ADAS evaluation in the Field – using the example of euroFOT

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Bringing intelligent vehicles to the road

Agenda

- Field Operational Test in general
- euroFOT approach
- euroFOT results

Why Field Operational Tests?

- Evaluation of ADAS normally conducted by means of
  - Test track
  - Driving simulator
  - Hardware In the Loop
  - Software In the Loop
- All these tests are conducted under controlled conditions
- Remaining question: How does the function and the driver behave under real conditions

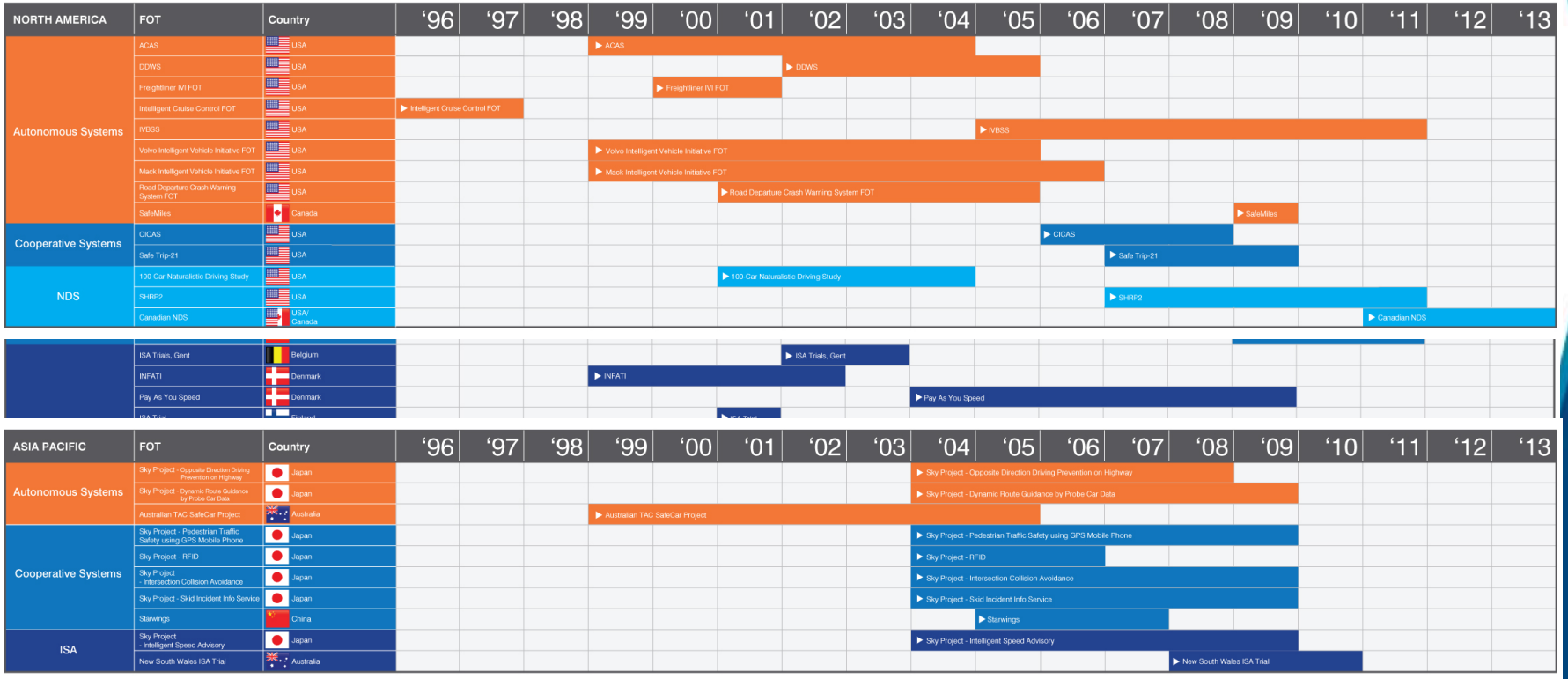
  → These information can be provided by means of Field Operational Test

Defintion of terms

- Field Operational Test:
  - A Field Operational Test (FOT) is a study undertaken to evaluate a function, or functions, under normal operating conditions in environments.
- Naturalistic driving study:
  - Naturalistic Driving Study (NDS) refers to studies undertaken using unobtrusive observation when driving in a natural setting. Both, Naturalistic Driving Studies and Naturalistic FOTs use this type of observation. In NDS, the driver becomes unaware of the observation as the data collection is organised as discreet as possible and preferably drivers use their own vehicles.

Source: wiki.fot-net.eu

Overview on Field Operational Tests



Source: http://www.fot-net.eu

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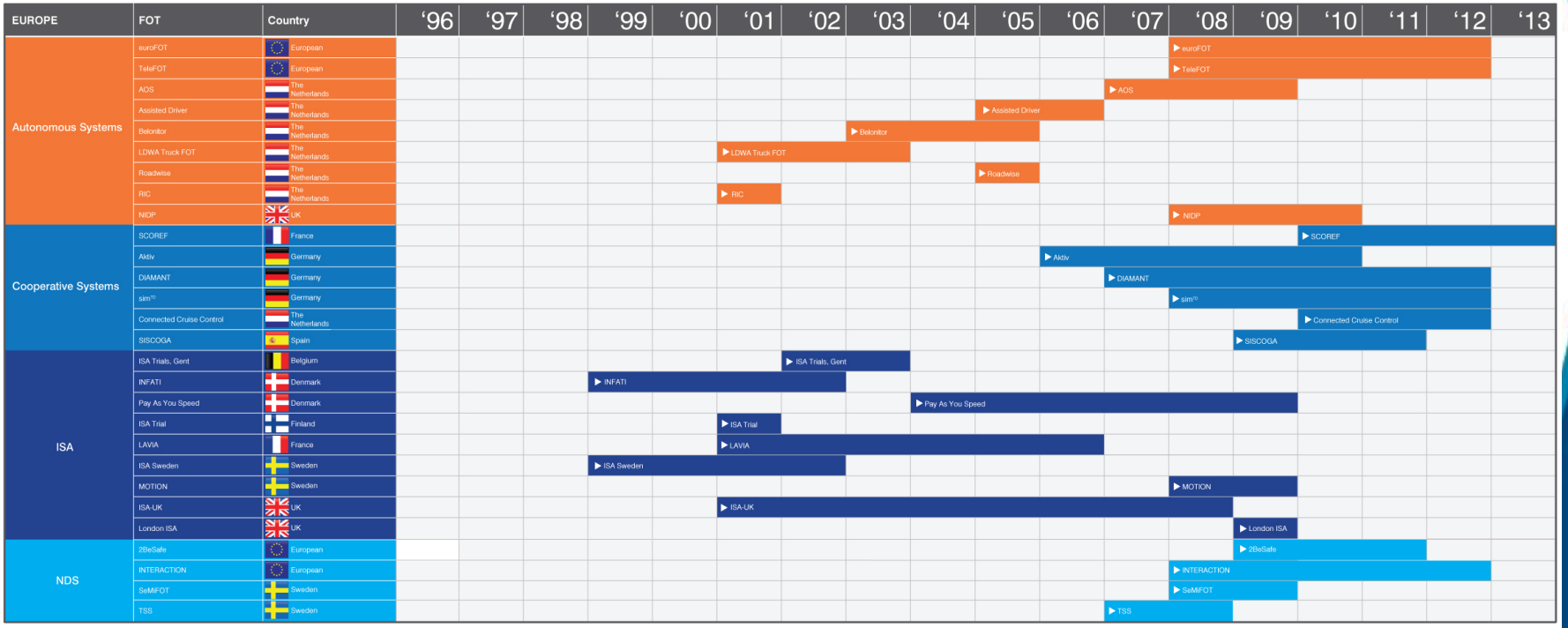
Overview on Field Operational Tests



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FOT Wiki

The FOT-Net Wiki is the Free Living Encyclopedia of FOTs that anyone can edit: it is the tool “for and by” the FOT community.

It can be accessed via:

www.wiki.fot-net.eu

What can I do?

- Create an account
- Update and upload information about your FOT
- Monitor FOTs in your geographical area/field of expertise and edit the Wiki directly or contact info@fot-net.eu

www.eurofot-ip.eu

Agenda

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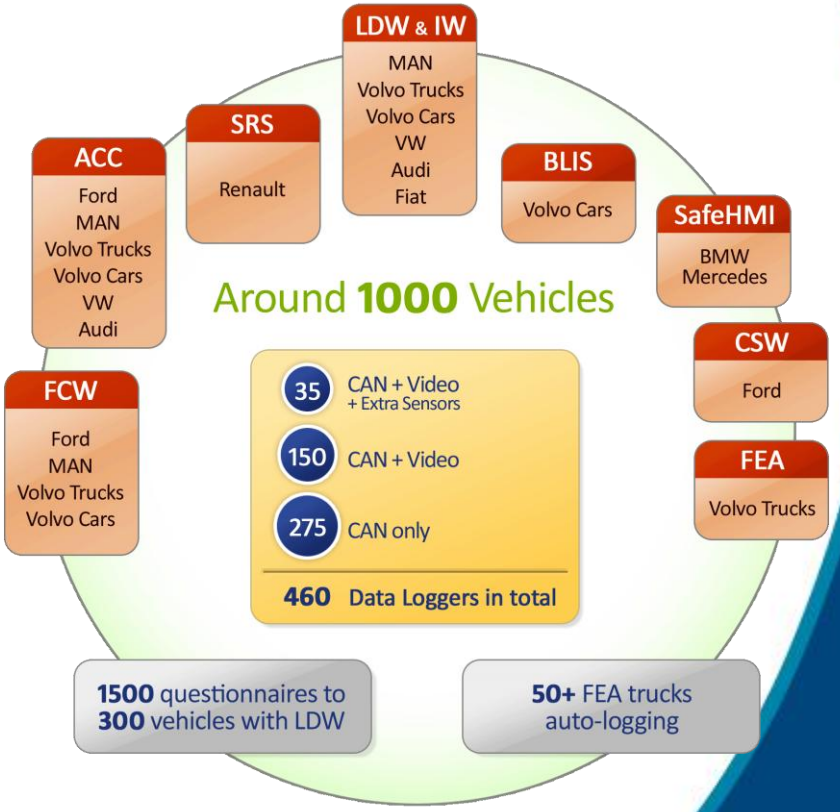
euroFOT

- First European Large-Scale Field Operational Test on In-Vehicle Systems
- Total indicative budget: 22 million €
- Total indicative funding: 14 million €
- Project duration: May 2008 - June 2012
- 28 partners from 10 different countries
- Coordinator: Aria Etemad (Ford Research & Advanced Engineering Europe)



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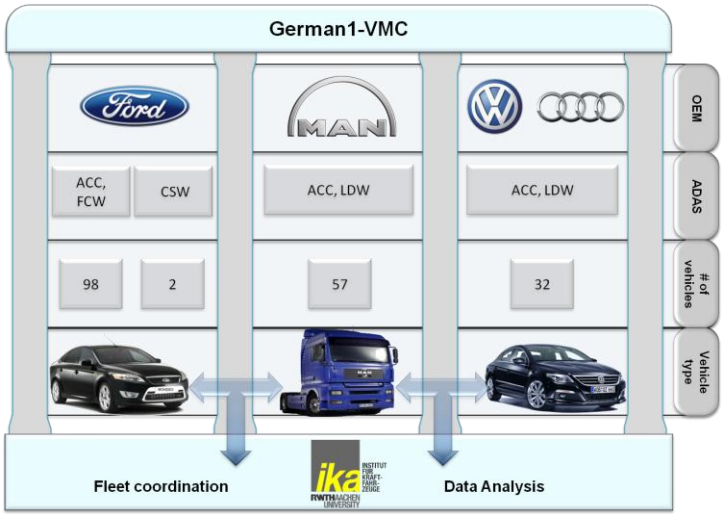
FOT status

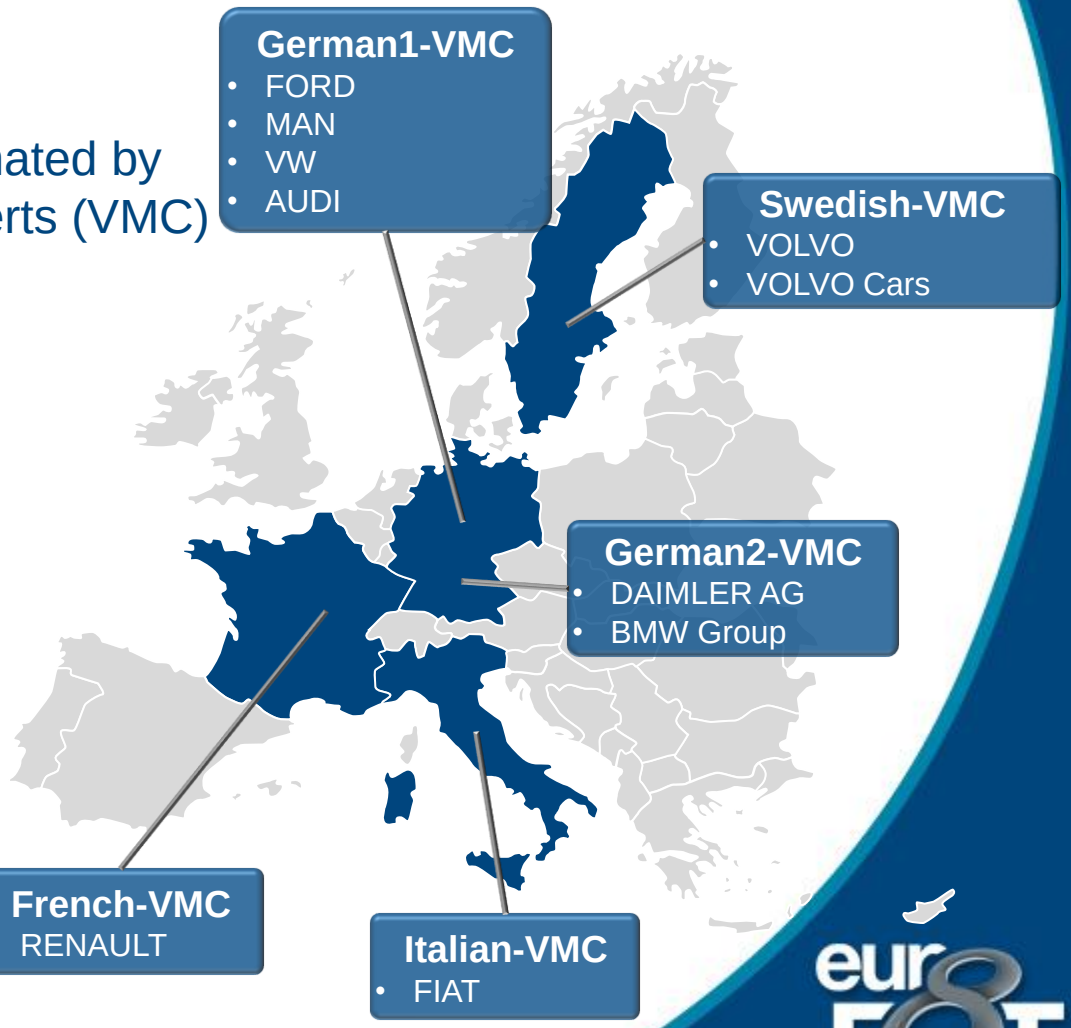
	French VMC	German VMC Operation Centre 1				German VMC Operation Centre 2		Italian VMC	Swedish VMC	
										
Target number of vehicles	35	100	100	40	0	15	15	500	100	80
No. of vehicles participated FOT	35 (+5)	98 (+2)	57	32	(20)	15	15	533	100	80
No. of vehicles currently running	35 (+5)	98 (+2)	57	0	2	15	3	401	100	15
No. of involved drivers	35	130	80	32	(20)	45	60	533	204	86
FOT start date	October 2010	April 2010	January 2011	June 2010	January 2011	August 2010	February 2010	February 2010	February 2010	May 2010

972 vehicles participated with 1068 drivers

euroFOT – German1-VMC

- The euroFOT fleet were coordinated by five Vehicle Management Centerts (VMC)





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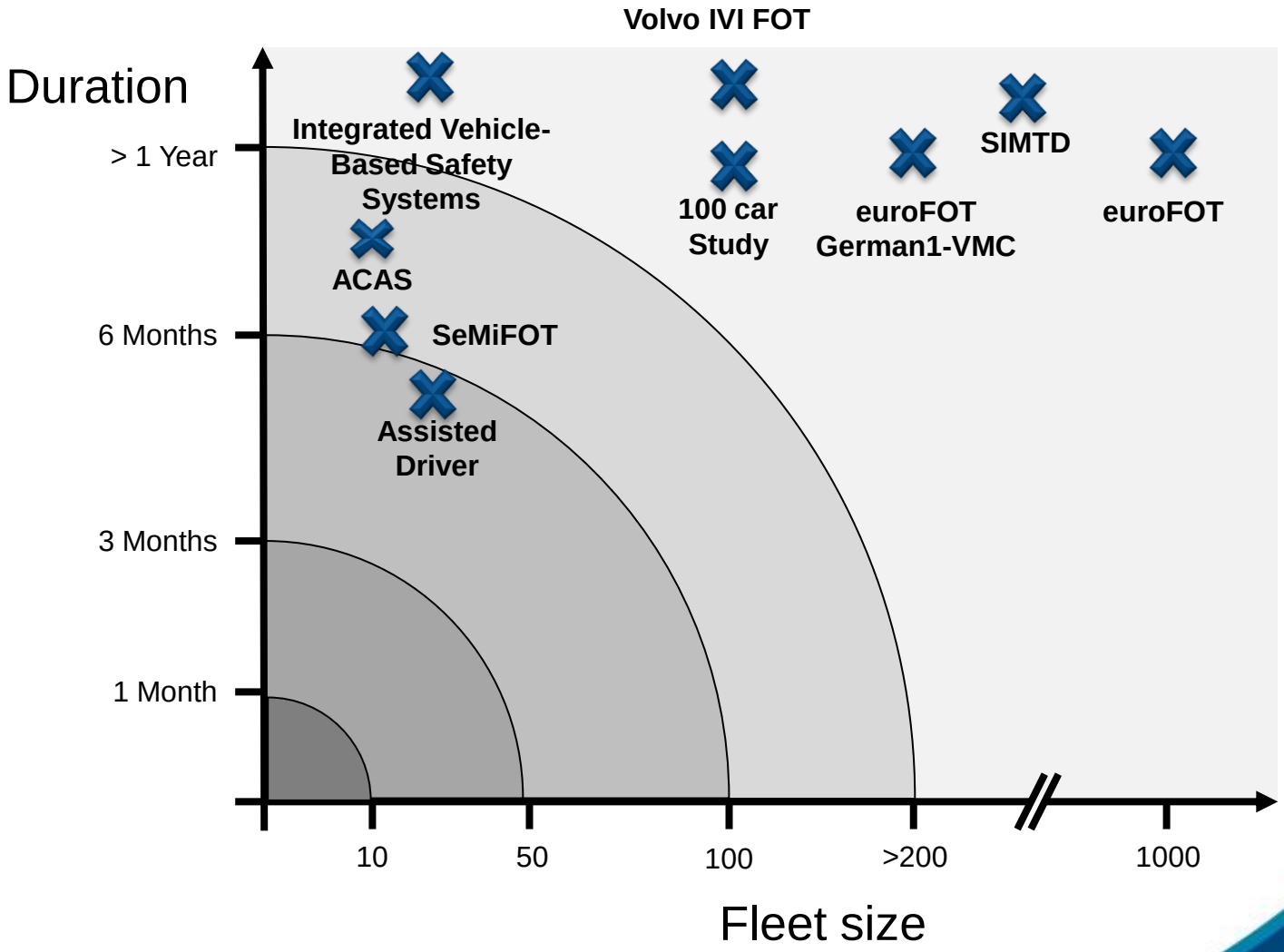
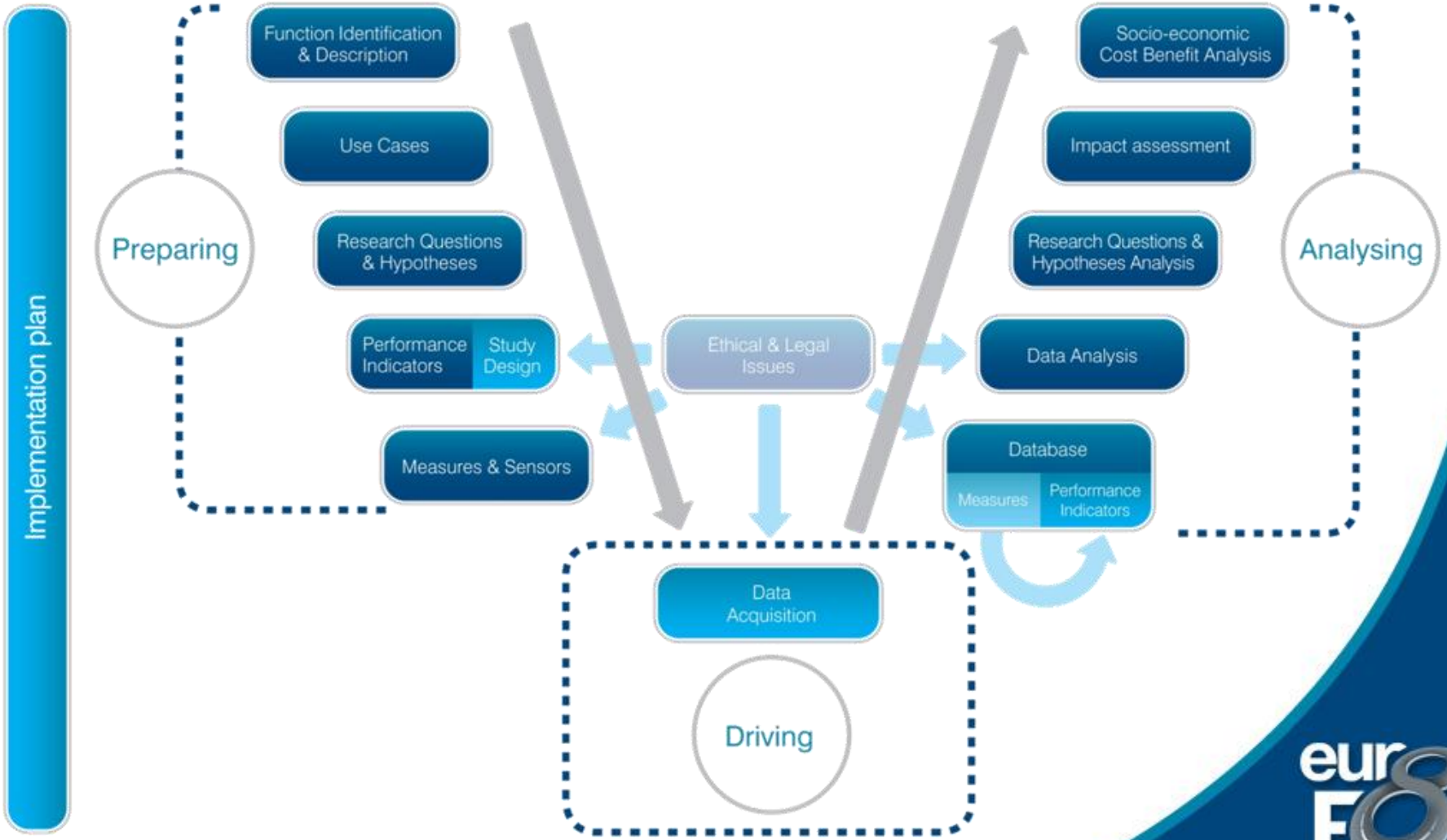
Complexity of FOT



Approach – FESTA V



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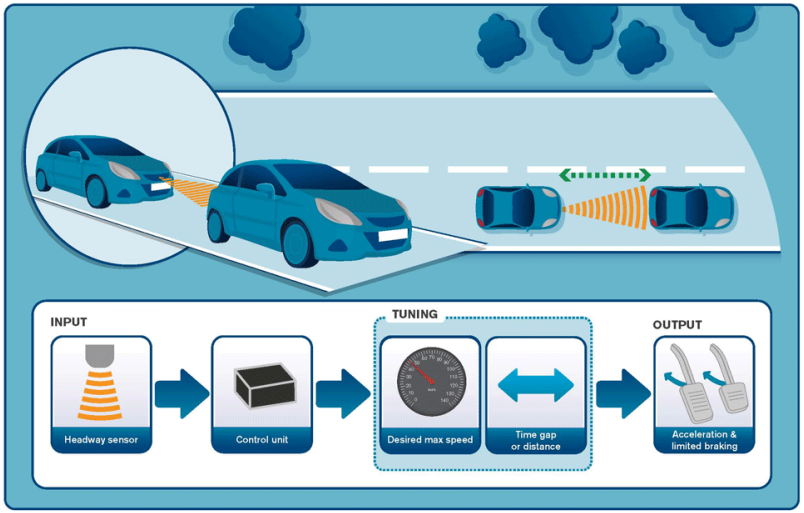
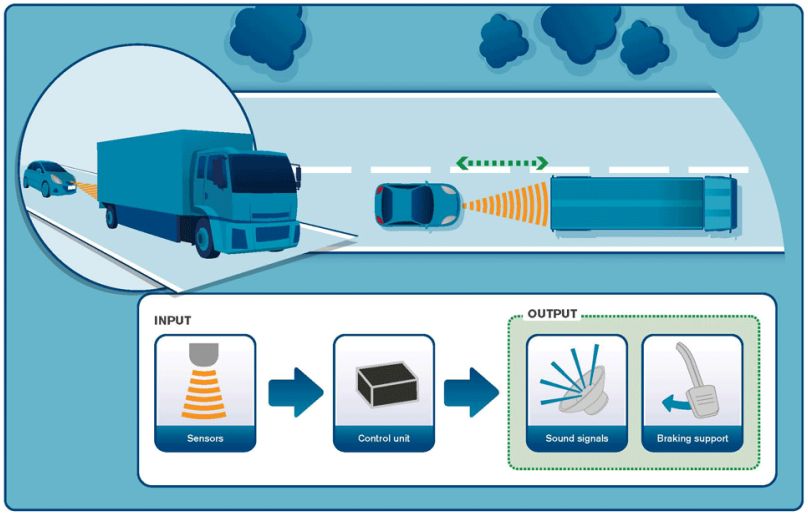
Function Definition: ACC and FCW

ACC Adaptive Cruise Control



FCW Forward Collision Warning



- ACC and FCW are integrated in one system
- Debundling of effects not always possible
- Analysis as a bundle ‘ACC and FCW’

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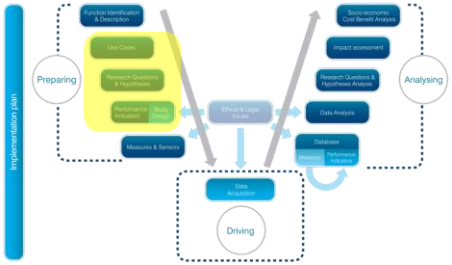
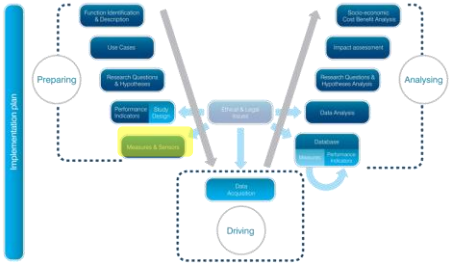
RQ, Hypotheses & Performance Indicators



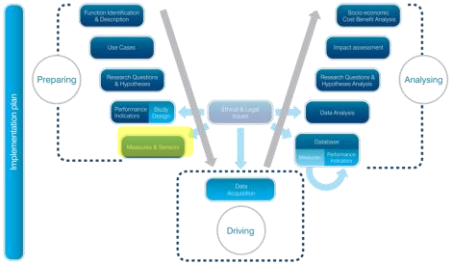
- Research Questions (RQ)
  - General Question on what should be evaluated by means of the FOT
  - Example: Make ACC+FCW road traffic safer?
- Hypotheses
  - Hypotheses are derived form the RQ in order to be able to answer the RQ.
  - Example: ACC+FCW reduces the number of hard braking
- Performance Indicators (PI)
  - “PIs are quantitative or qualitative measurements, agreed on beforehand, expressed as a percentage, index, rate or other value, which is monitored at regular or irregular intervals and can be compared with one or more criteria.” (FESTA Handbook)
  - Example: Max. Deceleration or number of hard braking events

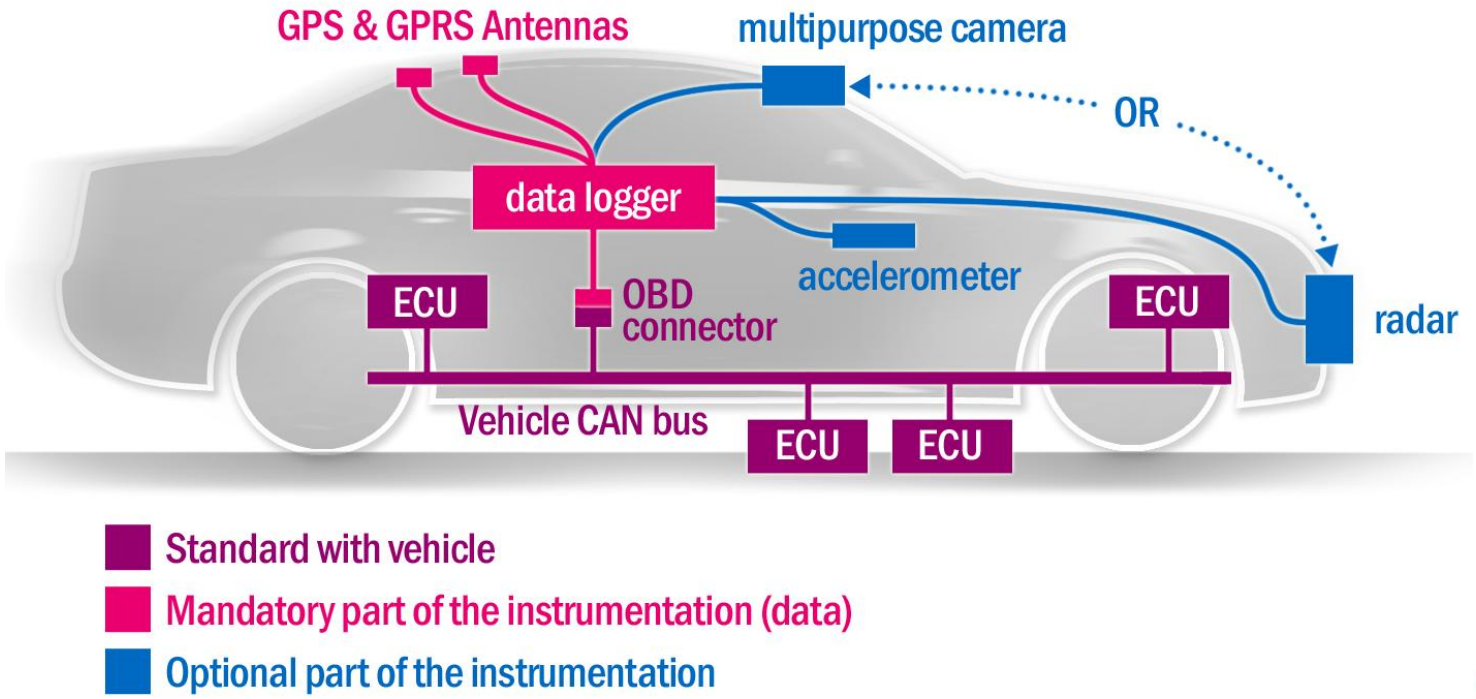
Data collection: Measures & Sensors



- There are different types of data, which can be logged during FOT
  - Questionnaires (Questionnaires at different time points)
  - Signal logging (e.g. from CAN-Bus, GPS, external sensors)
  - Video data (e.g. front camera, driver camera)
- Different data types can be classified by
  - Provided information (content as well as amount)
  - Necessary logging equipment
  - Handling of data transmission
  - Required effort for evaluation

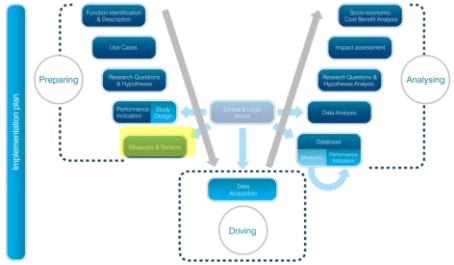
Data collection: Measures & Sensors





- Combinations of the data types are possible

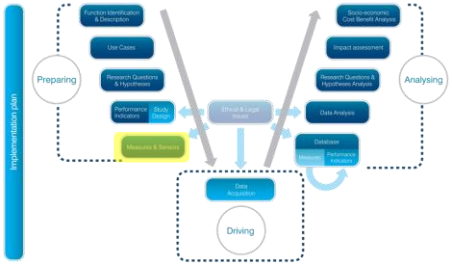
Data collection: Measures & Sensors



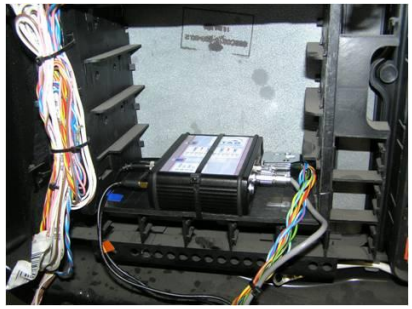
	Questionnarie	Signal logging	Video data
Type of data	Subjective data	Objective data	(Objective) data
Data amount	-	o	+
Effort for data logging	+	o	-
Effort for data transmission	o	+ (depends on implementation)	-
Evaluation effort	+	o	-

- Combinations of the data types are possible

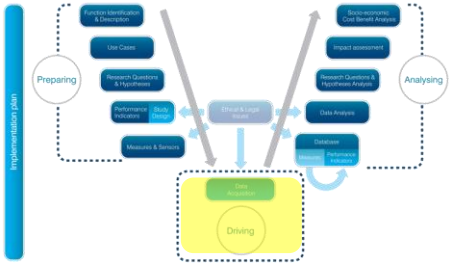
Data collection German 1 VMC

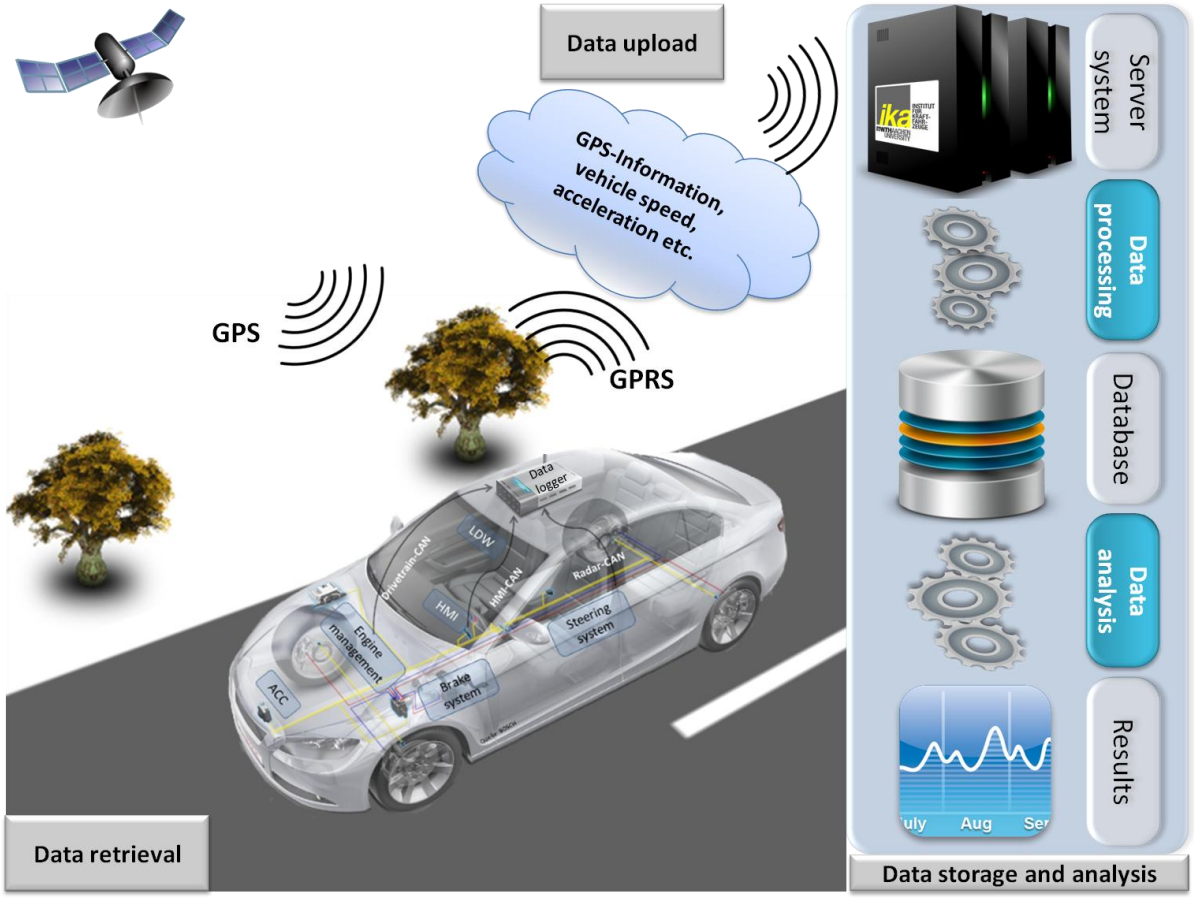


- Due to the high number of cars the aim was that the whole process runs autonomously without any interaction of the driver
- Data Sources at the German 1 VMC:
  - CAN-Data as well as GPS-data were logged
  - questionnaires
- Therefore all customer vehicles were equipped with a data acquisition system (DAS), which enables recording of all relevant signals
  - DAS is a small and compact unit that can easily be integrated in the vehicle without modifications on the customer vehicles
- DAS is equipped with a GPRS module
  - Wireless upload of collected data to centralised server



Data collection





- Collection of around 110 vehicle signals from CAN-Bus
- Process of data upload and processing is designed to work fully autonomously
- No driver interaction required

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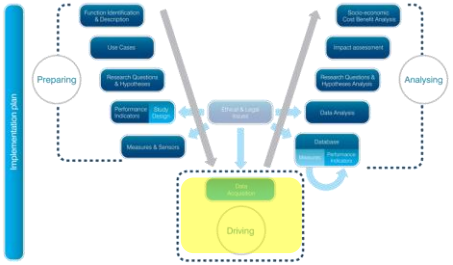
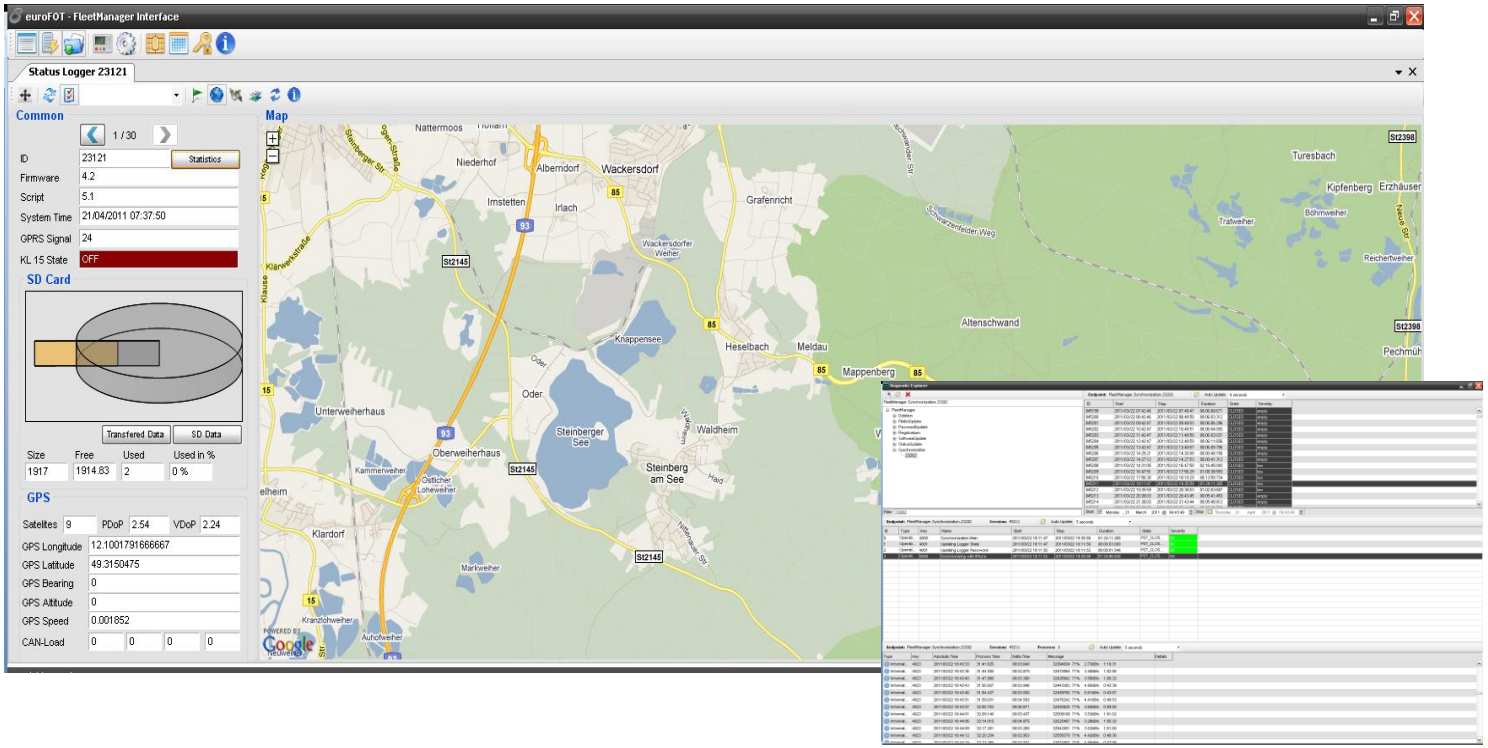
Data collection



If you are going for autonomous approach, monitoring is a crucial point!



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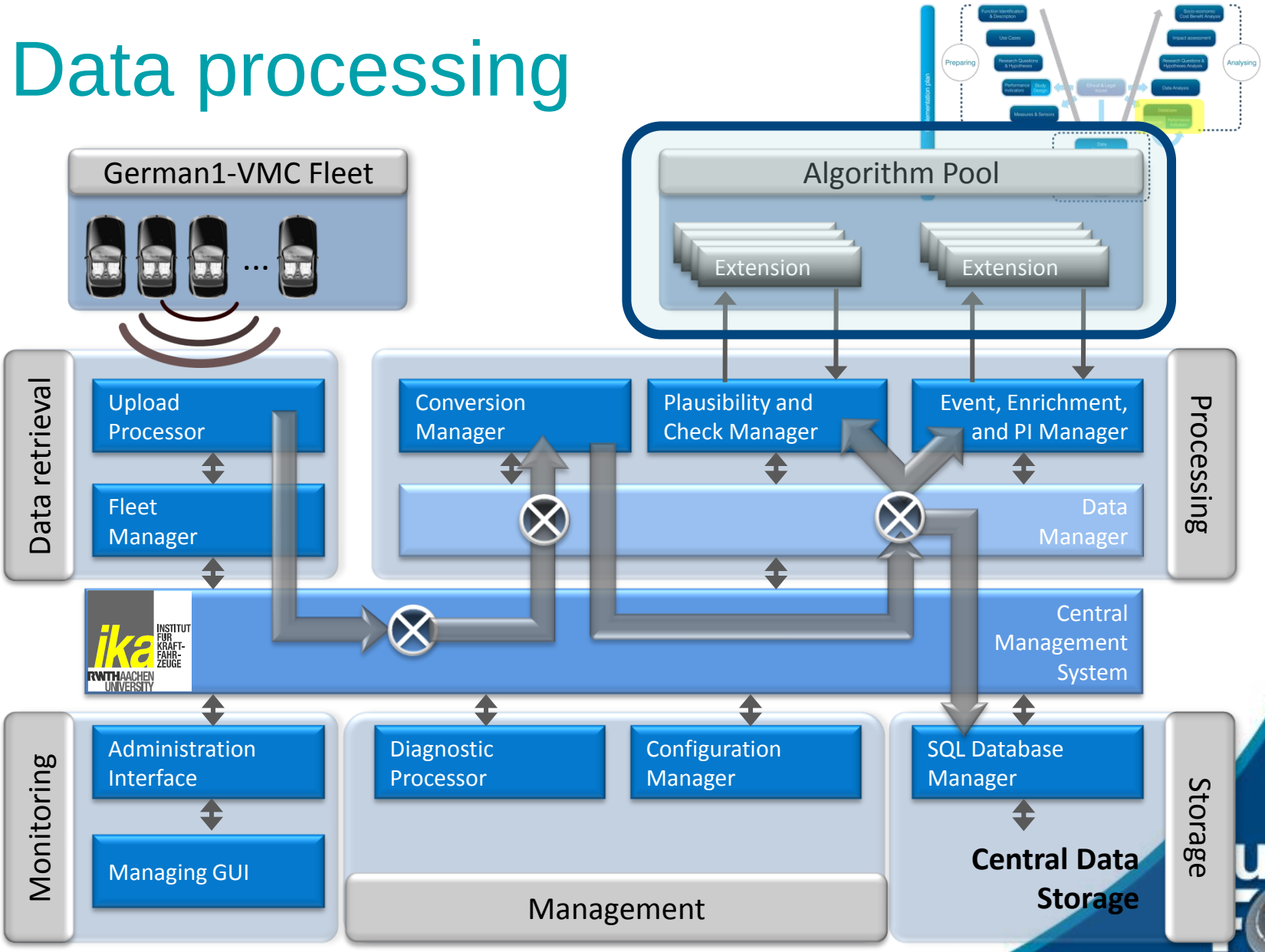
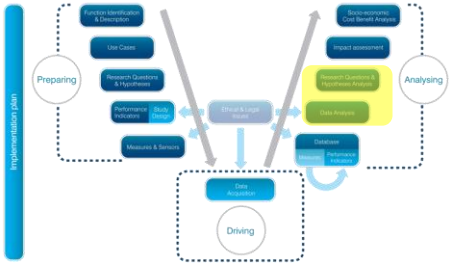
Data processing



Data Analysis: Detection of relevant events



Review of thresholds used in previous FOTs

First incident definition

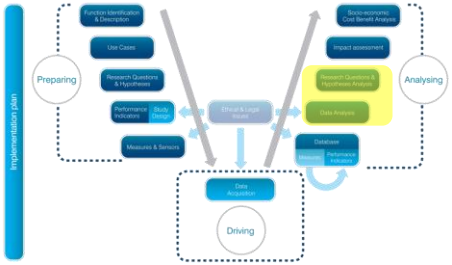
Testing within piloting phase

High false detection rate

Identification of factors caused false detections

New incident definition

Data Analysis: Detection of relevant events

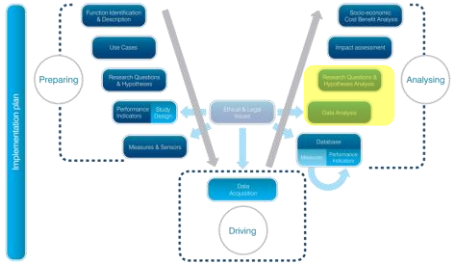


Revision of incident definition

Installation of video cameras into piloting vehicles	Use of data from driving experiments	Re-production of critical situations on test tracks
↓	↓	↓
Identification of factors caused false detections	Definition of extraordinary driving situation	Determination of further information on pre-history
↓	↓	↓
Elimination of factors	Definition of triggers and thresholds	Check of suitability of thresholds

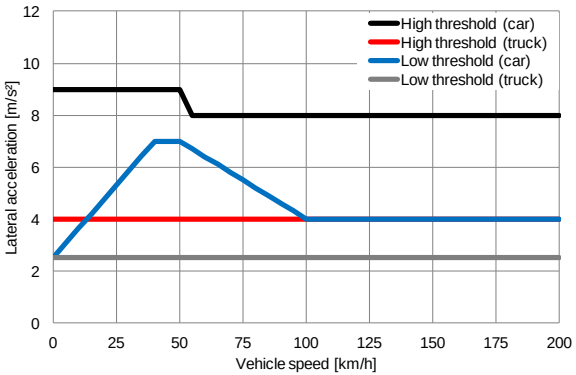
Reduction of false detection rate from 75 % to 5 %

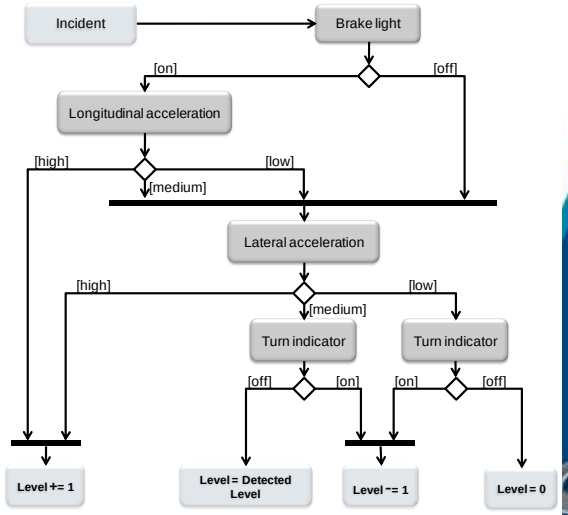
Data Analysis



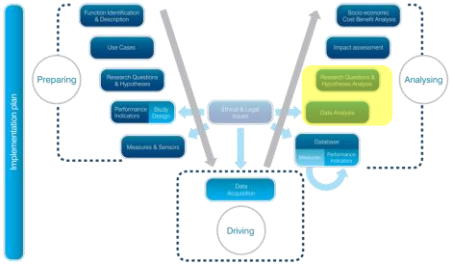
Example: Incident

- Incidents are critical driving situations, which are used as indicator for traffic safety, since the number of recorded number of accident is too low for statistical analysis.
- Two kinds of incidents
  - Incidents due to vehicle dynamics (Identified by means of lateral / longitudinal acceleration, Yaw rate, ESP and ABS)
  - Incidents due to distance behaviour and driver reaction (Identified by means of the vehicle speed, time-headway (THW), time-to-collision (TTC), relative speed and the state of the brake light)
    - Consider the reaction of the driver in order to overcome the lack of information





Processed data at German1-VMC



	Mileage [km]	*Number of drivers*	*Number of trips*	*Data amount*
Raw data	3.000.000	189	214.469	1046 GB
Data processing	2.500.000	189	170.000	2565 GB
Impact assessment				
Baseline	643.912	118	9.007	212 GB
Treatment	973.653	118	27.237	627 GB

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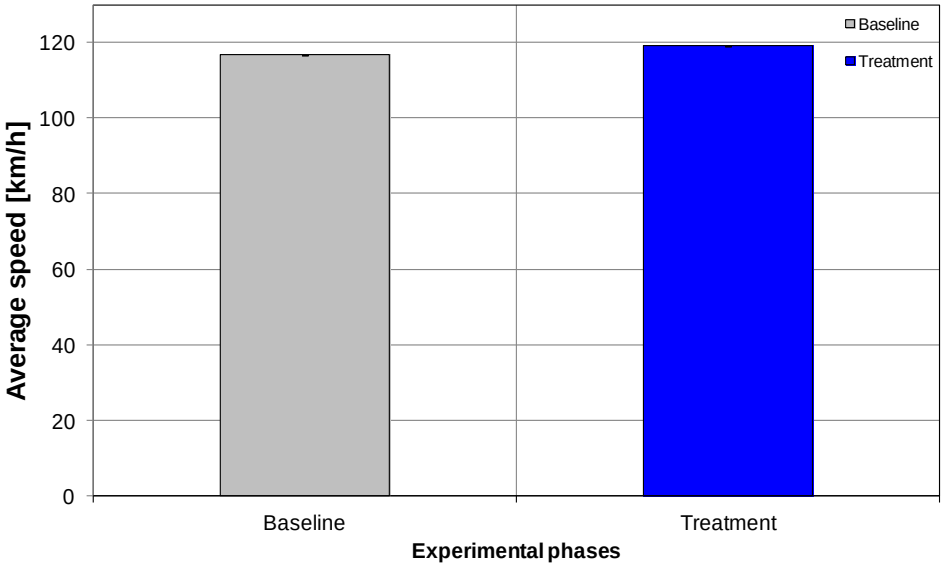
Available data

Ford	MAN	VOLVO	VOLVO	VW
✓	✓	✓	✓	✓

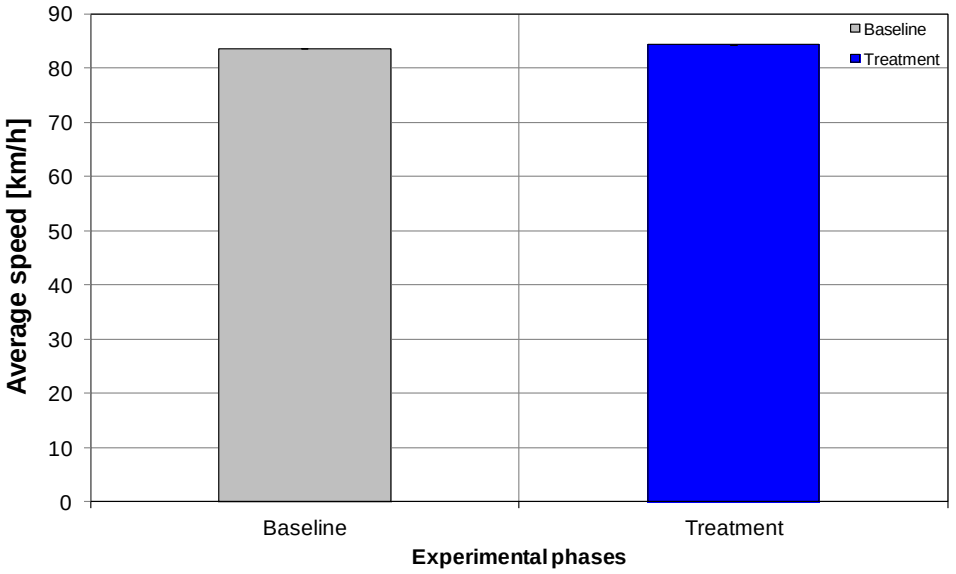
	Mileage		Number of drivers	
	Baseline	Treatment	$N_{passenger\ cars}$	N_{trucks}
Overall	727.114 km	623.615 km	174	53
Motorway	676.924 km	602.866 km	174	53
Rural	24.983 km	12.228 km	64	-
Urban	25.207 km	8.521 km	64	-

Average Speed

Passanger Cars



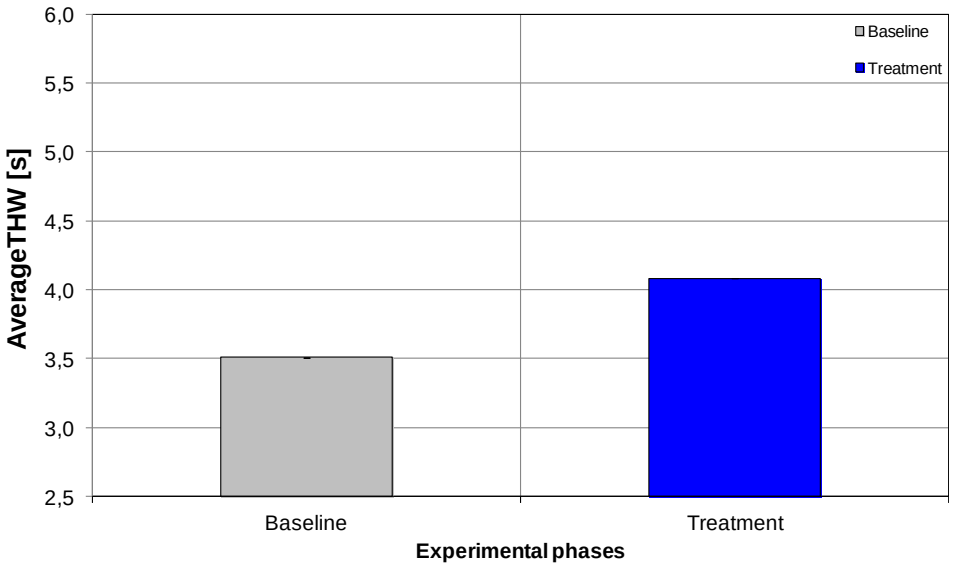
Trucks



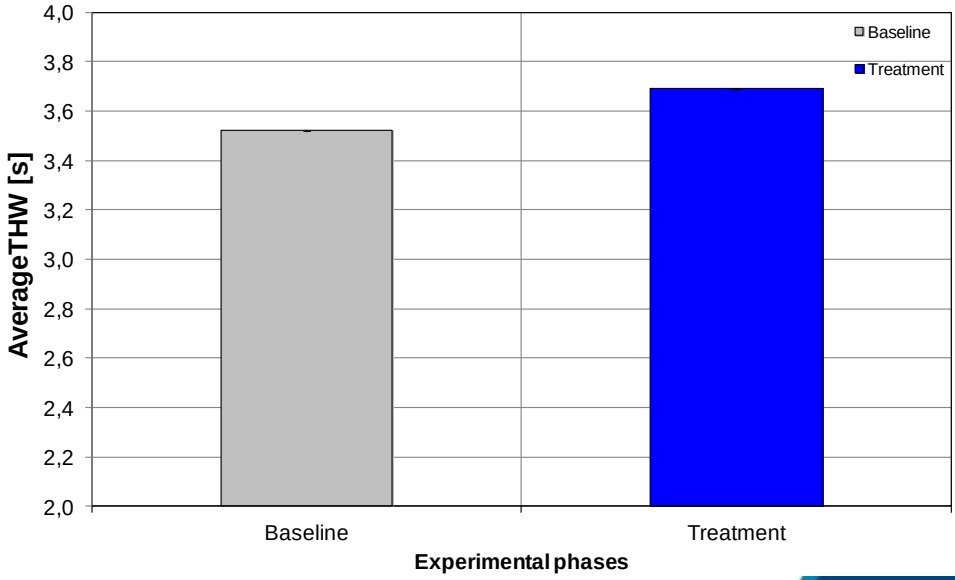
Vehicle Type	Conditions	Baseline	Treatment	% Increase/ Reduction	N	Mileage [km]
		Mean	Mean			
Car	motorway	116.7	119.0	2.0	174	709.607
Truck	motorway	83.6	84.3	0.9	53	570.183

Average THW

Passanger Cars



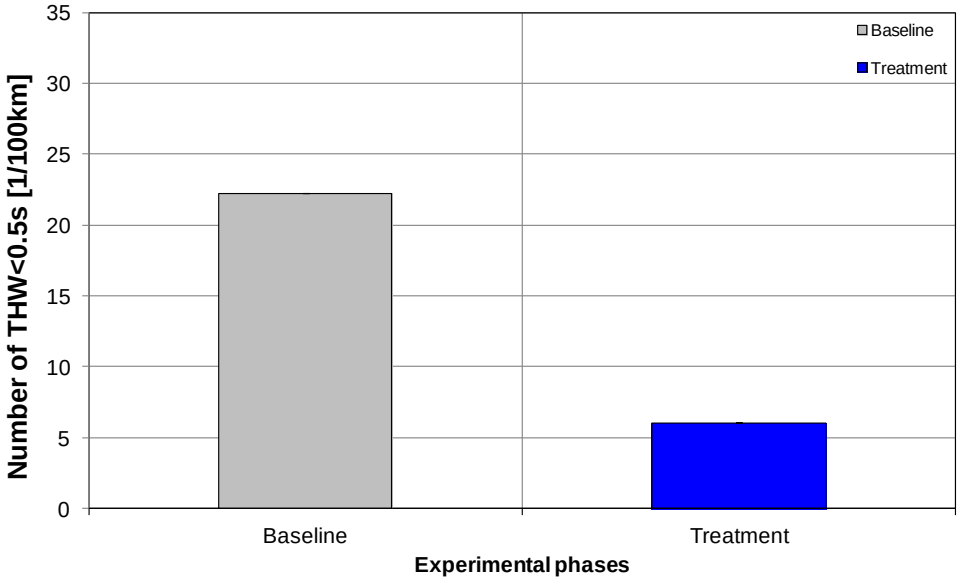
Trucks



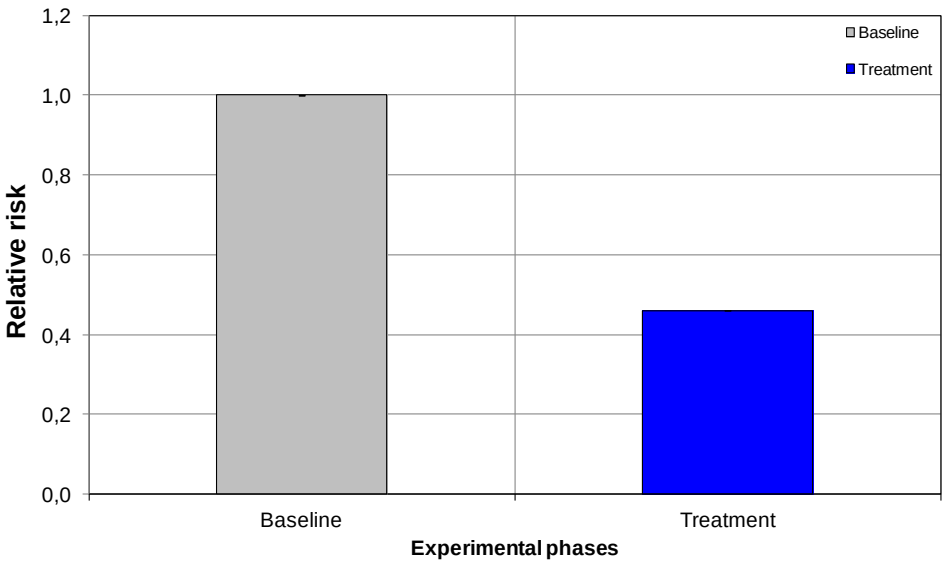
Vehicle Type	Conditions	Baseline	Treatment	% Increase/ Reduction	N	Mileage [km]
		Mean	Mean			
Car	motorway	3.51	4.08	16.2	173	709.607
Truck	motorway	3.52	3.69	4.8	53	570.183

Critical THW (< 0.5s)

Passanger Cars



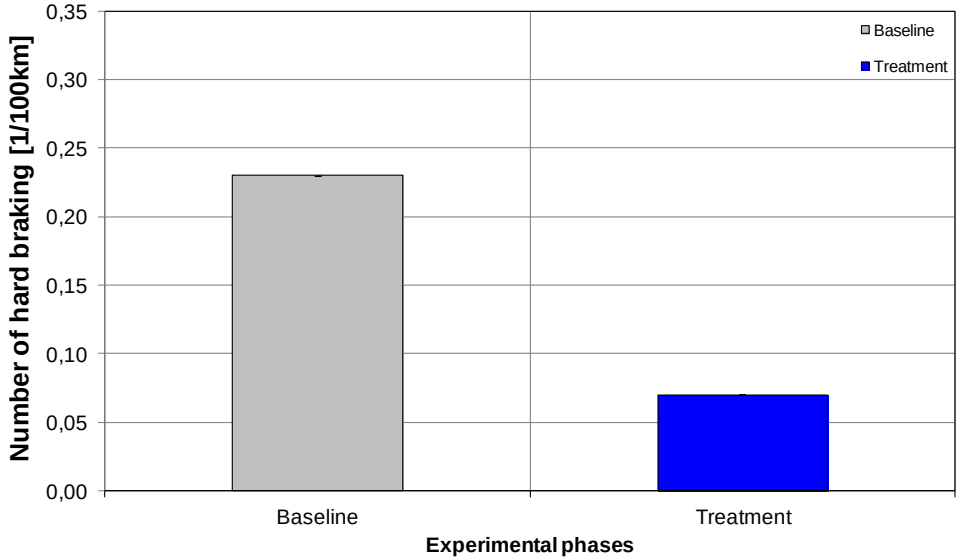
Trucks



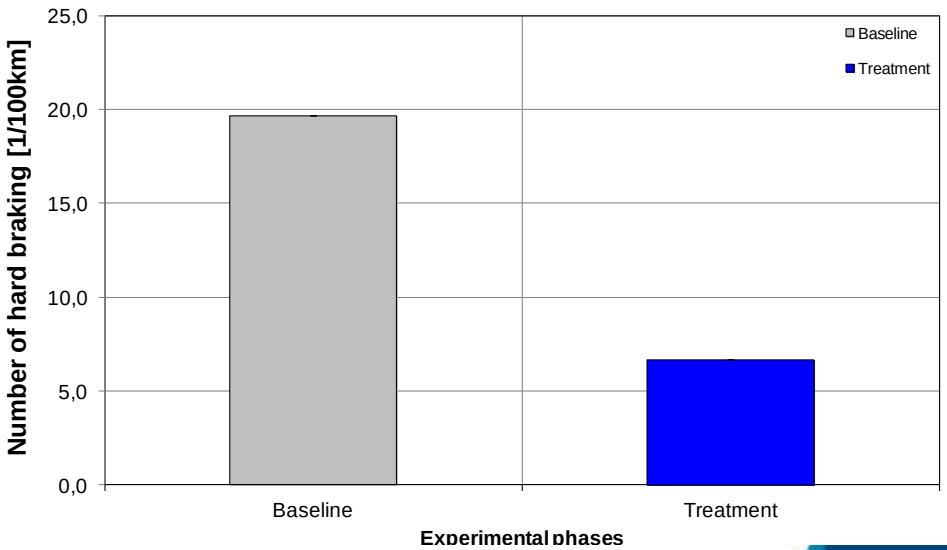
Vehicle Type	Conditions	Relative risk (risk treatment / risk baseline)	% Increase/ Reduction	N	Mileage [km]
Car	motorway	0.27	-72.9	174	709.607
Truck	motorway	0.46	-54.0	36	501.069

Hard braking

Passanger Cars

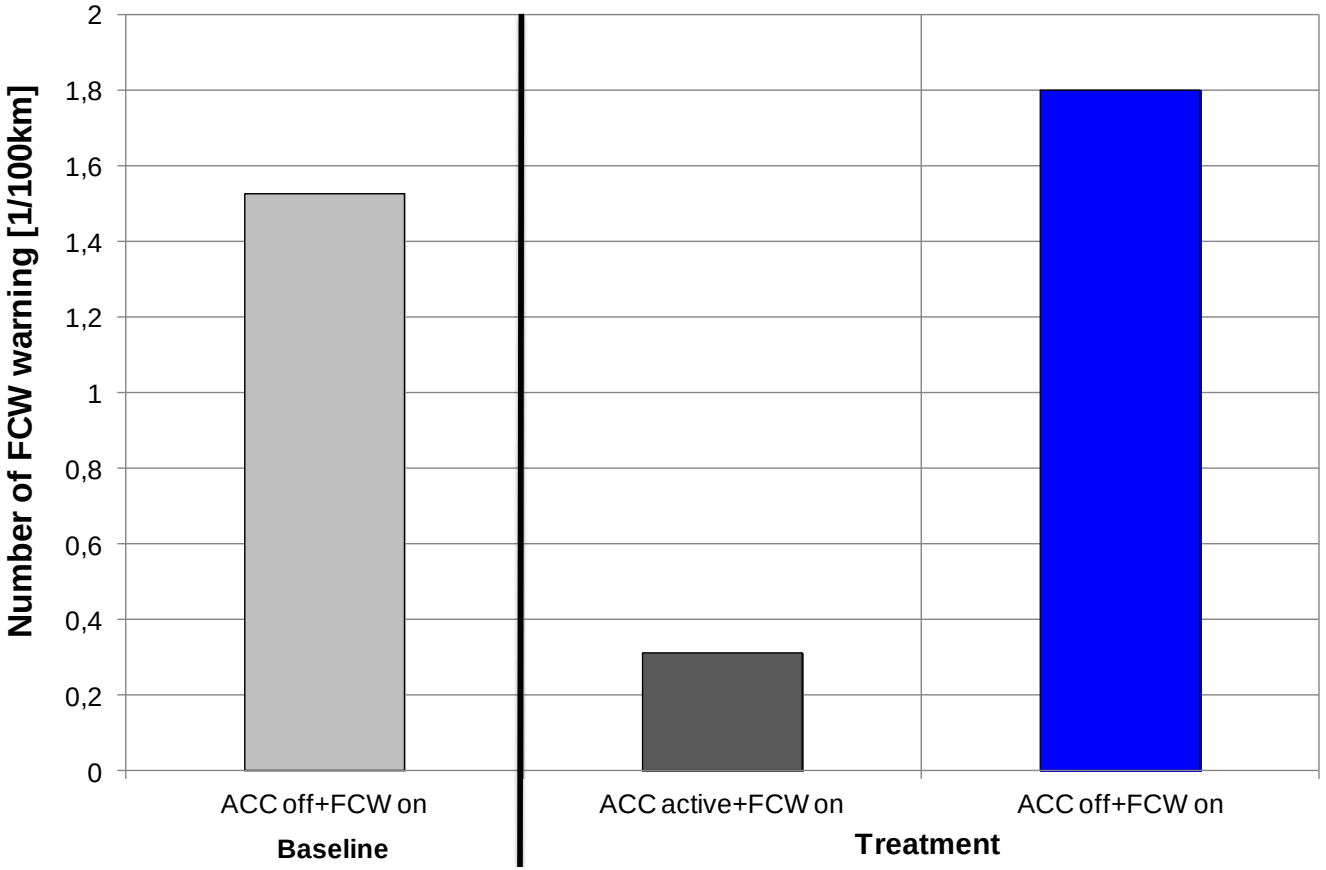


Trucks



Vehicle Type	Conditions	Baseline	Treatment	% Increase/ Reduction	N	Mileage [km]
		Mean	Mean			
Car	motorway	0.23	0.07	-69.2	110	651.099
Truck	motorway	1	0.59	-40.8	30	429.215

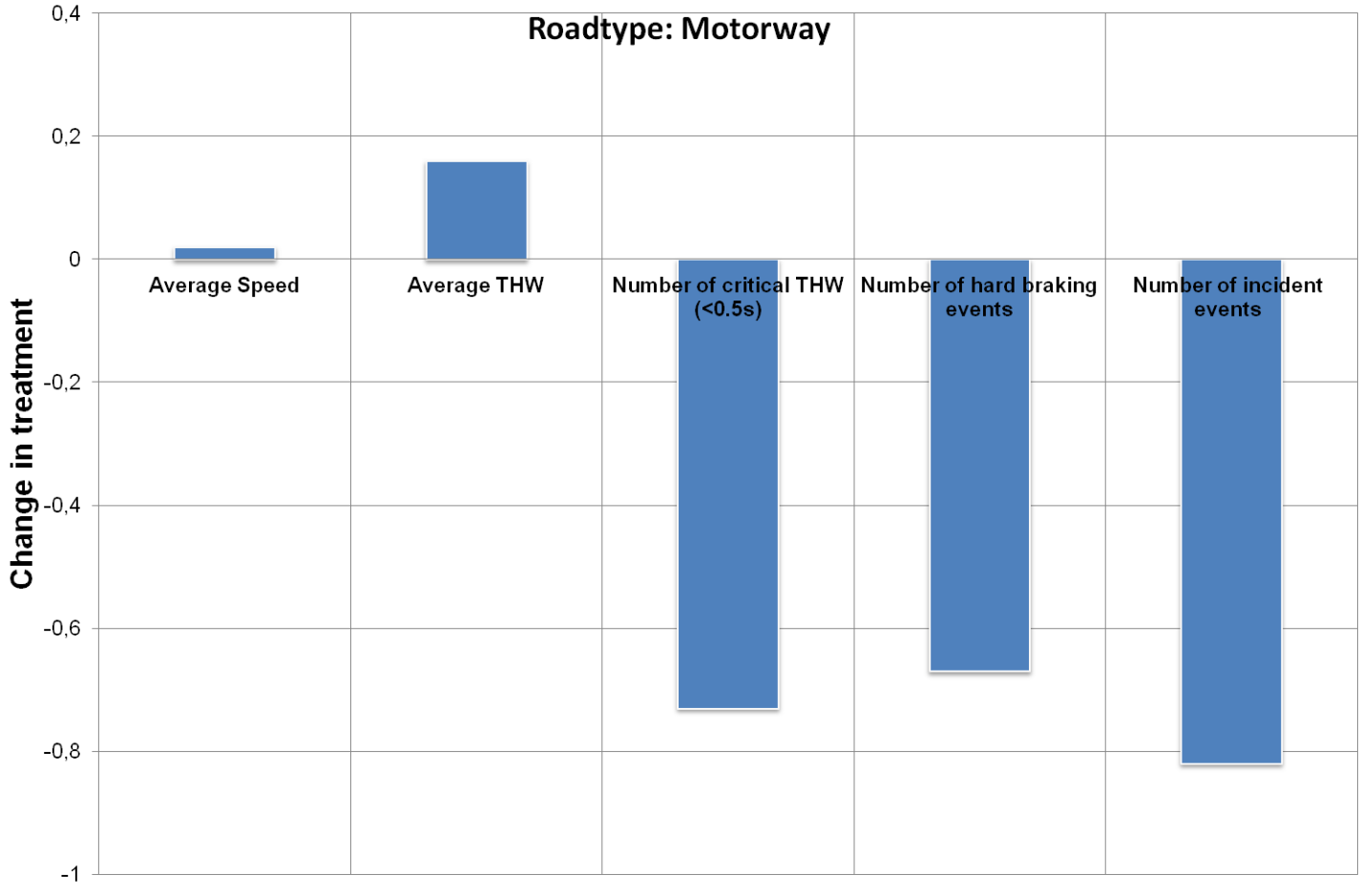
FCW warnings



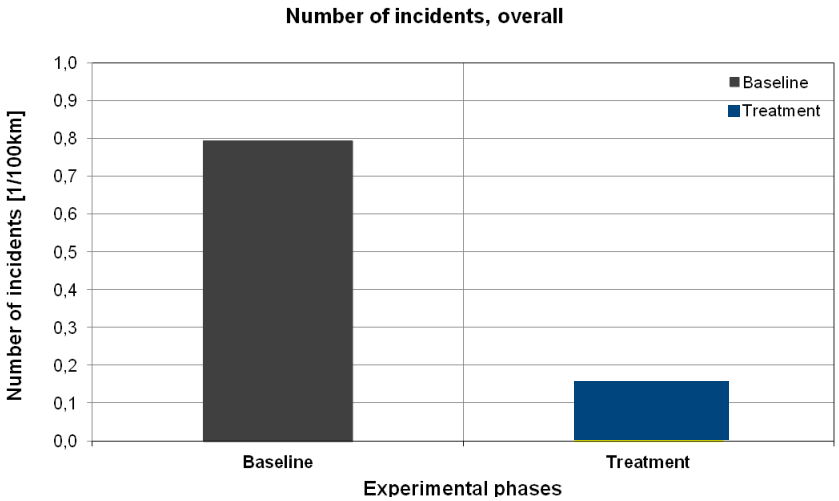
High reduction of FCW warnings in phases with ACC active on motorways:

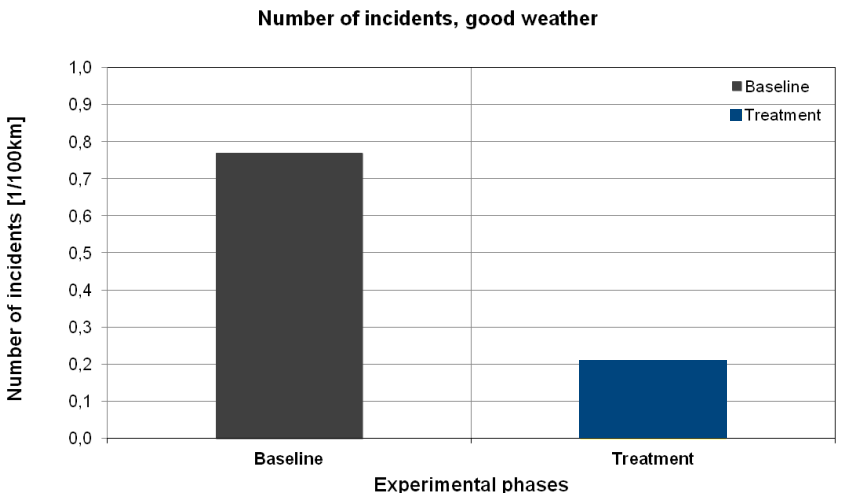
- 80% reduction when ACC active and FCW on

Overview on results



Incidents

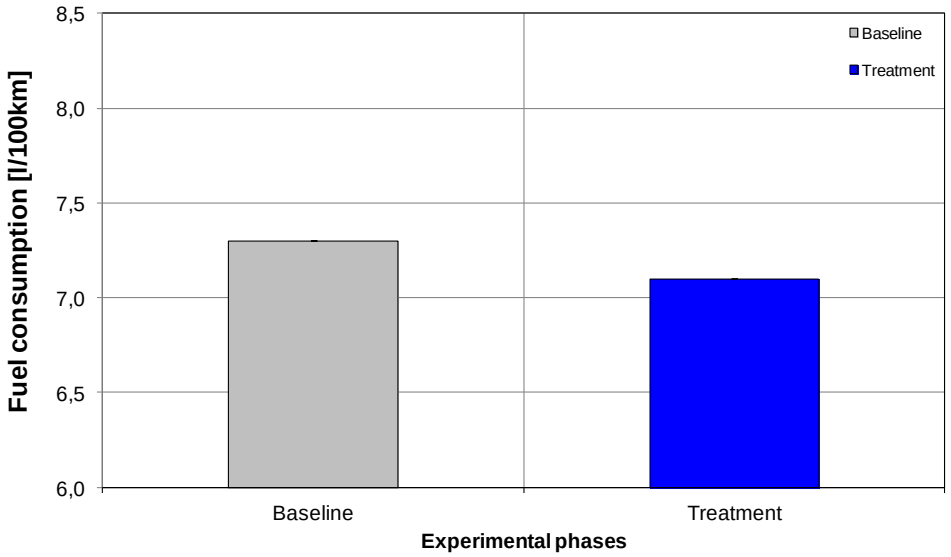




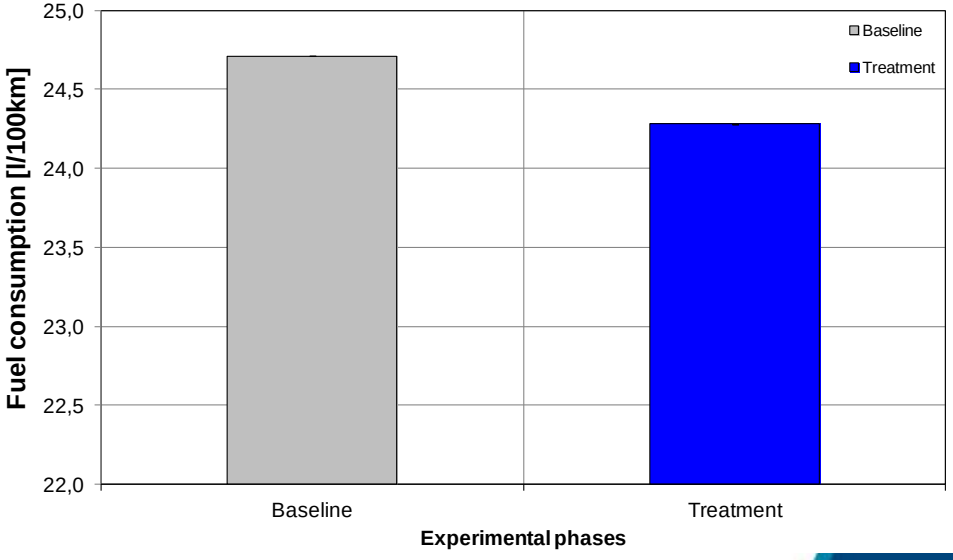
Results of significance tests			Descriptive statistics						Increase/ Reduction
Conditions	Effect	p-value	Baseline			Treatment			
			Mean	25-P.	75-P.	Mean	25-P.	75-P.	
overall	ACC	<0.0001	0.793	0.024	0.738	0.152	0.000	0.172	-80.8%
good weather	ACC	<0.0001	0.769	0.072	0.777	0.206	0.019	0.225	-73.3%
adverse weather	ACC	0.060	0.421	0.000	0.355	0.083	0.000	0.052	-80.4%
dark	ACC	0.002	0.710	0.000	0.775	0.219	0.000	0.128	-69.2%
daylight	ACC	<0.0001	0.869	0.048	0.786	0.167	0.012	0.268	-80.8%

Fuel consumption

Passanger Cars



Trucks



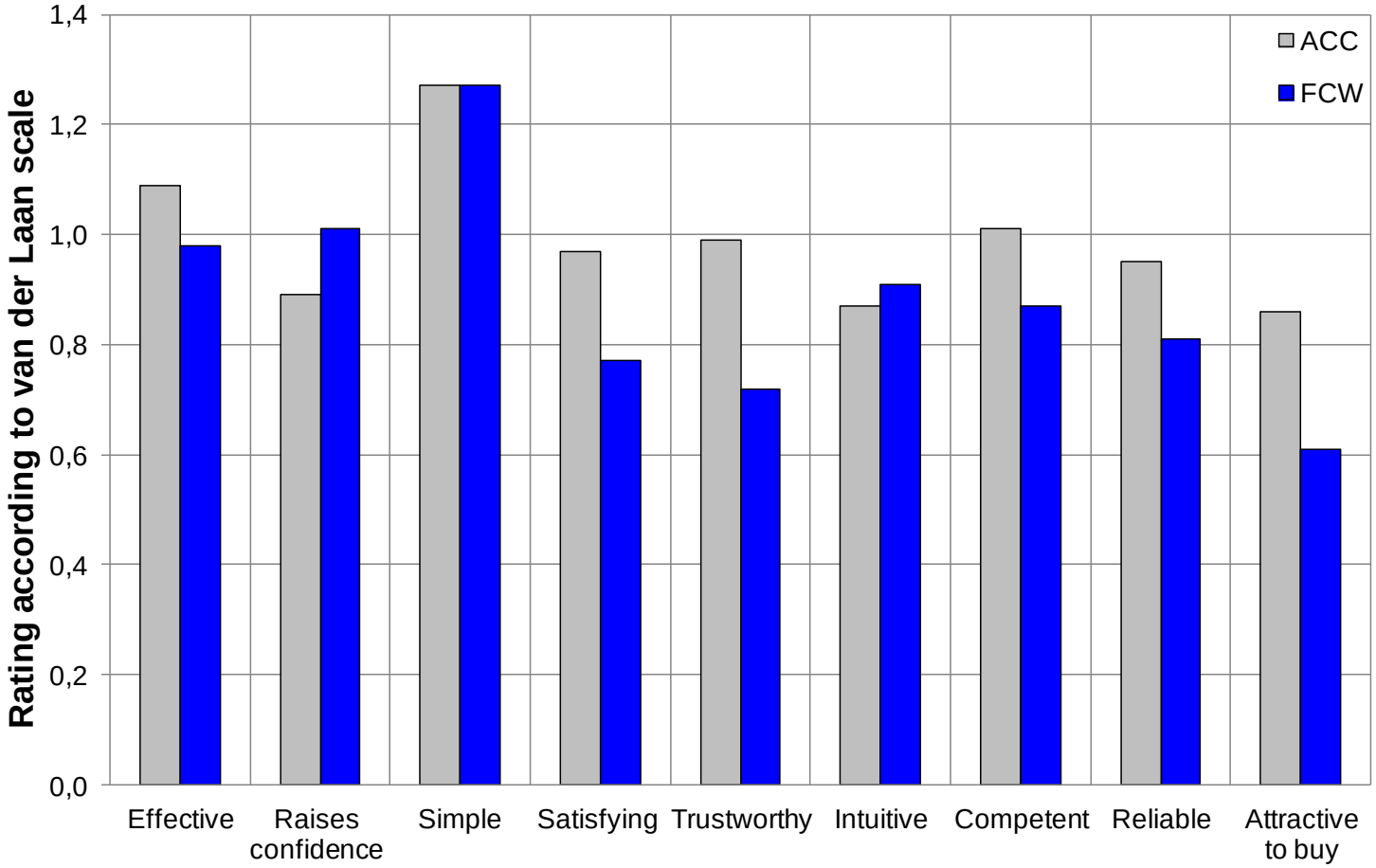
Vehilce Type	Conditions	Baseline	Treatment	% Increase/ Reduction	N	Mileage [km]
		Mean	Mean			
Car	motorway	7.30	7.10	-2.8	163	698.695
Truck	motorway	24.71	24.28	-1.8	23	327.295

Usage ACC

Type of measure	Performance indicator	Results		Relative Increase / Decrease
		First month treatment	Last month treatment	
Objective	Percentage of travel time travelled with active ACC	19 %	25 %	+31 %
Objective	Number of ACC activations per hour travelled	1.1	1.6	+53 %
Objective	Number of overriding per hour travelled with active ACC	29.2	26.2	-10 %
Subjective (Questionnaire)	Change of user practices in using the ACC	-	63 % (no change)	-

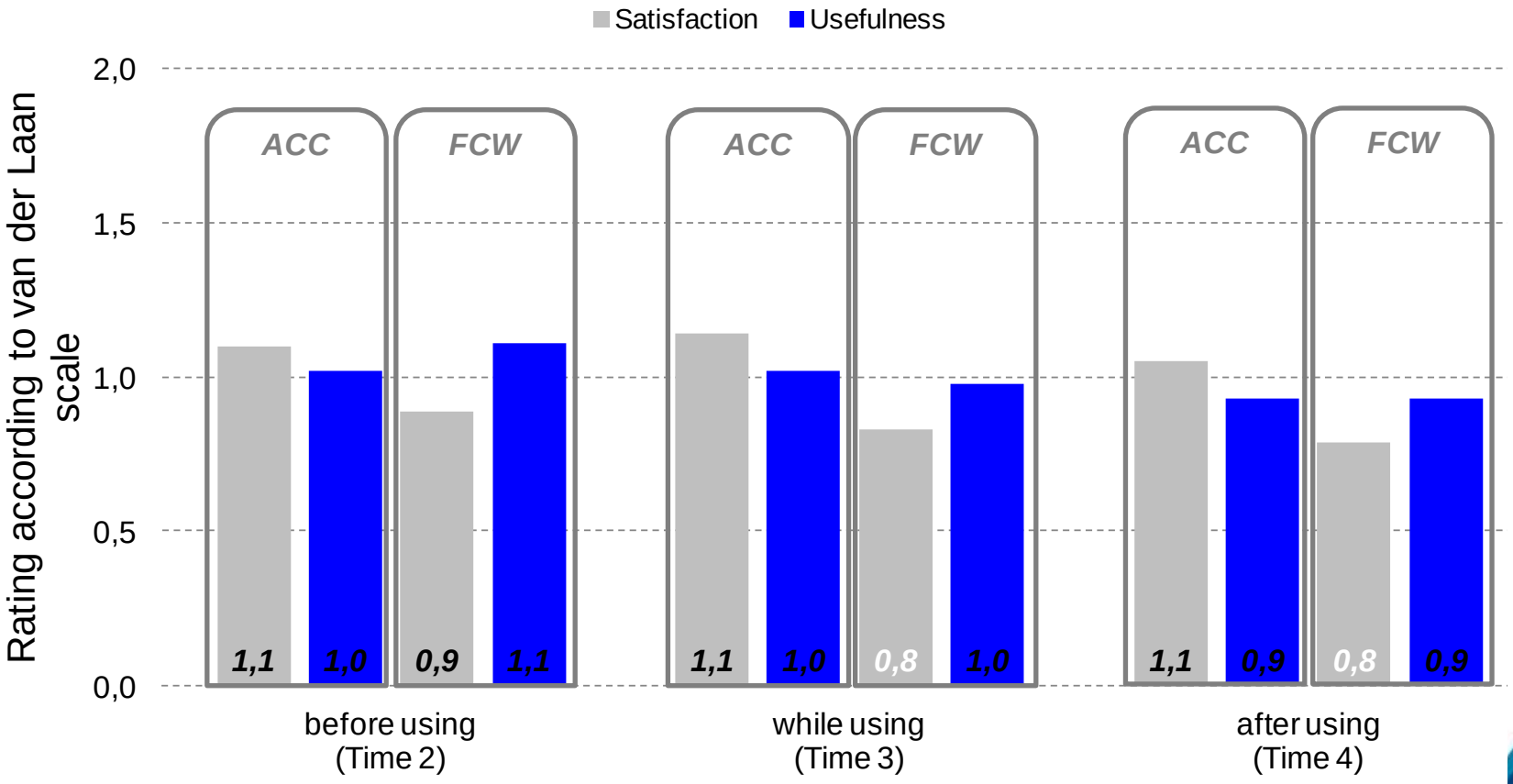
- Drivers use ACC more often and longer over time
- Slight decrease of overriding the ACC (not significant)
- Drivers report no change of ACC usage

Rating of acceptance indicators



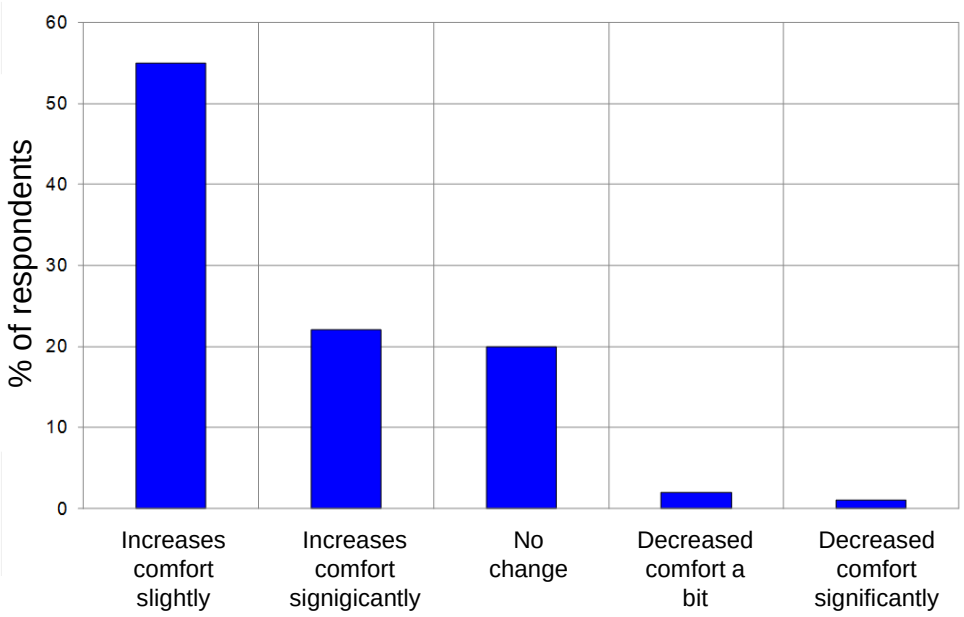
- Acceptance rating positive for ACC and FCW
- Van der Laan scale ranges from -2 to +2

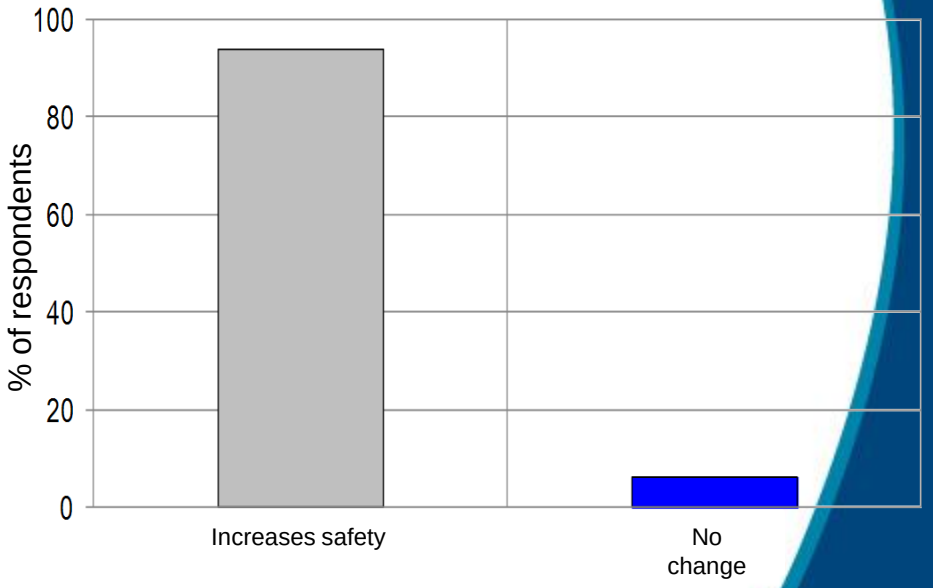
Acceptance - change over time



- No significant changes over time for ACC and FCW
- Acceptance rating of ACC and FCW is very positive

Perceived driving comfort and safety





ACC leads to an increase of perceived driving safety and perceived driving comfort:

- 94% of drivers feel that ACC increases safety
- 77% of drivers feel that ACC increases comfort

Conclusion for ACC

- Acceptance in terms of perceived usefulness and satisfaction is high (stable over time)
- Driver expectations were fulfilled
- More than 75% of the driver feel that driving comfort and safety increases
- ACC perceived to be most useful on motorways
- ACC has a positive influence on driver behaviour (increased THW), which leads to increased safety
- Fuel consumption is reduced when driving with ACC

Conclusion for FCW

- Almost 70% of drivers feel that FCW increases safety
- High expectations of drivers are mostly fulfilled
- Acceptance (usefulness, satisfaction) is high and stable over time
- FCW is perceived to be most useful on motorways
- Drivers were not all positive to the audio-visual warning

Thank you for your attention!

8 Functionalities, 28 Partners, 1000 Vehicles
1 Field Operational Test, 8 Functionalities
28 Partners, 1000 Vehicles, 1 Field Operational Test
8 Functionalities, 28 Partners, 1000 Vehicles
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