - Speed regulation System

VMC - Vehicle Management Centre