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## 4 List of Abbreviations

ABS	Anti Blocking System
ACC	Adaptive Cruise Control
ADAS	Advanced Driver Assistance System(s)
ADA system	Advanced Driver Assistance system
ADVISORS	<b>Action for advanced Driver assistance and Vehicle control systems Implementation, Standardisation, Optimum use of the Road network and Safety</b>
ASR	Acceleration Skid Control
ATT	Advanced Transport Telematics
BS	Blind Spot
CAN	Collision Automatic Notification
CAS	Collision Avoidance System
CCL	Close Circuit Lidar
CEN	European Committee for Standardisation
CD-ROM	Compact Disc – Read Only Memory
CO	Carbon monoxide
CO <sub>2</sub>	Carbon dioxide
CTP	Common Transport Policy
CW	Collision Warning
DGPS	Differential GPS
DMS	Driver Monitoring System
DSRC	Dedicated Short Range Communication
EEG	Electro Encephalogram
ELS	EyeLid Sensor
EOG	Electro Oculogram
ETS	Electronic Traction System
ETSC	European Transport Safety Council
EU	European Union
EMU	European Union monetary unit
FMEA	Failure Mode and Effects Analysis (risk estimation methodology)
FMECA	Failure Mode and Effects and Critical Analysis
FTA	Fault Tree Analysis
GPS	Global Positioning System
GSM	Global System for Mobile Communications
GSR	Galvanic Skin Response
HC	(1) Hydrocarbons (2) Headway control
HGV	Heavy Goods Vehicle
HMI	Human Machine Interaction
HUD	Head-up-display
HUTSIM	Microscopic – traffic/environmental model
IAS	Integrated ADAS system
ICC	Intelligent Cruise Control
ISA	Intelligent Speed Adaptation
ITS	Intelligent Transportation System
IVHS	Intelligent Vehicular Highway Systems
IVI	Intelligent Vehicle Initiative
LCS	Lane Change Support
LCW	Lane Change Warning
LED	Light Emitting Diode
LSS	Lateral Support System
LW	Lateral (Lane departure) Warning
MCA	Multiriteria analysis
NASA	North America Space Agency

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NAV	Navigation System and Fleet Management.
N/A	Not applicable
NO <sub>x</sub>	Nitric oxides
O/D	Origin/Destination
PCU	Passenger Car Unit
Pb	Lead
PDT	Peripheral Detection Task
PM	Particulates
RDS/TMC	Radio Data System/Traffic Message Channel
RF	Radio Frequency
RNB	Behavioural Risk Number
RNL	Legal Risk Number
RNO	Organisational Risk Number
RNT	Technical Risk Number
RP	Revealed preference
RTI	Road Traffic Information (systems)
RSME	Rating Scale Mental Effort
S&G	Stop and Go
SAE	Society of Automotive Engineers
SATURN	Macroscopic – network efficiency model
SIMONE	Microscopic – traffic model
SISTM	Microscopic – traffic/environmental model
SLIM	Success Likelihood Index Methodology
SLIM-MAUD	SLIM, using Multi-Attitude Utility Decomposition
SO <sub>2</sub>	Sulphur dioxide
SOP	Start of Production Prevision
SP	Stated Preference
SSL	Static Speed Limiter
SWOT	Strength, Weaknesses, Opportunities and Threats
SWT	Sidewall Torsion sensor
T45	Task 4.5
TEMAT	Macroscopic – environmental model
TLX	Task Load Index
TTC	Time to Collision
v/c	Volume over capacity ratio (level of service indicator)
VICS	Vehicle Information and Communication System
VMs	Vehicle Manufacturer(s)
VOC	Volatile Organic Carbons
WAP	Wireless Application Protocol
WP	Work Package
WTP	Willingness To Pay



## 5 Executive Publishable Summary

### **ADVISORS main achievements are:**

1. *The development of an integrated and common ADAS assessment methodology*

- a description of a comprehensive ADAS assessment approach
- with relevant criteria,
- involving various types of measurements related to: parameters of ADAS testing, and assessment of: road safety, usability and driver comfort, HMI factors and interaction safety, road network efficiency and environmental impacts,
- an evaluation checklist to allow ADA design and evaluation teams to rapidly check their systems

The Common Assessment Methodology, is an approach for selecting the relevant ADAS test aims, assessment of the ADAS effects, prioritization of implementation aims and devising implementation strategies. It is also applicable to other areas.

2. *The results of assessment of a set of ADAS on road safety, driver comfort and network efficiency*

Road safety and driver comfort assessments are made on:

- Interurban ACC
- Urban ACC with Stop & Go
- Lateral Support System
- Driver Monitoring System
- Board Computer in trucks
- Lane Warning and Collision Warning system

Network efficiency and environmental impacts are tested on:

1. ACC
2. ISA and
3. a combination of ACC and ISA

The Common Assessment Methodology has proven its usefulness, and a subset of variables is defined which is relatively easy to use and gives a clear picture of the effects of ADAS.

3. *A Multicriteria analysis (MCA) on a set of ADAS-types revealed a ranking of ADAS for which relevant criteria were considered most favourable.*

The ADAS chosen were types of: ACC, ISA, Driver Monitoring System (DMS) and Integrated ADAS system (IAS), and from the MCA the following criteria came out as primary (criteria presented below in decreasing level of importance):

- |                          |                               |
|--------------------------|-------------------------------|
| 1. Driver safety         | 6. Full user Cost             |
| 2. Third party safety    | 7. Socio-political acceptance |
| 3. Environmental impacts | 8. Driver comfort             |
| 4. Travel time duration  | 9. Public Expenditure         |
| 5. Technical feasibility |                               |

4. *A risk analysis method based on FMEA was developed and applied on behavioural, legal and organisational risks of a set of ADAS (a.o. ISA, ACC, Fleet Management & Navigation Systems, DMS).* The risk analyses set the agenda for pilot studies and implementation barriers to be solved.

5. *Identification of a set of multidimensional future priority scenarios for ADAS developments.* ACC on the motorway, intervening ISA in urban areas, a warning type DMS for professional drivers and Integrated ADAS are chosen.

6. *Identification of major legal, institutional, socio-economic, financial, organizational and user acceptance ADAS implementation problems*

7. *Formulation of implementation strategies to overcome implementation barriers for priority future scenarios for: ACC, ISA, DMS and IAS.*

8. *Dissemination of the results through various channels and production of user-friendly terminology.*



## 6 Objectives of the project

ADVISORS main objectives (ADVISORS technical Annex, issued 16-12-1999) are:

- To identify a set of ADAS with high potential to overcome important safety hazards, road capacity bottlenecks, driver behaviour problems and environmental load in several road types.
- To identify the major legal, institutional, socio-economic, financial, organisational and user acceptance barriers to the implementation of such systems embedded in a decision framework and identify measures and strategies to overcome them.
- To develop an integrated assessment methodology and relevant criteria to reliably assess traffic safety, usability, interaction safety, user acceptance, road network efficiency and environmental impacts of ADAS.
- To assess the impact of emerging longitudinal, lateral and combined ADAS on road safety, driver comfort, as well as on the overall road network efficiency and the environment, using the above methodology, through multipurpose Pilots.
- To develop recommendations for type approval, a common legal framework and standards in the area of advanced driver assistance systems, as well as to propose funding and incentive mechanisms for their social optimum deployment.
- To promote user and stakeholder awareness of such aids and through it to enhance societal acceptance of them.
- To help realise exploitable ADA systems.



## 7 Scientific and technical description of the results

### 7.1 Overall approach

#### 7.1.1 Introduction

In accidents in the European Community around 40.000 people are killed, the economical costs as a result of congestion are huge, and there is a strong motivation in trying to reduce the emissions of various pollutants, as defined in the Kyoto agreement.

Intelligent transport systems, especially systems that may assist the driver (like ADAS: Advanced Driver Assistance Systems), are expected to increase road safety and road capacity, and to attenuate environmental load in traffic. However, car manufacturers are developing many of these systems for commercial reasons, mainly. Several of these systems will enter the market, some sooner, some later.

The ADVISORS project has formulated as its overall objective to develop a comprehensive framework to analyse, assess and predict the implications of a range of ADAS, as well as to develop implementation strategies for ADAS expected to have a large positive impact on one or more of these effects.

The core of the ADVISORS approach is the ADVISORS Common Assessment Methodology, in which the development of the methodological framework has taken place. The methodological framework is to be understood as an approach in defining the considerations for decision making concerning the procedure of choosing ADAS, defining indicators and criteria for assessment of relevant impacts and defining implementation strategies. Below, the common assessment methodology is explained and illustrated. The procedure is then applied in this report with two exceptions: the development of the indicators and measurement methods is presented first, in paragraph 7.2, and the initial definition of criteria and weights is presented later, in paragraph 7.7.2, to facilitate reading.

#### 7.1.2 Common Assessment Methodology

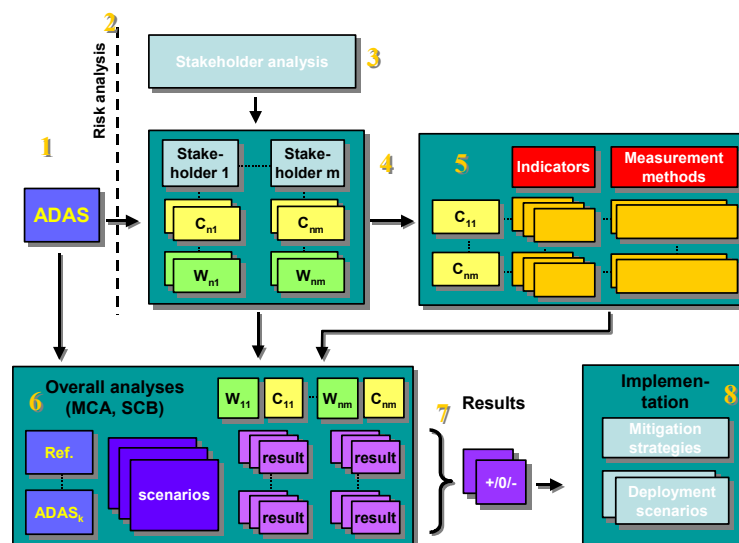


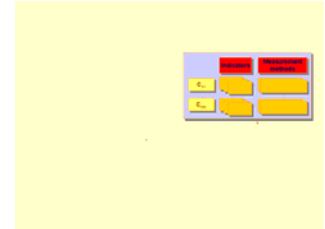
Figure 1 Common Assessment Methodology

The “mission statement” of ADVISORS is summarized in Figure 1. The figure explains our methodology for assessment of ADAS effects, prioritization and devising implementation strategies. However, like most mission statements, behind it is a lot of research, analysis, discussion and synthesis. Please refer to the following paragraphs for a description of the approach.

1. Identification of ADAS for evaluation. Classification involves labeling of ADAS function (according to commonly agreed terminology), defining technical capabilities and scope, and considering the scenarios where the ADAS will be used. Please refer to paragraph 7.3.2.
2. Risk Analysis concerns an assessment of the risks concerning the impact of ADAS market penetration and successful implementation of the ADAS, previously identified. ADVISORS bases its approach on Failure Mode and Effects Analysis (FMEA) methodology. The relevant indicators of *severity*, *occurrence probability*, *delectability* and *recoverability* are expanded to cover not only technical risk but also *behavioural*, *legal and organisational – related* risks. Please refer to paragraph 7.4.
3. In stage 3, actor (stakeholder) analysis is performed: it is essential to provide a sound understanding of the needs and requirements of the different stakeholders (actors) involved with the deployment of ADAS, in order to assess the playing fields for ADAS deployment. A stakeholder analysis will assist in identifying the range of people who are likely to use a system or be influenced either directly or indirectly by its use. It is an aid for identifying the range of stakeholders whose views should be considered and consulted. It can be of use in both the *development phase* and the *evaluation phase* of an ADA system. Please refer to paragraph 7.5
4. Criteria and weights. Following the identification of stakeholders and their goals, the next stage is to identify the costs and benefits that a system may give to each stakeholder group and the costs and benefits associated with its use. The appropriate assessment criteria should then be identified. Clearly, the costs and benefit criteria differ considerably between stakeholders; assessment criteria and definition of the weights are the next step in quantifying the differential costs and benefits. Please refer to paragraph 7.7.
5. In this stage, the previously identified stakeholder criteria are “operationalised” by identifying specific indicators (also called metrics or variables) that can be used to measure whether, and in case to what extent, a specific criteria is achieved. The indicators are generated by measurement methods and are specified in detail. Different methods will be appropriate depending on the indicator. The indicators and measurement method comprise a measurement methodology, to be applied in empirical studies on ADAS impacts. Please refer to paragraph 7.2.
6. Stage 6 contains two parts:
  - Pilot studies, for gathering empirical data about the actual impacts of ADAS on safety, traffic flow and the environment are to be performed in the next step. Please refer to 7.6.
  - The translation of the empirical results into a prioritisation of the ADAS and defining of future scenarios for various categories of stakeholders. In multi-criteria analysis, decision-makers’ objectives are used to establish criteria and values for the analysis. The analysis records any aspect that is relevant to the decision which is being considered. The objectives are defined by goals, and criteria are defined by concrete, operable goals. The analysis produces goal-achievement indices which are derived by weighting the measured criteria. Please refer to paragraph 7.7.
7. Results of the MCA relate towards the decision with regard to ADAS implementation on the basis of future scenario ratings. Please refer to paragraph 7.8.
8. Finally, a set of implementation strategies are developed and presented in the following stages of development:
  - Choice of future implementation scenarios
  - Consideration of barriers and risks
  - Design of Implementation Strategies
  - Strategy validation
  - Please refer to paragraph 7.9.

Furthermore, ADVISORS objectives involve promotion of user and stakeholder awareness of ADAS and through it to enhance societal acceptance of them, and finally to help realise exploitable ADA systems. Paragraph 7.10 is aimed towards these goals.

## 7.2 The development of an integrated ADAS assessment methodology



This work has been performed under Workpackage 4 and is reported in the deliverables:

ADVISORS_Del 4a.pdf	Part I: A set of indicators on safety, usability and environmental criteria towards assessment of ADA systems
ADVISORS_Del 4b_5b.pdf	Part II: An integrated methodology and evaluation checklist and ADA design.

### 7.2.1 Comprehensive ADAS assessment approach and Evaluation Checklist

The traffic system as a whole can be seen as comprising of three interactive components: vehicles, road users, and the road environment. Any traffic situation is the result of the interaction between these three components. Normally the traffic situation develops as planned, but in certain circumstances, the resulting interaction will result in a critical situation or an accident.

Human errors in information processing are one of the main contributing factors in traffic accidents. The cause of human error lies in the limited capacity of the human information processing system, although this differs depending on age, experience, and idiosyncratic characteristics.

According to Sanders and McCormick (1993) the purpose of evaluation research is to compare the actual impacts of a specific system with the predefined objectives and intentions. Within the area of road transport telematics (e.g. ADAS) the importance of assessing side-effects (unintended effects) are recognised and many evaluation techniques are available. The sequence of assessments should take into account both the actual system functionality and the stage of system development. The great variety of available research methods must be selected carefully taking into account the objectives of the specific ADAS.

To investigate the effects of driver support systems, three global categories are distinguished in the field: measures of task performance, subjective reports and physiological measures (see also Brookhuis & De Waard, 2001).

Essential fundamental principles guiding the choice of test methods of relevance for evaluations of ADA systems are the following:

- Test methods should have high reliability and should be validated before being put to extensive use.
- Test methods should not disturb the measurement of other relevant variables in a way that true effects of experimental manipulations will not appear. For example, a method intended to measure mental workload or stress reactions should not in itself cause significant increases in mental workload or stress reactions and thereby greatly reduce or eliminate true differences between ADA systems or between different versions of ADA systems.
- Test methods should represent the appropriate required aggregation level of data
- Test methods should be optimized in terms of cost-benefits.

The complete ADVISORS Checklist (*Annex 1*), a help for setting up the pilot testing is constructed as follows:

- 1) various categories of approaches for conducting an evaluation study definition of system type in terms of automation level
- 2) testing the test vehicle?? on characterization of functionality of various ADAS elements
- 3) definition of participants
- 4) definition of environmental characteristics
- 5) domains of measures
- 6) methods for assessment of various categories of dependent variables:
  - errors
  - mental workload
  - drowsiness



- stress
- situation awareness
- usability and driver comfort
- driver impairment
- road safety, traffic efficiency and environmental impact
- on various other higher level transport goals

### ADVISORS common set of variables

ADVISORS has applied the methodology in pilot studies and defined a set of dependent variables to be used in all pilots (the set of “prescribed” variables), and another set of variables which are “recommended”. Although this has been an ADVISORS choice, and partly dependent on the specifications of the ADAS tested and the research questions and the limitations of the measurement device, in many instances researchers will find themselves reviewing similar considerations.

The common set of variables are part of the collection of dependent variables: the variables that can be measured in the pilot tests: performance measures (the actual driving quality); subjective reports (by observer ratings or self-ratings) and physiological measures (brain activities, workload measures, strain measures and state measures). The ADVISORS Toolbox (Annex 4) gives an overview.

<b>Measurement area</b>	<b>Option</b>	<b>Measure</b>
<b>Task performance</b>	Prescribed	Trial time with and without system Errors with system use
	Recommended	Fuel use Number of incidents / accidents Etc.
<b>Driver Performance</b>	Prescribed	Speed (average & SD) Lateral position (average & SD)
	Recommended	Steering wheel movements (SD) Car following (time headway, distance to car in front) Time to collision Time to line crossing Braking force Etc.
<b>Driver Workload</b>	Prescribed	RSME (Zijlstra, 1993)
	Recommended	NASA TLX (Byers et al., 1992; Hart & Staveland, 1988) SWAT MHC Heart rate (incl. variability) Perclos (= percentage of eye-lid closure) Other scales or measures
<b>Usability</b>	Prescribed	Usability questionnaire (Brooke, 1996)
	Recommended	Driving quality scale (Brookhuis, 1993) Other usability questions
<b>User Acceptance</b>	Prescribed	User Acceptance Scale (Van der Laan et al., 1997)
	Recommended	Other acceptance scales / questions
<b>Willingness to pay</b>	Prescribed	Willingness to pay questionnaire
	Recommended	Additional questions / scales
<b>User profile</b>	Prescribed	User profile questionnaire
	Recommended	Additional questions
<b>Terminology</b>	Prescribed	User friendly terminology
<b>Situation Awareness</b>	Recommended	Freeze and SAGAT (Endsley, 1995b; Endsley, 2000)

Table 1 ADVISORS Common set of measures

## 7.2.2 Parameters of ADAS testing

Assessment parameters are those parameters that define the independent variables and the manipulations of the ADAS tests.

The scenario used when assessing an ADAS determines the assessment parameters. The scenario is a key methodology issue as the prevailing conditions outside (and inside) the vehicle strongly influence the outcome of the assessment and the conclusions that can be drawn. Scenario specification and assessment parameter definitions have to be included when assessment methodologies are developed.

The assessment parameters, defined by the scenario, and identified as necessary to consider for ADAS assessment are:

- the driver
- the vehicle
- the road infrastructure
- the traffic conditions
- the environmental conditions

The ADAS can be seen either as a component that stands for itself or as being part of the vehicle component. One way of illustrating the scenario concept is shown in Figure 2. It is important to note that the significance of the different scenario components may vary in different assessments. Also, the components are related to each other and interact in different ways in different cases.

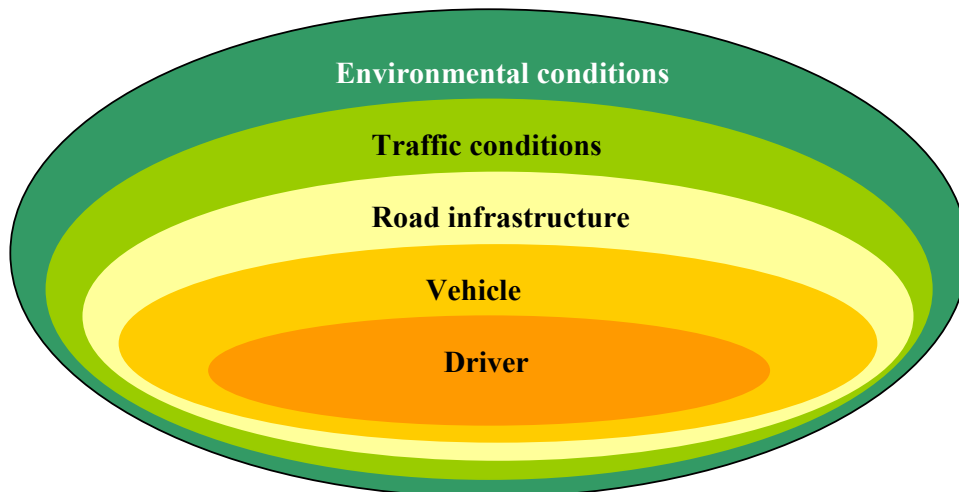


Figure 2 Main components to be considered and specified when building assessment scenarios.

### Evaluation type

The evaluation types identified as relevant for ADAS assessment are:

- simulator
- test track
- real traffic

Further evaluations can be carried out by traffic modeling, using both:

- microscopic
- and
- macroscopic simulations

### System type

From manual control to full automation five different grades of automation can be distinguished (Endsley & Kiris, 1995; Annex 3). The lowest level of automation is of course (1) no automation. Increasing the levels of

automation lead via (2) decision support, (3) consensual Artificial Intelligence (AI), (4) monitored AI to (5) full automation.

**Driver**

The participants to be included in ADAS assessments, i.e. drivers in the European Driver Population, should belong to the following categories:

- professional/private driver
- age (18-24; 25-60; over 60)
- experience, or total mileage driven (< 10.000; 10.000-100.000; > 100.000; > 1.000.000)
- gender
- special characteristics, needs etc. (e.g. experience with specific system, sleep apnea, extreme personality characteristics, etc)

The average driver: 25-50 years, driving experience 10.000 – 1000.000 km, both male and female.

**Vehicle**

The vehicle type used in ADAS assessment may also impact the results of the assessment and should therefore be carefully defined. The vehicle type used should be that for which the ADAS is designed. If the ADAS is meant for more than one type of vehicle then it would be advisable to test the system in all vehicle types.

Vehicle types might include:

- mini
- super mini
- small family
- medium
- executive
- sports
- four by four
- people carrier
- van
- HGV

**Road infrastructure**

The road type and infrastructure used within the assessment of ADAS will also affect assessment results and therefore needs to be defined. The system should be assessed on all roads for which it is designed.

Road types will include:

- Rural
- Urban
- Motorway

The road infrastructure will also include details of, for example, the traffic junctions and traffic lights to be included within the assessment.

**Traffic Conditions**

The surrounding traffic conditions involved during an ADAS assessment need to be defined and will be affected by the type of evaluation (testing environment). For example, on a test track there is not likely to be additional traffic and in real traffic the traffic conditions will be out of the experimenters control.

Traffic conditions can be defined as:

- Light
- Medium
- Heavy

Traffic conditions will affect both the speed of the traffic and the stop/start nature of the traffic.

**Environmental characteristics**

The overall environmental contexts in which the ADA system will operate and their interaction with the

system need to be defined, as external characteristics can influence results of measurements or surveys during system assessment.

Environmental conditions which need to be defined include:

- Weather conditions (rain, fog, snow)
- Lighting conditions (day, night, lit, unlit)
- Road surface conditions (wet, damp, low/high friction)

### 7.2.3 Assessment of: driver safety, usability and driver comfort, HMI factors and interaction safety

#### **Errors, Workload, Stress and Fatigue**

*Human errors* in information processing are one of the main contributing factors in traffic accidents. The cause of human error lies in the limited capacity of the human information processing system, although this differs depending on age, experience, and idiosyncratic characteristics.

Driver errors are classified according to Reason (slips and lapses, mistakes and intentional unsafe acts). They may be difficult to study experimentally, but self-assessment methods may be used in field studies where drivers use ADA systems for an extended period of time.

*Measurement methods:*

- Mistakes, lapses, slips in the simulator
- Diary methods
- Self assessment (Driver behaviour questionnaire: lapses and slips, mistakes and violations)

*Mental workload* is defined in many ways, but central is the issue that it depends on the relation between the task demands and the amount of resources the operator can or is willing to allocate, and therefore it is related to the (driving) task but also to the momentary state. In experimental studies, spare capacity measurements (PDT) belong to the viable methods

*Measurement methods:*

- Task performance (PDT)
- Self reports (NASA TLX, RSME)
- Physiological measures (Heart rate variability, galvanic skin response)

According to Matthews et al., (1997), driving-induced *stress reactions* are often relatively mild, but severe stress reactions may disrupt driving performance and reduce safety. An essential element of the severe stress reaction is the high emotional content. The key causal factors in driver stress are supposed to be the driver's appraisals of the demands of the traffic environment, appraisals of personal competence, and choice of coping strategy. The stress imposed by time pressure and, especially, by too much information – or in general terms, high mental workload - appears to be the most relevant type of stress reactions that may be encountered in connection with the use of ADAS. Attentional narrowing is one of the effects of stress. There is some evidence that stress leads to consistent shifts in processing strategy. Task accuracy may go down, whereas speed on the task may remain unchanged. Experimental studies have shown that decisions of various forms degrade under stress. Severe stress reactions may not be easy to create experimentally. However, mild stress reactions could be studied.

*Measurement methods:*

- Physiological methods (GSR)
- Self reports (activation-deactivation checklist)

Falling asleep behind the wheel or *drowsiness* in general constitutes a serious problem from a traffic safety point of view. Åkerstedt & Kecklund (2000) made the conservative estimation that 10-20% of the traffic accidents are sleep-related. Some major factors affecting drowsiness positively are driving time, not taking rests, monotonous conditions, high temperature, low driving experience, medical conditions. Drowsiness could best be studied in prolonged driving sessions with performance measures, combined with other measurement methods. To collect and analyse physiological measures is much more complicated than performance or self-report data.

*Measurement methods:*

- Electronic applications to detect drowsiness (e.g. as developed in AWAKE project)

- Self reports (Karolinska sleepiness scale)
- Task performance (lateral position deviation, lane departures, Time to line crossing, Time to collision or subsidiary reaction time tasks)
- Physiological measures (EEG, combined with EOG)

### **Situation Awareness**

Situation Awareness refers to the degree of accuracy by which a person's perception of the current environment mirrors reality. Endsley (1987) refers to Situation awareness as the perception of the elements in the environment within a volume of time and space (Level 1), the comprehension of their meaning (Level 2), and the projection of their status in the near future (Level 3). Situation awareness is required in dynamic environments where many decisions must be made across a narrow space of time, and tasks are dependent on ongoing and up to date environment analysis, it is therefore fundamental to the driving task. Automation of driving tasks may occur when implementing ADAS. This may lead to reduced situation awareness, by influencing factors such as attention, perception and mental models in the long-term memory. It is therefore essential to assess the impact of ADAS on situation awareness. Several measures have been used to assess levels of situation awareness. ADVISORS promotes the use of freezing techniques, where a simulation is halted, the system screens blanked, and the questionnaire administered.

#### *Measurement methods:*

- Eye tracking
- Performance
- Subjective ratings (SART, SAGAT)
- Observer ratings
- Questionnaires
- Freezing technique

### **Vehicle Measures, including Driver Impairment**

One could define impaired driving as those driver errors which may function as antecedents to actual accidents, as may induces in the critical incident / accident precursor method. Harvey et al (1975) defined a driver error as "any action or lack of action by drivers that would require them or other road users to implement a correction in order to make the situation safe again".

To investigate the effects of driver support systems in the experiments in terms of safety as planned, criteria for measures of task performance to determine whether driving is safe, have to be assessed (see also Brookhuis & De Waard, 2001, Brookhuis & De Waard, in press.).

Brookhuis (1998) showed that more parameters are potential candidates to indicate driver impairment.

However, the categorisation of driving behaviour into "normal" versus "impaired" grouping in general is still a contentious procedure.

At the level of vehicle control, accidents where the driver bears the sole responsibility may result from either:

1. a loss of lateral vehicle control (e.g. lane weaving)
2. an inappropriate use of lateral vehicle control (e.g. swerving into adjacent lane)
3. an inappropriate use of longitudinal vehicle control (e.g. speeding, close following)
4. concurrent occurrence of (2) and (3) (e.g. at overtaking)
5. concurrent occurrence of (1) and (3) (e.g. skidding)

#### *Measurement methods:*

- Vehicle control (Longitudinal, lateral)
- Time headway
- Time to collision
- Speed
- Lane keeping

<b>ERROR</b>	<b>VEHICLE MEASURES</b>
<b><i>Following too closely</i></b>	time headway to lead vehicle time-to-collision (TTC) to lead vehicle
<b><i>Overtaking in face of oncoming traffic</i></b>	speed lateral position of vehicle time headway to vehicle in adjacent lane TTC to vehicle in adjacent lane
<b><i>Overtaking at junction</i></b>	speed lateral position of vehicle TTC to "give way" line
<b><i>Following too closely to overtaking vehicle</i></b>	speed lateral position of vehicle time headway to lead vehicle time-to-collision (TTC) to lead vehicle
<b><i>Changing lanes abruptly</i></b>	steering wheel activity speed lateral position of vehicle time-to-line crossing
<b><i>Straddling lanes</i></b>	steering wheel activity lateral position of vehicle time-to-line crossing
<b><i>Driving too fast for circumstances</i></b>	speed

*Table 2 Errors and associated vehicle measures for assessment of driver impairment*

#### **Driver comfort assessment**

Rosenberg and Hovland (1960) define attitudes as entities which have as well affective (e.g. this system is frustrating me and making me angry) as cognitive (I think it is safe to drive faster on this road than this system allows me) and behavioural dimensions (I often drive faster on these types of road than strictly allowed). Attitudes are related towards acceptance: a positive attitude towards a particular system may infer the behaviour of purchasing the system.

Moreover acceptance depends on mainly three aspects: (Holte in press; Rudinger, Holte and Espey, 1999), whereby the main determinants of the use of a system are driving comfort, usability, safety benefits.

#### **Measurement methods:**

- Van der Laan et al. (1997) acceptance scale (usefulness of the system and experienced satisfaction)
- Usability questionnaire
- Driving quality scale
- Willingness to pay questionnaire (Brooke et al., 1996; TRAVEL-GUIDE, 1999)

#### **HMI factors and safety**

It is of vital importance that the ADAS user interface has a high level of usability, because drivers will tend to adjust the settings of the ADAS while driving. On the other hand, for the Navigation systems, it may only be possible to adjust the set when the vehicle is not moving, still, if errors are made in the adjustment, it can lead to reduced attention to the driving task while driving.

#### **Expert evaluation**

For evaluation by experts: the AUTO-ERGO method is adjusted to satisfy ADVISORS needs.

The set of criteria of the AUTO-ERGO method is crosschecked with the "European Statement of Principles on Human Machine Interface" (EC 2000), which have also been used to compile the TRL safety checklist (Stevens 1999).

The resulting ADAS QuickCheck is a checklist for checking the human-machine interface (HMI) of advanced driving assistance systems (ADAS) on usability and safety. It is available in electronic format as a spreadsheet application. The current version is a draft version. It includes anthropometrical, biomechanical and perceptive/cognitive aspects. The checklist consists of 3 sections: general criteria;

criteria related to control (input) functions; criteria related to display (output) functions.

Due to its flexibility ADAS QuickCheck (Annex 2) is expected to be used in all phases of the product lifecycle. It is applicable for system concepts, virtual prototypes, physical prototypes, products on the markets, and generic products. In some cases not all items can be answered. However there will always be hints on imminent or potential deficiencies of the systems evaluated.

#### *ADAS QuickCheck for the Internet*

In order to provide an easily accessible version of ADAS QuickCheck, an application for the use on the World Wide Web was developed in a draft version. Using HTML as a document presentation format on the one hand and Java Script as a programming language on the other hand in one data file, which can be downloaded from the internet, allows for an elaborate open format with useful features such as:

- display only explanations/specifications, which are currently required by the user
- platform-independent solution
- option to interface a database of evaluations for intranet and internet application

#### **Standard procedures for confirmation of the testing vehicle**

In preparation of an empirical ADAS assessment, it is essential that the exact technical characteristics of the ADAS-equipped vehicle are pre-defined and tested.

Testing procedures for the ADAS sensors, specifically the ACC Radar Sensor and CCD Camera for Road Recognition are described in the deliverable D4.2 (both static and dynamic test procedures).

### 7.2.4 Assessment of road network efficiency and environmental impacts

The proposed methodology for the estimation of the impact of ADAS on traffic and environmental conditions is expected to be useful for the identification of the priorities in the development of these systems.

The proposed methodology integrates *several degrees of analysis*. Detailed existing models examine the impact of ADAS at the microscopic level. Their findings are used as input for a set of macroscopic models in order to examine the ADAS impact on a network level. Necessary inputs to the methodology include system penetration level, the demand level of the network elements, the various modelled ADA systems' functional characteristics, the driver behaviour parameters, the traffic demand and composition and the vehicle consumption/emission characteristics.

A *microscopic* traffic model produces a set of outputs, including capacity information and headway curves, which are used by the macroscopic traffic model, and speed profiles that are used by the environmental models. A microscopic environmental model calculates emissions and fuel consumption per vehicle. A macroscopic traffic model produces information on average speed for each link and the whole network considered while a macroscopic environmental model calculates emission factors and changes in pollutants per link and on a network basis (Figure 3).

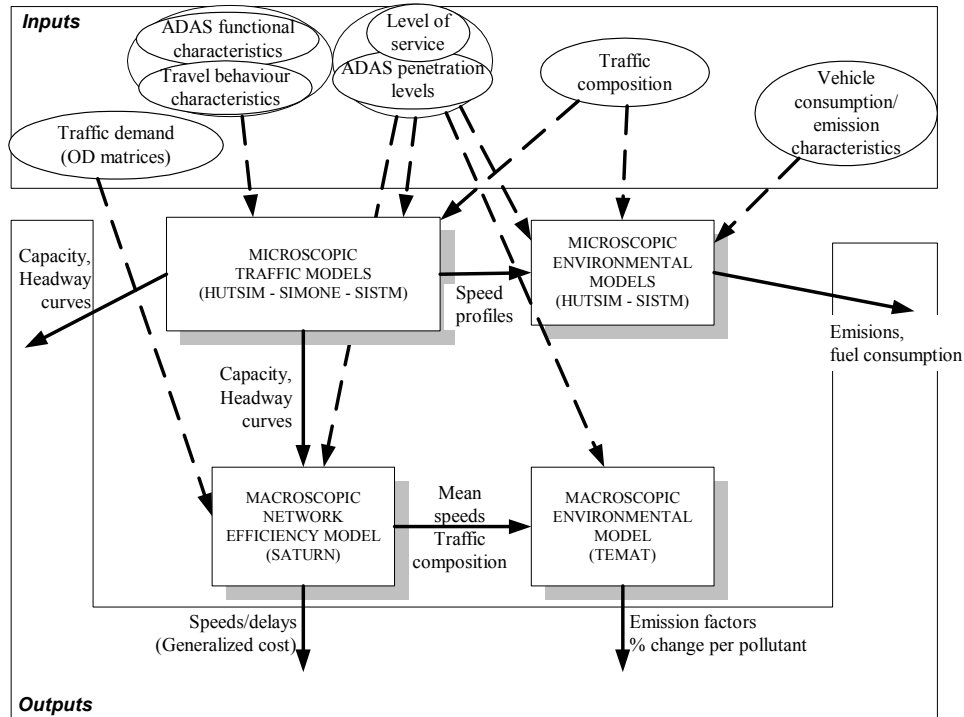


Figure 3 Overall methodology macroscopic and microscopic simulations

The scenarios that have been considered in the models are composed by a selection of the following key dimensions (of course, a number of other parameters and assumptions have been used, on a case by case basis):

- Type of impact: Traffic/ network efficiency and environmental;
- Level of impact: Microscopic and macroscopic;
- Type of longitudinal control ADAS: the two longitudinal systems that have been selected for consideration within the scope of this task are ACC and variable speed limiter (ISA). A combination of the two systems (ISA + ACC) has also been considered, while the no-ADAS base case has been included in the modelling and is used as the reference scenario.
- Penetration level: no penetration (0%) levels for the no-ADAS case, and a number of levels of penetration for the ISA, ACC, and combination of ISA and ACC (ranging from 5% to 100%); and
- Network parameters: Network configurations with urban/interurban characteristics have been used for the microscopic models. Similarly, for the macroscopic network efficiency and environmental models an urban network has been used.

The sensitivity of the simulated impacts to the prevailing demand level has also been tackled, where it was feasible.

#### The models

The *microscopic models* used are: SIMONE (Minderhoud, 1999, and Minderhoud and Bovy, 1999) from the TRAIL/University of Delft, SISTM of the Transport Research Laboratory (Stevens et al, 2000), and HUTSIM (Kosonen, 1999) developed by the Helsinki University of Technology. All these models simulate traffic conditions, while SISTM and HUTSIM also simulated environmental conditions, based on the traffic simulation that they performed.

The *macroscopic network efficiency model* [SATURN, see Hall et al (1980) and Van Vliet (1982)] uses the microscopic traffic estimates to simulate the sensitivity of traffic impacts of the introduction of ADAS. Similarly, the *macroscopic environmental model* (TEMAT, see MEET, 1999) uses macroscopic traffic information (from the macroscopic network efficiency model) to estimate the macroscopic environmental impacts of the introduction of ADAS.



The impacts of the introduction of ADAS are determined through a *with/without analysis* of several scenarios. The necessary information for this analysis is obtained by first running the models for a fleet without ADAS-equipped vehicles, and subsequently running the models again for each ADA system and combinations thereof. Thus, *ceteris paribus* the change in the network efficiency and environmental conditions may be attributed to the introduction of these systems; such changes describe the impact of the introduction of ADAS.

Concluding, a flexible methodology has been developed that can be used to examine the *sensitivity of the impact* of ADAS with respect to several parameters, such as traffic conditions, level of ADAS penetration, etc. Furthermore, the methodology has been developed in a way to allow expandability and evolution; a number of dimensions that have not been considered explicitly within this work, such as different fleet compositions, can easily be incorporated in the methodology without altering its overall structure or invalidating the existing model framework.

### 7.2.5 Relevant criteria

ADVISORS proposes to define absolute criteria by those instances of driving behaviour which are deemed to be unsafe. These criteria may be defined in a qualitative fashion, e.g. driver running off-road, or in a quantitative manner, e.g. SDLP of the vehicle surpassing a trigger level of 26 cm as in the alcohol case. For the purpose of defining impaired driving, a first focus should be on the detection of impairment within a highway driving scenario (Fairclough et al., 1993). The focus will be on the detection of three categories of driver errors: following too closely, straddling lanes and driving in excess of the speed limit.

A preliminary list of impairment criteria was proposed by Brookhuis (1995). He characterised criteria in terms of absolute levels (i.e. the cut-off point which defines impaired driving) and relative change (i.e. the relative change which indicates a significant change in individual driver performance). The criteria proposed below are based on work on the effects of illegal levels of alcohol intoxication, visual occlusion, driver inattention and prolonged journey time on driving behaviour. The tables of criteria will thus be constructed for either the group of average drivers or each individual driver. Please refer to Annex 3.

### 7.2.6 ADVISORS Toolbox

The test toolbox is a comprehensive package of tools and techniques that could be used to evaluate a variety of aspects of advanced driver assistance systems.

The toolbox consists of eight main sections:

- A. Definitions
- B. Driver profile
- C. Subjective
- D. Physiological
- E. Performance
- F. Behavioural
- G. Expert Evaluation
- H. Models of Driver Behaviour.

Within each section there are subsections including mood, attitudes, mental workload, stress and attention and within each subsection there are numerous tools and techniques (Annex 4).

Journal articles, reports and books have been collected and reviewed for each technique and tool and a summary written. These summaries can be seen in the appendix of this report.

All papers and summaries are logically stored within the Advisors toolbox. Please refer for an overview to Deliverable D4.1.

## 7.2.7 Discussion and Conclusions, Recommendations

The overview of the dependent variables is up to date and lists the important measurement methods. Still, what is to be understood, is that it is necessary to use several indicators to understand the full effect of an ADAS. It is very possible that the effects of ADAS may not show initially on driving behaviour, but that other indicators show, for instance, that the driver compensates for reduced alertness. This means that a variety of indicators is always necessary to fully grasp the processes. A mix of dependent variables is always needed, after all, the driver will adjust driving behaviour when the vehicle has an ADAS fitted.

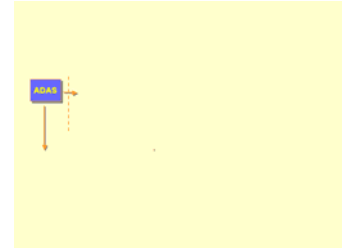
Furthermore, the evaluator has to decide whether, for instance, short trips suffice, or that longer trips may be needed, or that the drivers have to acquire more experience, or that a particular group of drivers have to be chosen. The overview of assessment parameters can help the evaluator. These issues and the fact that although reliability, validity, ways for use and level of aggregation for each measurement method is given, expert knowledge about testing is needed for viable choice and application of the measurement method.

For many tests, the standard set of measurements, as in the ADVISORS common set of measures, will (nearly) suffice.

Now it becomes important to collect criteria, to define exactly what are too high-levels, or too low-levels of particular indicators. A start has been made for this (Annex 3), but again, the problem is often that several indicators together paint the picture of a particular process.

The collection of criteria, and the collection of patterns of changes in indicators is an important task and would contribute significantly to the research in this field.

### 7.3 To identify a set of ADAS with high potential to overcome important safety hazards, road capacity bottlenecks, driver behaviour problems and environmental load in several road types.



This work has been performed under Workpackage 1 and 2 and is reported in the deliverables:

ADVISORS_Del 1a.pdf	Inventory of main problems on various road types, and selection of potentially powerful ADA systems. Actor categorisation process
ADVISORS_Del 1b.pdf	State of the art on ADA systems, their evaluation results and current implementation trends and user needs

#### 7.3.1 Problem analysis

##### Approach

Three different aspects are considered: Safety, environmental and road capacity. For each of them specific models, requirements and criteria are taken into account. It should be noticed that road capacity problems and environmental aspect are strongly related.

##### Safety problems

The approach of the safety analyses incorporates a theoretical model, which is a logical combination of generally accepted theories and models in the field of traffic psychology and information processing theory. Theories of Rasmussen, Reason, Michon, Sternberg and Endsley are integrated in order to identify type of errors from the drivers as a cause for manoeuvres listed in the accident databases, which preceded the accidents. These are also the theories applied in the work on development of the ADVISORS common assessment methodology.

Of particular importance are errors of the following type: the erroneous manoeuvres which are a result of errors made earlier in the control process and based on errors in the situation awareness. These types of errors were identified relatively frequently in the accident database analyses, and furthermore, situation awareness is of particular importance, since literature shows that operator *performance suffers due to decreased situation awareness when (parts of) the task become automated* (Endsley, 2000).

The type of errors related to situation awareness are identified as:

- *mode errors*: this important category represents errors in the internal representation and/or interpretation of the actual situation. These errors may lead to errors in the whole control chain: errors in perception (looking at the wrong aspects), faulty interpretation/anticipation, erroneous decisions and actions.
  - Mode 1 errors are: errors in the judgement of own capabilities; errors in the judgement of the vehicle's capabilities; errors in assessing the state of the environment.
  - Mode 2 errors are: related to errors in interpreting the other traffic participants' behaviour: to erroneous expectations of the behaviour of other road users; misinterpretation of other's behaviour; ignorance (correct representation is not available due to inexperience).

The probability of errors is dependent upon certain error shaping conditions that can be related to accident registration:

- external conditions e/g limitation of vision by obstructions or blinding etc
- errors caused by distraction of the driver's attention
- overload: too many tasks to be performed in a short time or too rapid changes in the traffic situation making it impossible to exert adequate control.
- underload, caused by extended absence of sufficient stimuli ("highway hypnosis")
- physical condition of the driver (fatigue, certain medical conditions, alcohol or drugs).
- intentionally deviant behaviour (e.g. reckless driving)

Databases from The Netherlands, Greece, Finland, the UK, Italy, Germany and the Czech Republic are gathered and analysed (Annex 5).

It was found that there is a common cause in the accident data: incorrect situation awareness (mode errors), which is recognised as a primary cause in 20%-34% of all accidents in these data-bases. Furthermore, intentionally deviant behaviour makes up a significant percentage of the accidents. In Finland, alcohol use and in the Czech Republic, adverse road conditions are error shaping conditions that occur widely.

### Environmental problems

From literature research it was found that reducing fuel consumption is a main objective:

- limitation of road traffic:
  - influencing pre-trip choices: change towards use of different forms of public transportation
  - stimulating the use of non-motorised vehicles for private transport
  - optimal combination of the use of private- and public transportation (e/g by using on-trip information on public transport)
  - using dynamic taxation as a mechanism to control the use of private vehicles
  - limiting access by motorised vehicles to certain protected areas (e/g national parks etc.)
- regulation/ stimulation of fuel-saving driving behaviour:
  - purchase/use of fuel-efficient vehicles
  - promoting an efficient driving style by improved use of accelerator and gear shift
  - speed control
- traffic management

### Road capacity problems

Results as far as could be found mainly show the following pattern:

- congestion is mainly a problem inside built-up areas and on motorways
- the congestion on motorways is strongly related to problems in the built-up areas that are the targets for the traffic on the motorways and to interconnections of motorways
- congestion of secondary road seems most strongly related to mixed traffic
- high traffic demand is always a basic cause: this will occur daily during commuter traffic (rush hours) and also periodically during the holiday season
- another fundamental cause is a high concentration of people in limited areas
- in the former eastern European countries the quality and maintenance of the infrastructure may sometimes be a decisive factor.

## 7.3.2 State of the art and user requirements

### Identification of ADAS

An overview is produced of types of ADAS and their categories (Table 3; please refer to ADVISORS deliverable 1/2.1. and 1.2 and Annex 6). It should be noted that many of these ADAS are now being combined to create more sophisticated functions. The trend towards further integration of functions is evident. The main focus within ADVISORS is upon pre-crash systems.

<i>Overview of ADAS types</i>
<p><b><i>Navigation based function</i></b></p> <ul style="list-style-type: none"> <li>• Enhanced navigation, navigation routing</li> <li>• Integrated navigation</li> <li>• Real time traffic and traveller information – distributed navigation</li> </ul> <p><b><i>Driver monitoring</i></b></p> <ul style="list-style-type: none"> <li>• Driver vigilance monitoring</li> <li>• Driver health monitoring</li> </ul> <p><b><i>Vehicle status monitoring</i></b></p> <ul style="list-style-type: none"> <li>• Tachograph (data recorder)</li> <li>• Vehicle diagnostics</li> </ul>

<p><b>Longitudinal control</b></p> <ul style="list-style-type: none"> <li>• Speed control (ISA)</li> <li>• Adaptive Cruise Control (ACC)-Stop and Go</li> </ul> <p><b>Lateral control</b></p> <ul style="list-style-type: none"> <li>• Road departure /lane departure collision avoidance</li> <li>• Lane change and merge collision avoidance</li> <li>• ACC + Curve Management</li> <li>• Curve Warning</li> </ul> <p><b>General control</b></p> <ul style="list-style-type: none"> <li>• IVHS-platooning</li> <li>• Overtake checker</li> </ul> <p><b>Collision avoidance</b></p> <ul style="list-style-type: none"> <li>• Rear End Collision avoidance - Pre-crash sensing</li> <li>• Obstacle detection - pedestrian detection</li> <li>• Intersection collision avoidance</li> <li>• Rail-road crossing collision avoidance</li> </ul> <p><b>Perception</b></p> <ul style="list-style-type: none"> <li>• Vision enhancement</li> <li>• Electronic mirror</li> <li>• Blind Spot detection</li> <li>• Reversing Aid / Parking aid</li> <li>• State of the road surface ; low friction warning</li> </ul> <p><b>Man-Machine Communication</b></p> <ul style="list-style-type: none"> <li>• Automated transactions – electronic toll collection</li> </ul> <p><b>Driver convenience communication</b></p> <ul style="list-style-type: none"> <li>• On-board hands-free functions</li> <li>• Driver identification and automatic cockpit configuration</li> </ul>
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Table 3 Overview of general ADAS types

**Identification of technical capabilities and scope**

Having identified the ADAS it is then necessary to identify the technical capabilities, scope and range of operation of the ADAS. This can be done using the following structuring principles:

<b>Characteristics of ADAS</b>
<p><b>Levels in the driving task which are supported by the ADAS</b></p> <p><b>Subtasks supported by the ADAS</b></p> <p><b>Feedback types from ADAS</b></p> <p><b>ADAS Application Domain:</b></p> <ul style="list-style-type: none"> <li>• User Categories</li> <li>• Vehicle types</li> <li>• Road types</li> <li>• Scope of the ADAS function</li> <li>• Infrastructural support needed</li> </ul>

Table 4 Structuring principles ADAS characteristics

### 7.3.3 ADAS shortlist

Finally, ADVISORS has decided upon a shortlist of ADAS to continue with (Figure 4). The following considerations have played a major role in the choices made (Only those systems are listed for which there are reasonable data availability / collectability to be able to organize pilots or perform research in the other parts of ADVISORS)

ADAS functionalities that are expected to have:

1. Positive Safety impact, or
2. Negative Safety impact, and/or
3. Market penetration expected to be significant (2000-2010), and/or
4. Key actors want it, and/or
5. Positive effect on environment / traffic fluency

Sometimes, the expectancies are mixed for a system: both positive and negative safety impacts can be expected. Sometimes there are mixed empirical results; sometimes the pattern of effects of the ADAS on driving behaviour is very diverse.

<p><b>1. Positive safety impacts are expected for:</b></p> <ul style="list-style-type: none"> <li>• ISA</li> <li>• Blind spot</li> <li>• Driver Vigilance Monitoring</li> <li>• Emergency Call</li> </ul>
<p><b>3. Significant market penetration (2000-2010) expected and 2. possibly negative Negative safety impact for:</b></p> <ul style="list-style-type: none"> <li>• ACC</li> <li>• ACC &amp; Stop and Go</li> <li>• Enhanced Navigation</li> <li>• ISA &amp; ACC</li> </ul>
<p><b>4. Key actors (e.g. fleet owners) want it:</b></p> <ul style="list-style-type: none"> <li>• Navigation &amp; Fleet planning</li> <li>• Integrated Navigation</li> <li>• Enhanced Navigation</li> <li>• Driver Vigilance Monitoring</li> <li>• Emergency Call</li> <li>• ACA</li> </ul>
<p><b>5. Positive effect on environment / traffic fluency</b></p> <ul style="list-style-type: none"> <li>• ACC</li> <li>• ISA</li> <li>• ISA &amp; ACC</li> <li>• Enhanced Navigation</li> <li>• Integrated Navigation</li> <li>• ACA</li> </ul>

Table 5 Criteria and Choices of ADAS for the ADVISORS Shortlist



Figure 4 ADAS extended shortlist for analyses in various parts of the project, decided by ADVISORS

The ADVISORS shortlist with the key fields of interest follows below. For an extensive description of the systems, refer to the Annex 7.

ADAS	ADVISORS analyses
Adaptive Cruise Control (ACC)	Actor analysis, Risk analysis (Technical, Behavioural, Legal) Empirical pilot study, Future scenarios, MCA, Implementation strategies
(ACC and) Stop&Go (S&G)	Risk Analysis (Behavioural) Empirical pilot study, Future scenarios, MCA
Intelligent Speed Adaptation (ISA)	Actor analysis Risk analysis (Technical, Behavioural, Legal) Simulation study, Future scenarios, MCA, Implementation strategies
Lateral Support System (LSS) / Lane Change Support (LCS)	Risk Analysis (Legal, Behavioural) Empirical pilot study, Future scenarios, MCA, Implementation strategies
Driver Monitoring System (DMS)	Actor analysis, Risk analysis (Technical, Behavioural) Empirical pilot study, Future scenarios, MCA, Implementation strategies
Navigation System and Fleet Management (NAV)	Actor analysis Risk analysis (Technical) Empirical pilot study
Integrated ADAS (comprising of: Dynamic Navigation, ACC, S&G and ISA)	Actor analysis, Future scenarios, MCA, Implementation strategies

Table 6 The ADVISORS Shortlist and analyses

### 7.3.4 Discussion and Conclusions, Recommendations

From the accident analyses and the other problem analyses it can be concluded that in general the attention should be drawn to ADAS which: Increase situation awareness (Help with the interpretation of the situation or the behaviour of other drivers and with predicting the effect of own actions); Prevent adverse driver conditions; Prevent incorrect overtaking and merging/turning, Prevent intended violations; Prevent distraction of attention and/or Reduce information load at crossings and intersections.

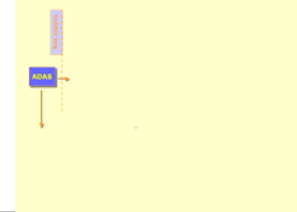
The choice of potentially important ADAS is based on the manoeuvres causing most of the accidents (mainly inside built up-area): Head/tail collisions, Turning, Obstacle collisions, Frontal collisions and intersection collisions.

Based on previous results and these considerations, potentially the most powerful ADAS are Intelligent Speed Adaptation (ISA: speed reduction), information- and vision enhancement and attention directing systems, e.g. Navigation systems (particularly for complex road crossings), blind spot detection systems and driver vigilance and health monitoring systems (DMS).

The accident analyses suffered from lack of standardization of the national databases: the elements are all differently defined. The CARE data base is European, but is less specific than most of the national databases. However, the results show a clear picture, which is also in line with other publications (e.g. the White Paper).



## 7.4 Development and execution of a multidimensional risk analysis



This work has been performed under Workpackage 3 and has been reported in the Deliverable:

ADVISORS_Del 3a_8a.pdf	Part I: Compendium of existing Insurance schemes and Laws risk analysis of ADA systems and expected driver behavioural changes.
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### 7.4.1 Approach

The basic approach to the risk analysis within ADVISORS has been based upon a FMEA (Failure Mode and Effects Analysis) methodology. The relevant methodology is really innovative, as FMEA so far has been used strictly for technical risk assessment.

FMEA aims to determine the relationship between failures, malfunctions, operational constrains, and degradation of performance. It determines the effect of each failure on the system and those failures critical to system success or personal safety, called *single failure points*. It also ranks each failure according to the criticality of the consequences and the probability of occurrence. This procedure is the result of two steps; Failure mode effect analysis and critical analysis (together abbreviated as FMECA).

Performing a FMEA starts with defining the system to be analysed, constructing a block diagram and finally identifying all potential items and interface failure modes.

FMECA steps	Explanation
<b>System definition</b>	Definition of its functional, environmental and regulatory requirements. This includes the systems' primary and secondary functions, system constraints, acceptable and unacceptable performance, etc.
<b>Development of block diagrams</b>	The diagrams should show relationships of the different elements and the interdependencies between them. More than one diagram may be needed to show the different modes of operations. A task analysis or fault tree analysis may be used for this.
<b>Failure modes, causes and effects</b>	Identification of failure modes, their cause and effects, their importance and their sequence. This identification can be enhanced by the use of a list of failure modes. The failure effects identified at the lower level, may become failure modes at a higher level.
<b>Design alternatives</b>	Identification and evaluation of design alternatives like elements that allow continued operation when one or more functions fail, or the identification of alarm devices.
<b>Criticality of failure mode</b>	It may be relevant to quantify the criticality of a failure effect. This can be done by defining a list of critical failures for each item of equipment, based on their consequences.
<b>Probability of failure mode</b>	Probability of occurrence can be estimated using reliability databases and is expressed in for example $p = 0.005$ , which means that the failure occurs 5 times out of one thousand. Another option is to rate probability according to the following levels: Frequent, Probable, Occasional, Remote, Unlikely.
<b>Criticality evaluation</b>	The evaluation of criticality may be undertaken using a criticality grid. It must be noted that in many circumstances the probability or criticality scale is non-linear.

Table 7 FMECA steps and their explanation

The following table was used to summarise the issues. Each issue was assigned a severity. Strategies for reducing (mitigating) the problem were considered, whenever possible, and the probability of their success was assessed.

ADAS function	Technical Issue and Actors affected	Problem severity (now)	Mitigation strategy	Mitigation possibility
.....	.....	.....	.....	.....

Table 8 Tabular format for the technical risk analysis of ADAS

The relevant indicators of *severity*, *occurrence probability*, *detectability* and *recoverability* have been expanded to cover not only technical risk but also *behavioural*, *legal and organisational – related* risks. For each identified type of problem, the failure effect, cause, detection and recognition and mitigation strategy are also defined. Here, it is *implementation risk* that is being considered. Risks represent potential barriers to implementation of the ADAS and need to be explored, assessed and minimised or neutralized. The developed methodology includes supporting information, checklists and forms to assist in: *analysis* of the four "domains" (technical, behavioural, legal and institutional); *assessment* and presentation of the main risk issues; *development* of possible approaches to reducing risk (mitigation strategies). A formula has been developed to quantify the overall level of risk:

$$Risk = Severity \times Occurrence\ probability \times ((Detectability + Recoverability)/2)$$

This formula is applied to generate a risk number: the Technical Risk Number (RNT).

The analysis is performed as follows:

1. First a description of the context of the analysis is made: an explanation of the type of system under review, identification of the actors and stakeholders involved.
2. Next an examination of the likely scenarios of use of the system is made.
3. Then the risks of each of those issues are assessed and possible mitigating strategies identified.
4. The main issues are summarised according to the format below and assigned an overall risk (or threat) rating.
5. In addition, the issues with a significant risk are further analysed to determine the possibility of mitigating strategies. The possibility of a successful mitigating strategy (over a 10 year horizon) should also be assessed and rated.

*Issue severity* is distinguished at the levels: Insignificant, Slight, Moderate, Severe, Extremely severe. Each level has a well defined description.

*Mitigation possibility* is distinguished at the levels: Improbable, Low, Medium, High. Each level also is previously defined.

*Risk reduction* is an iterative process involving dependencies between the different issues. In terms of mitigation strategies, risk can be reduced in a number of generic ways:

- reducing the magnitude (severity) of the consequences of the potential risk;
- reducing the probability of the risk occurring;
- increasing failure detection speed and probability;
- protecting against the risk
- mitigating strategies to compensate for a failure (e.g. back-ups);
- transferring the risk to another Party.

#### 7.4.2 Technical Risk Analysis

Then, using the above methodology, technical risk analysis was performed for a selected number of ADAS, which include:

ADAS	State of the Art, ADVISORS D1.2
ISA (Intelligent Speed Adaptation)	Paragraph 3.4.4.1 Speed Control
DMS (Driver vigilance and health monitoring systems)	Paragraph 3.4.2 Driver monitoring
ACC (Adaptive Cruise Control)	Paragraph 3.4.4.2
Extended Navigation System	Paragraph 4.1.2 Integrated Navigation
Route guidance navigation and vehicle status system (mainly for truck applications)	Paragraph 3.4.1.1 Enhanced navigation, navigation routing, and paragraph 3.4.9.2/3 Driver convenience communication

Table 9 ADAS selected for the Technical Risk Analysis

The selection of these 5 ADAS – cases to apply the relevant methodology was performed according to a few additional factors as to the ADAS Shortlist, such as:

- *technological maturity* status (it is difficult to perform technical risk assessment, if not enough prototypes and test reports on them exist in the literature);
- *implementation priorities*, as recognised in ADVISORS D1 (target ADAS which implementation is imminent);
- *coverage of the issues* (to extend the analysis to all technical fields of ADAS, covering longitudinal and lateral control, private and professional applications, cars and trucks, and as many technological fields as possible).

### Conclusions on Technical Risk Analysis

Refer to Annex 8 for an overview of the results. The major open questions to be studied during the Project Pilots are:

#### The major open questions

##### For ISA:

- Impact of action feedback and explanation of this feedback to the driver using various HMI layouts (i.e. "Your speed is reduced to \_\_\_\_\_ because of a \_\_\_\_\_ km/h speed limit).
- Driver overriding the system or not. Calculation of optimum system re-activation time out in cases of an overridable system.

##### For driver vigilance and health monitoring:

- Test different types of warning media combinations to find the most secure combination.

##### For ACC:

- Define optimum thresholds on the time of the throttle control and speed change (both minimum and maximum), in relation to specific scenarios of use.
- Define the optimum embedded time out of visual and audio warnings.
- Define the driver training required to operate the system safely.

##### For extended navigation:

- Define the optimal strategy and HMI of driver feedback, simulating various system errors / inaccuracies,
- Define the optimal combination of redundant driver warning modalities.

##### For route guidance, navigation and vehicle status / position monitoring for truck applications:

- Define the limits and optimal content of transmitted message lengths for a list of key communication functionalities.
- Optimise the HMI of exchanged messages, to minimise the required driver / base personnel training and enhance systems safety.
- Simulate a few complex message exchanges to verify the message understandability and involved actors' interactions, using the proposed vs current message contents and layouts.

Table 10 Major open questions on Technical Risk Analysis

### 7.4.3 Behavioural risk analysis

The introduction of ADAS, as with any changes to the driving environment, may lead to changes in driver behaviour. However, the nature of these behaviour changes in response to changes in the driving environment, has on occasions proved to be the opposite of that which was intended. Grayson (1996) pointed out that 'people can respond to innovation and change in ways that are unexpected, unpredictable, or even wilfully perverse'. For example, Adams (1985) claimed that the introduction of seatbelts in vehicles leads to a perception of greater safety, in turn leading to drivers increasing their speed on the road.

It has been suggested that improved safety cannot be predicted directly from the efficiency resulting from improved technology, as people adapt to some kinds of improved efficiency by taking more risks, (Howarth, 1993). The introduction of safety measures may lead to compensatory behaviours that may reduce the benefits of the measures being implemented. This phenomenon has most recently been described as 'behavioural adaptation', (OECD, 1990). However previous models explaining the behaviour have termed it as 'risk compensation' and 'risk homeostasis'.

The following approaches are discussed: effects of automaticity, Locus of Control, Models and Theories of Behavioural Adaptation (Risk Homeostasis, Risk Compensation, Utility Maximisation, Threat Avoidance, Behavioural Adaptation, Empirical Evidence).

Certain factors were identified for consideration in the behavioural assessment when relevant. Thus, the influence of ADAS use on the driving task/individual driver behaviour can depend on:

- Human sense addressed
- Degree of driver control/ADAS automation
- Timing and "intelligence" of ADAS action
- ADAS interruption in driver scripts/routines
- Driving skill and experience of user
- Driver's motive of using and not using ADAS
- Driver's comprehension of ADAS functionality and limitations
- The drivers' experienced pros and cons of the ADAS
- Driver's attitude to and acceptance of ADAS
- Level of integration of discrete ADAS

At the individual driver's level ADAS use can lead to different types of behavioural changes (in risk analysis mainly problems). These changes can be divided into:

- Perceptive changes (seeing, hearing, feeling)
- Cognitive changes (comprehending, interpreting, prioritising, selecting, deciding)
- Performance changes (driving, system handling, error, behavioural adaptation)
- Driver state changes (attentiveness/awareness, workload, stress, drowsiness)
- Attitudinal changes (acceptance, rejection, overtrust, mistrust)
- Changes in adaptation to environmental conditions (weather)??

<b>ADAS</b>	<b>State of the Art, ADVISORS D1.2</b>
ISA (Intelligent Speed Adaptation)	Paragraph 3.4.4.1 Speed Control
DMS (Driver vigilance and health monitoring systems)	Paragraph 3.4.2 Driver monitoring
ACC + S&G (Urban: Adaptive Cruise Control and Stop and Go)	Paragraph 3.4.4.2
Navigation System	Paragraph 3.4.1.1
Blind Spot system	Paragraph 3.4.8.3
CAS (Collision Avoidance System)	Paragraph 3.4.7.1

Table 11 ADAS selected for the Behavioural Risk Analysis

### Conclusions on the Behavioural Risk Analysis

Please refer to Annex 9 for the results. In general, major problems are related to the adaptation of drivers' behaviour, overreliance on the systems, diverted attention, reduced situation awareness or lack of training.

<i>ACC Adaptations in driver behaviour</i>	
<i>Short term</i>	<i>Long term</i>
Mistrust: distrusting the ACC system	Spare capacity: using spare capacity for other in-vehicle tasks
Brake pedal forces: increasing brake pedal forces	Over-reliance: relying too much on the ACC system Fatigue: ACC could take over too many driving tasks causing fatigue
Imitation: unequipped vehicles imitate equipped vehicles	Quick approach to vehicle in front: the development of new behaviour
Reliance on vehicle in front: vehicle in front might have poor driving behaviour	Time-headway: driving with smaller time-headways Indication for overtaking: use ACC as an indication of when to overtake Overtaking: difficulties with overtaking and being overtaken

Table 12 Behavioural Risk analysis on ACC

<i>DMS Adaptations in driver behaviour</i>	
<i>Short term</i>	<i>Long term</i>
Reliability and trust: Drivers may choose for reliance on the system instead of performing self regulating activities and use the warnings as alarm clock. Maybe too late, because most of these systems warn <i>after</i> a dangerous action	Drivers adapt to sensors: Change driving style as a compromise to the sensor because they know they are monitored. Especially when the system is linked to black box
Warnings: Early warnings can help the driver in self regulation; Late warnings can interfere negatively with the driving task	Drivers with specific needs may increase exposure and rely on the system

Table 13 Behavioural Risk Analysis on DMS

<b>ISA Adaptations in driver behaviour</b>	
<b>Short term</b>	
<p>Drivers tend to compensate by driving faster through junctions and other tracks</p> <p>Drivers' arousal may drop</p> <p>Smaller Gap acceptance: The mandatory or variable systems seemed to cause smaller gaps than when not using the system. No such effect was demonstrated for the driver select system.</p> <p>Closer car-following: More close following (less than 1 s) in both rural and urban areas.</p> <p>More frustration and time pressure experienced by drivers using a mandatory system</p> <p>Highest speed reductions found in case of incidental warnings in stead of continuous (warning type ISA)</p>	

Table 14 Behavioural Risk Analysis on ISA

<b>CAS Adaptations in driver behaviour</b>	
<b>Short term</b>	<b>Long term</b>
<p>Negative affect, irritation, unwanted interference by driver: Intervention may occur when the driver does not perceive the situation as hazardous.</p> <p>Intervention by the system can have the effect that there occur dangerous situations for the surrounding traffic; they may have difficulty adjusting their behaviour</p>	<p>Drivers may change driving style in order to prevent the system to interfere (e.g. staying in the left lane)</p>

Table 15 Behavioural Risk Analysis on CAS

<b>Navigation systems Adaptations in driver behaviour</b>	
<b>Short term</b>	<b>Long term</b>
<p>Necessary is training and accommodation to the system, to learn how to understand the system, otherwise attention will be diverted from driving when using the system, tendency to solve navigation problems primarily. Mental stress.</p> <p>By using the system, also after training, attention is diverted from external transport environment - watching standard traffic signs and information boards, reduced watchfulness and ability to anticipate situations</p>	<p>Drivers will have a tendency to utilise acquired time and mental capacity in a "more useful" way - telephoning, executing business matters, conversation</p> <p>Regressive adoption of the standard navigation using maps and information traffic signs - i.e. a problem to be solved (how long does it take, what problems are involved, how dangerous it is, within what time period and how much of his/her ability</p>

Table 16 Behavioural Risk Analysis on Navigation systems

<i>Blind Spot Adaptations in driver behaviour</i>	
<i>Short term</i>	<i>Long term</i>
Attention concentrated onto vehicle interior, onto watching the indicator,	False sensation of safety, transfer of responsibility to an external subject,
Suspense in respect of its utilisation and of reactions during a training period.	Reduction of cognitive activities, danger of overlooking another action off the vehicle  Accommodation time in the case of transfer back to driving vehicles not equipped with these systems, the so-called "grow-lazy effect" elimination of this activity from the set of learned procedures when driving vehicles (both upon transfer to a different vehicle and upon failure or disconnection of the system in a vehicle used for a long time-period),

Table 17 *Behavioural Risk Analysis on Blind Spot*

#### 7.4.4 Legal and insurance risk analysis

##### **Approach**

ADVISORS targeted the analysis of the legal, insurance and organizational issues, of ADAS through a multi-step approach. Initially the relevant legal, institutional and insurance framework in each European country has been considered, including the road accidents liability regimes, the product liability laws and the insurance schemes. That has been extended to the second step by the review of other research work on the subjects coming mainly from the EU Research project RESPONSE (TR 4022) and the analysis of three of its Deliverables, namely D7.1, D7.2 and D7.3. These two steps led to the preliminary identification of gaps and barriers to the implementation of ADAS, stemming from legislation, organizational or insurance issues, which have been included in sections 5 and 6 of ADVISORS D3/8.1.

As a consequence the Consortium developed two specific questionnaires, one on legal/insurance and another one on organisational issues that were used in interviews with experts to get more detailed feedback on the recognised potential problems. They are briefly described below, within this section.

The gathered answers were used to produce a first consensus document on such issues, which was discussed at three Workshops, on legal and organisational issues, performed in Athens (Greece), Thessaloniki (Greece) and Apeldoorn (the Netherlands). In these Workshops the issues of T3.3 (legal) and T3.4 (organisational) were discussed jointly, as several experts would cover both fields of knowledge.

The revised results, following the aforementioned Workshops, were used by the Consortium experts to fill-in the legal and organisational issues Risk Analysis tables of FMEA methodology, as set in ADVISORS D3/8.1 (section 2). For this action, additional input from Partners' contacts and literature survey has also been utilised.

Finally, based on the gaps/barriers, mitigation strategies and priorities recognised within these tables, specific implementation policies, as well as actions for further research are proposed. The final results of this work are then to be used as input for ADVISORS WP7, in combination with the input from other work streams of the project, to result in a common recommendations framework.

##### **Legal and Insurance issues Questionnaire**

One of the initial key recommendations based on a preliminary analysis on legal and insurance issues within ADVISORS D3/8.1, has been that such issues cannot be dealt with in a generic way, i.e. giving generic answers to generic questions. Liability of the driver versus the system manufacturers, including insurance companies, car manufacturers, system developers, etc. is likely to be looked upon on a case by case basis at the court. Hence, useful results may only then derive if one considers specific ADAS as well as application scenarios for them. The analysis has been performed on the following ADAS:



ADAS	State of the Art, ADVISORS D1.2
ISA (Intelligent Speed Adaptation)	Paragraph 3.4.4.1 Speed Control
Lateral Support System (LSS) / Lane Change Support (LCS).	Paragraph 3.4.5.1
ACC (Advanced Cruise Control)	Paragraph 3.4.4.2

Table 18 ADAS for the Legal and Insurance Risk Analysis

This was the reason why 6 specific scenarios were proposed. The scenarios cover the following cases, some of them including different sub-cases:

**Scenario 1:** Accident avoidance due to the use of an ACC (warning) system as well as accident occurrence in the case of platooning, despite the existence of an ACC (warning) system.

**Scenario 2:** Accident avoidance due to the use of a lane deviation (warning) system as well as accident occurrence because of road departure, despite the existence of a lane deviation (warning) system.

**Scenario 3:** Accident avoidance due to the use of a lane exit (warning) system.

**Scenario 4:** Accident avoidance at intersection due to an intervention type of ACC as well as accident occurrence due to another vehicle sudden changing lanes, in spite of the existence of an intervention type of ACC.

**Scenario 5 and 6:** Accident occurrence due to a vehicle speed limitation (ISA) system (in different traffic situation).

Furthermore, in several scenarios and sub-scenarios there are various cases, depending upon the re-action of the driver to the system warnings.

The questionnaire survey results are analysed both case per case and in accordance with the overall conclusions.

## Results

It is made clear, that the respondents start having doubts regarding the inclusion of an ADAS in the insurance premium from the minute the system intervenes into the driving function. It is surprising how cautious the insurers are in front of a case where the driver shares the control of the vehicle with the system. More precisely, the comments made are cited below.

- Need for profound research on accidents' rate. It was emphasised that the system's effect on the accidents rate should be monitored for several years before any decisions can be made. The benefits of the system should be evaluated for a long time, so as to see its effect on accidents, i.e. prove the decrease of accidents, after the system becomes widely implemented.
- Intervention of ADAS into the driving functions seems too ambiguous. The doubt detected through the responses on systems that intervene into the driving function was clearly stated in the following comment: Functionalities that take over part of the driver's control over the car have also a reverse side. There is a doubt whether this functionality leads to the driver's losing the rest of the control, in case s/he is not familiar enough with the system and under special circumstances (e.g. especially on a slippery road). Does the driver trust too much the auto-control of her/his car and lacks her/his own attentiveness?
- Need for signalling the ADAS equipped vehicles. Another point made concerns the signalling of vehicles equipped with ADAS. The concern was expressed in the following question: Can those drivers who come behind the ADAS car see this kind of function to avoid a rear-end collision?
- Need for predictive data on implementation strategies. Predictions such as "when would e.g. half of the Finnish car fleet be equipped with such a system?" are necessary to be answered primarily (penetration rate).



**Driver's liability**

The responses clearly show that it is highly unlikely that a driver will be able to defend him/herself based on the fact that an ADAS did not operate properly. Her/His responsibility is in all cases found higher than any other factor's responsibility, when the driver is not unanimously held liable. The idea behind this is that the ADAS are supposed to be clearly advisory systems. As such, they cannot substitute the driver's duty for alertness in whichever case. The driver can therefore in no case claim alleviation from liability. Most probably he/she wouldn't be able to chain "shared liability" from the manufacturer either.

However, it is clear that the respondents' opinions were divided as soon as the system function was interfering with the driver's performance. Even then, the driver may have accumulated the highest responsibility, but the responses showed a clearly reduced polarity. The case that accumulated the respondents' most doubts was the implementation of the Collision Avoidance System, where the automatic braking functionality did not perform as expected.

As for alleviative elements, the respondents claimed that there are basically none to completely excuse the driver's unsatisfying performance. It should be underlined however that as long as intervening systems are involved, the experts questioned found more reasons to alleviate the driver from part of her/his liability.

**Vehicle owner's liability**

The vehicle owner is in general found not liable. However, the owner's liability depends on the situation/relation between the driver and the owner. More precisely, when the driver is undoubtedly responsible for a bad driving performance, e.g. tired, sleepy, drunk, then no liability can be really placed on the owner. There are cases, e.g. car hire, employer/employee situations or situations where the owner has knowingly given her/his consent to a driver not fit to drive, when the owner can be indeed held liable. In addition to the above, there are legal regimes that establish co-liability of the owner of the car. In these regimes, car owners can be held liable for damage caused by their vehicles, regardless of fault of the driver or the owner. Below is given an overview of the comments made with regard to the owner's liability:

**ADAS manufacturer liability**

In general the ADAS manufacturer is not held liable in most cases. The situations where the ADAS manufacturer can be considered liable are those when the system does not perform according to its specifications, including the case of complete failure of the system. In these cases the liability is shared between the driver and the manufacturer. In all other cases the manufacturer is not to be held liable, unless there is an issue of defective product specifications or lack of appropriate warnings/instructions.

*At this point it would be worthy initiating further examination on what would be the effects on the verdict when the system is obligatorily imposed, by a EU policy for example.*

An overview of the comments made to support the manufacturer's liability is cited below.

**Car manufacturer liability**

If car manufacturers deliver their cars (optionally) equipped with ADAS systems, as is for instance the case with ACC, they are liable on the same grounds as the producer of the system. In case a defective system caused an accident, injured parties can choose who they want to hold liable for their damage, the system manufacturer or car manufacturer. In many cases, it will be more convenient for them to hold the car manufacturer liable for their damage.

Only when systems are installed after purchasing the car (after market), then there may be a difference between liability of the system manufacturer and the car manufacturer.

**Traffic Authorities' liability**

The opinion of the respondents with regard to the traffic authorities' liability was in general divided. No conclusive answer on the authorities' responsibility was given.

Several examples were given on alternative driving behaviour that would have lead to the accident's avoidance and would further burden the driver.

In the case of the two scenarios in which a non-overridable system implementation was investigated, the fact that the system is non-overridable does not seem to affect the driver's liability, according to most of the answers. However no clear opinion can be concluded on the issue.

## General Issues

### Type of road effect

The type of road seems to be, according to the respondents, more important in those cases where the ADAS does intervene into the driving function. Most probably, the reason for this is that in such cases the liability for a bad manoeuvre may be shared between the driver and the system (which “takes initiative”).

Hence, the respondents have claimed that there is or should be no effect of the road condition on the liability verdict of the driver, as the driver is expected to always take the type of road s/he is driving on, into consideration. In the last scenarios, however, where the system is interfering with the driving behaviour, the answer to the same question is “maybe”. Below is given an overview of the remarks made:

- ❖ The Highway Code states that the driver should appropriately adapt driving to the type and condition of the road.
- ❖ It is possible that the type of road plays a role in the question of liability: there may well be a difference in judging a case of accident that took place on a motorway and on a road with a 30 mph limit.
- ❖ The extent to which the type of road affects the liability verdict burdening the different factors involved (driver, owner, ADAS manufacturer, etc.) depends upon the predefined specifications of the system, as well as on the road specifications, with regard to its capacity in supporting such systems.

### Corporal damage effect

The corporal damage would not alter the initial responses of the experts questioned, even though it could aggravate the penalty charging of the driver.

### Review of responses

The remarks made above, reveal the need for a concentrated campaign before implementing ADA systems. The need for preparing the drivers and the car industries for a smooth and effective mass implementation is made clear.

Special Centres could be assigned the systematic and profound training of drivers that will be future ADAS–equipped vehicles’ drivers. Concrete and solid curricula, use of simulators, preparation of appropriate and concise on-road tests will be the material that has to be carefully prepared and provided before any action is taken. To this effort, the assistance of the car manufacturers is irreplaceable. The manufacturer’s expertise but also a significant part of the required infrastructure are requested as a “must” support. The promotion of ADAS–equipped vehicles is to a great extent depending on the public awareness and therefore should concern all parties involved, this including authorities, car industries, ADAS industries, drivers’ trainers, etc.

### Overall Conclusions on Legal issues

Major findings regarding legal aspects work, can be summarised as follows:

- The concept of “reasonable safety” has to be defined and then promoted against the current “strict liability” concept, regarding ADAS application; in order to be able to enter the Market in high penetration rates in the foreseeable future.
- Manufacturers need to promote relevant R&D as well as driver training activities on ADAS, to be protected against product liability claims.
- The current vehicle type approval needs to be adapted, to include ADAS; with the development of relevant homologation procedures.
- The burden of proof of liability, as a starting points needs to rest upon the manufacturer.
- It should be taken care that ADAS do not store driver or vehicle data, nor enhance driver responsibility in case of an accident.
- The types of road and other operational conditions and limitations of the ADAS should be clearly defined in its manual and highlighted, in accordance to the local conditions, in each translated/national version. The need for additional incentives by the manufacturers, related to drivers’ training in the use of ADAS, needs to be further investigated.

- There might be cases where not only the driver, but also the owner of the vehicle might be held responsible, e.g. in car hire, employer/employee situations or situations where the owner has knowingly given his/her consent to a driver not fit to driver his/her vehicle. In some legal regimes, the owners co-liability applies in general.

### **Conclusions on Insurance issues**

The main conclusions of ADVISORS work on ADAS relation to insurance schemes and policies are the following:

- In principle, insurance companies are interested in promoting safety, by supporting new technological aids, but safety is not their ultimate goal.
- Current practices followed in car insurances may not be characterised as very “innovative”.
- Motor vehicle insurance premium setting, is based on statistical principles, creating a time-lag problem towards new technologies.
- Furthermore, current insurance databases seem not to be adequate to build up ADAS accident records.
- Insurance companies would not voluntarily promote safety ADAS that are not highly accepted and wanted by their clients; even if they may have a high safety potential.
- Although no current insurance scheme or practice would officially hinder the coverage of an ADAS equipped vehicle, insurance companies are expected to require guarantees, as far as liability is concerned.
- The best chance to bridge the existing time lag problem and get insurance companies support of ADAS, is to use their marketing budget for a possible 5-10% reduction of the insurance fee, when acquiring certain ADAS types.

### **7.4.5 Organisational risk analysis**

On the basis of workshops and questionnaires the following major organisational issues and relevant suggestions identified are:

- Inadequate driver training: The biggest obstacle in ADAS application to professional vehicle fleets is the inadequate driver training. Specific driver training packages on ADAS are thus required as well as incentives (i.e. public finance, counter-finance by car/system manufacturers), to speed-up and optimise their application. This training subsidy could be provided to the drivers for their skills improvement, rather to their companies.
- Properly adapted national manuals: The ADAS manual needs not only to be translated to the different languages, but to be adapted to the local road network and even drivers mentality conditions, to guarantee their proper application in each area.
- Set proper implementation priorities: The highest priority ADAS for professional drivers and their transportation companies representatives was driver hypovigilance monitoring, whereas the least wanted was ISA; in spite of the fact that most trucks have already speed limiters.
- Workplaces is skills effect: Although the application of ADAS may shift working hours or even job types (i.e. less need for personnel in planning department, more in specialised equipment procurement and maintenance), the feeling is that the overall number of workplaces will not be seriously affected, but the skills will (hence, there is a need for retraining, training on the job and life-long learning schemes).
- Support SME's: Small companies will be on disadvantage with ADAS, since their application requires significant resources and their optimal use the need for a centre of operations. They also need specialised personnel for ADAS. Thus, again the need for financial and other support by the Governments to SME's was stressed, to be able to migrate to the telematics era.
- Protect small workshops and garages: The ADAS application endangers the position of small workshops and garages, that will not be able to intervene to the CAN-bus of the equipped vehicle, due to lack of relevant access codes. Their position against car manufacturers protected data needs to be legislatively protected.

## 7.4.6 Discussion and Conclusions, Recommendations

The risk analysis method has shown various risks of several types : the technical and behavioural risk analysis refers to risks in applying the system actually on the road; the legal and insurance risk analysis and organizational risk analysis refers to implementation problems of the system in Europe. Therefore, these risk analyses are of a different category.

Performing a full technical risk analysis is reasonably possible for the systems used, but for the integrated systems, in which various ADAS are integrated in one, one should take into consideration that it will be a big task to perform. Also, a behavioural analysis will be much more complex and will bear more uncertainties. The behavioural risk analysis has set the agenda for the pilot testing. Notice that various expected behavioural risks have to do with behavioural adjustments, and in particular with adjustments over the longer term. Therefore, it is time that pilot testing with much longer pilots, and with drivers who have longer experience with the system participate. Unfortunately, neither the time nor the funds were available in ADVISORS.

For all systems is made clear that insurance premiums discounts are only a matter of consideration after years of experience with the systems on the road, and even then, some insurance companies are not interested. In general, drivers liability is a fact for most of the situations; and this is based upon the notion that ADAS are supposed to be advisory systems. In cases of interfering between the system's behaviour and the driver's behaviour, there was disagreement: mostly in the case of the CAS with failing braking function.

### **ACC**

The risk analyses and the user requirements reveal that:

*technical specifications* need to be decided (relation throttle control and speed change; define optimal embedded time); driver preparation (driver training required),  
*driver attitude and image of the system* must be researched (mistrust, overreliance),  
*driver behaviour effects assessed* (increasing brake pedal forces, imitating driver behaviour vehicle in front, also when it is bad; misusing the system as a collision avoidance system, using smaller time headways, diverting attention from the driving task, reduced vigilance; experiencing difficulties in overtaking, other drivers getting confused).

### **ISA**

The risk analyses and the user requirements reveal that:

*Changing driver attitude and image of the system* must be researched of non-mandatory systems  
*Take into consideration that driver behaviour effects assessed compensatory speeding behaviour, smaller gaps taking, closer car following*

### **LSS**

The risk analyses and the user requirements reveal that:

*Driver attitude and image of the system* must be researched  
*Driver behaviour effects*: possibly reduction situation awareness because of overreliance, too much attention directed towards the system, transfer problems when driving vehicles not equipped with the system)

### **CAS**

The risk analyses and the user requirements reveal that:

*Driver attitude and image of the system* must be researched (irritation , frustration)  
*Driver behaviour effects assessed* (effects of possible irritation, frustration, reduced alertness, changes in driving style)

### **DMS**

The risk analyses and the user requirements reveal that:

*Driver attitude and image of the system* must be researched (increase exposure driving while not fit for driving, overreliance)  
*Driver behaviour effects assessed* (effects warnings on driving quality, defining the most appropriate warnings)

**Navigation systems**

The risk analyses and the user requirements reveal that:

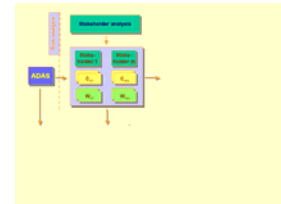
*Research is needed for driver preparation* (how much and what type of driver training required),

*Driver attitude and image of the system* must be researched (what is positive, what is perceived as negative)

*Driver behaviour effects assessed* (attention diverted from the driving task), details about length and mode of messaging, HMI, verification messages and redundant information)

### 7.5 Actor interests, acceptance and responsibilities

The work has been performed under Work package 2 and is reported in the deliverable:



ADVISORS_Del 2.pdf	A priori user acceptance of ADA systems, user implementation priorities, a user friendly ADAS terminology and the decision framework
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#### 7.5.1 Approach

In general, the approach to a stakeholder analysis consists of the following steps that need to be performed by the panel:

1. Identification of the stakeholders and their roles: *who are the stakeholders in this domain?*
2. Identification of the goals of the stakeholders: *what are the needs and goals of the stakeholders (considering the system's functionality)?*

Furthermore, the stakeholder analysis can be used to distinguish *key stakeholders* that should be considered in a more detailed fashion in the remainder of the study, for instance to set-up the assessment criteria.

Key actors:

- *The user* who decides whether to accept the new technologies and systems. The acceptability of a system further affects end-users' willingness to pay for such systems, and determines overall the effects of the systems on e.g. traffic safety.
- *Vehicle and system manufacturers*. They have the greatest knowledge of the technical possibilities and feasibility of the systems. On the other hand, their product development is driven at least partially by marketing studies telling them what end-users want, and what are they willing to pay for the new systems. Furthermore, manufacturers are dependent on legislation and are actuated by the responsibility issues.
- *The authorities and administrations*. They are expected to maintain the welfare of the society and must therefore consider new system implementations and impacts of new technologies on the society as a whole, considering all the possible impacts of the new systems - both for users and non-users. They have the possibility to affect the implementation of new systems through legislation and information directing user opinions.

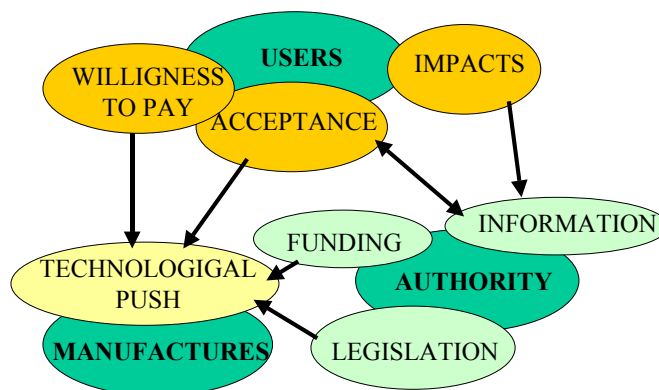


Figure 5 Actors in the field of ADAS Implementation

## 7.5.2 Interview study

### Opinions about Traffic related problems and ADAS

A telephone interview study (94 respondents) revealed that (Annex 11 for figures and tables):

- *All interviewed actors* of the transport system considered traffic-related problems as almost equally severe Europe-wide. Currently, the most severe problems are related to traffic safety. On the other hand, problems related to traffic safety were assessed to ease by the year 2010. This most probably is because of all the actions and plans that have been made in the past years (e.g. vision zero). At least that is the desired trend. On the contrary, all interviewed actor groups expected an increasing trend for problems related to road network and its costs.
- *The authorities and administrations* assessed problems related to road network to worsen most by the year 2010. Also problems related to environmental effects were assumed to worsen in the future, and problems concerning travel time and traffic safety were assumed to ease.
- *System and vehicle manufacturers* had an optimistic view of the future of travel time, safety and environmental problems, they believed that the problems will ease up in the future. However, we need to keep in mind the fact, that we only had in maximum 11 manufacturers to answer to these questions. *Fleet managers*, however, had a pessimistic view of all the problems, and believed them to worsen in the future.

Overall there was little difference between the opinions of different actor groups. Key actors<sup>1</sup> considered traffic-related problems in general as a little bit more severe than actors classified as "other important actors." Key actors also believed problems related to accessibility of public transport to worsen in the future, whereas the "other important actors" believed them to ease up.

While asking more detailed questions about the problems related to traffic safety, the means of the grades of all interviewees varied between 5,0–8.9. Overall the worst problems were considered to be speeding, traffic safety in urban areas as well as drinking and driving (Annex 11).

While asking more detailed questions about the problems related to environmental effects of traffic were exhaust emissions, noise, greenhouse gases and energy consumption considered equally severe. Naturally the usage of de-icing salt is not a problem Europe-wide, as it is rarely used outside Scandinavia. Also vibrations from traffic were considered as less severe. Means of grades for different problems related to environmental effects of traffic are given in Annex 11.

### The future of ADA systems

Among all interviewed actors the most desirable ADA systems to be implemented by the year 2010 were emergency calls and speed control/adaptation (ISA). Least desirable was the implementation of platooning. The desirability of the implementation of different ADA systems by the year 2010 is presented in Annex 11.

### Acceptance ISA, ACC, Navigation systems

User acceptance is one of the most important elements of success. Comparison of the interview results of drivers and other actors still showed quite large differences in opinion on which ADA systems should be implemented in the near future. *The future challenge therefore is to win drivers' acceptance* while attaining the desired effects (safety ... increased traffic flow .... decrease environmental load) on the traffic system as whole. Issues are:

- Which ADA-functions do different driver groups, e.g. private and professional drivers, find most attractive?
- How does the level of intervention (warning, informing, assisting, controlling?) affect their opinions?
- How important a factor is the expected price of the system?
- In addition, drivers' expectations towards the systems' effects on traffic safety, driving comfort, travel time and fuel consumption were of interest.

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<sup>1</sup> The actors who either have an extensive knowledge of the traffic system and its problems or who can have a great influence of the implementation of ADA systems were defined as the key actors. The actors who also have a wide knowledge of traffic-related problems and who can influence the implementation of ADA systems a great deal, but who have different background than the key actors were defined as "other important actors".

### 7.5.3 Conjoint analysis study

A conjoint analysis approach was chosen to explore the relationship between attribute levels and overall preference of the following ADAS:

- ACC, adaptive cruise control; defined to the drivers as *distance keeping* (attributes: distance warning, vehicle following and stop & go assistance),
- ISA, intelligent speed adaptation; defined to the drivers as *speed limiting* (attributes: no speed limiting, speeding warning, speed limiting),
- *Navigation* (attributes: no route info, static route info, actual route info)

In particular, both the awaited effects of ADAS on individual driving goals (traffic safety, driving comfort, travel time and fuel consumption) as well as overall attractiveness have been measured using conjoint analysis technique.

#### Results conjoint analysis

*In general*, of the selected ADA systems and their levels of intervention, the navigation function was found the most important function when considering the overall attractiveness of the ADA system profile.

However, heavy vehicle drivers indicated the navigation function as being the most important factor only in general - in motorway and rural roads environment the ACC function was indicated as being the most important function to heavy vehicle drivers. Also the importance of the ISA function was considered more important in all roads environments but motorways and rural roads. Price was considered the second most important factor except for heavy vehicle users to whom the investment costs of the system would only concern their employers (Annex 11).

With ACC and ISA functions, the *most preferred attribute level* (level of intervention) was the system only warning the driver. With the navigation function, navigation with actual route information was clearly the most preferred attribute level. However, heavy vehicle drivers indicated also the navigation system with static route information to increase the overall attractiveness of the system profile, especially on motorways and rural roads.

When considering the possible *safety effects* that ADA systems might have, car drivers indicated ISA and heavy vehicle drivers ACC as being the most important function affecting the traffic safety. However, in all road types environment, all drivers indicated ACC as being the most important ADA function affecting traffic safety. Still, only the warning attribute levels both in ISA and ACC were indicated as having positive effects on traffic safety.

When considering *driving comfort*, car drivers indicated the navigation function as being the most important function in all three environments. Heavy vehicle drivers indicated ACC as being the most important function increasing the driving comfort, except in all road types environment, where ISA was indicated as the most important factor. With ISA and ACC only the warning system was indicated as increasing driving comfort. In fact, with ISA the greatest effect that drivers indicated (magnitude, absolute value) was the decreasing effect of speed limitation system on driving comfort.

When considering *travel time*, all drivers indicated the navigation function as being the most important function in all three environments. Navigation with actual route information was indicated clearly as having the greatest positive effect on travel time. ISA with speed limitation was in the other hand indicated as having the greatest negative effects on travel time.

When considering *fuel consumption*, car drivers indicated navigation function and heavy vehicle drivers indicated ACC as being the most important function. Car drivers indicated that navigation with actual route information would have the greatest positive effects on fuel consumption where as heavy vehicle drivers indicated that with ACC function the greatest effect with the system would be negative effects when using stop&go attribute level.

### 7.5.4 Discussion and Conclusions, Recommendations

As expected, different actors had different opinions about the most likeable or most desirable ADA systems. In general, drivers seemed quite sceptical about adopting system functions such as stop&go. This is quite understandable; intelligent systems that take over part of the driving task are not easy to fathom without first

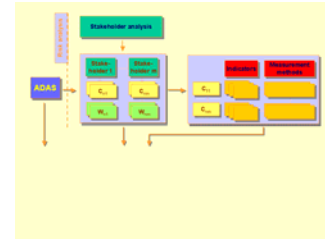


trying them out and understanding their technical feasibility. The authorities – at least to the extent that actors were interviewed in task 2.1 – found emergency calls and ISA (intelligent speed adaptation) to be among the most desirable ADA systems for implementation by the year 2010. This result is clearly in line with those presented earlier, e.g. in the ETSC report. By contrast, and as expected, manufacturers and especially drivers were not that willing for limiting ISA to be among the first ADAS implemented. However, drivers did seem to react more positively to the idea of ISA, provided the system was only a warning and not a limiting system, especially in a non-motorway environment.

The ADA systems are intended to enhance traffic safety. It is quite a demanding task, and to what extent it will succeed depends on several factors. User acceptance is one of the most important elements of success. Comparison of the interview results of drivers and other actors still showed quite large differences in opinions on which ADA systems should be implemented in the near future. The future challenge therefore is to win drivers' acceptance while attaining the desired effects on the traffic system as a whole. Public campaigns and marketing by manufacturers should clearly portray the systems as realistically as possible to end-users. In addition, public campaigns should in the future also aim also to change end-user opinions of different ADAS and enable the future users to attain the correct representation of the systems.

For those ADAS that are likely to be implemented in the near future, the most acute need is to ensure safe use, and clear legislation on responsibility-related issues regarding the systems, through the development of standards and legislation. Furthermore, some regulations or legislative steps may be needed to ensure that the benefits of the whole system, such as traffic safety, are achieved. It is not likely for an individual driver to concern him- or herself with the overall effects of an ADAS when deciding whether or not to adopt a new ADA system - this needs to be done by authorities and administrations in European countries.

## 7.6 The results of assessment of a set of ADAS on road safety, driver comfort and network efficiency



This work has been performed under Workpackage 5 and is reported in the deliverables:

ADVISORS_Del 5a.pdf	Pilot plans
ADVISORS_Del 4b_5b.pdf	Part III: Pilot Evaluation Results

### 7.6.1 Objectives of the Piloting Activity

1. To assess safety, user acceptance, usability, and behavioural impact of particular types of ADAS, on different road categories and different vehicle types.
2. To investigate the impact of ADAS on network efficiency and the environment.
3. To test the proposed integrated assessment methodology of WP4 in combined pilots.

To meet these objectives, and because the pilots are one of several means to reach the overall project goals, certain demands were put on the design of the experiments. The pilots should:

- Include different types of (available) ADAS.
- Direct the assessments towards different issues identifying different impact categories, which are related to e.g. safety, system usability, HMI, driver behaviour, acceptance and workload.
- Use different test-beds and research tools, like laboratory settings, driving simulators, and on the road tests using ordinary vehicles.
- Use the common assessment methodology drafted in the project.

So, the purpose of the pilots was firstly to investigate the drafted methodology, the reliability, validity, robustness, and sensitivity of the proposed methods, tools and indicators, and secondly to assess the effects of a number of individual ADAS. The ADVISORS pilots form only a small part of all the experiments and field tests being carried out currently and in the recent past. Therefore the amount of relevant data acquired concerning the specific ADAS effects can only be modest.

#### Selection

The selected set of ADAS (Annex 12) was chosen on account of a number of criteria:

- Type of ADAS, i.e. the problem intended to be solved, or the driving task intended to be supported by the ADAS. A reasonable coverage of different ADAS types was sought.
- System design (functionality, HMI etc.)
- Expected impacts, mainly safety related taking into account positive/wanted as well as negative/unwanted effects, resulting from the undertaken risk analyses.
- Phase of system development, expected time for market introduction/penetration, short-term and long-term perspective.
- Key actors' demand.
- Expected effect on environment and traffic fluency (efficiency).
- Data availability and collectability.
- Feasibility of test methods in terms of validity, sensitivity, reflecting acceptability and usability, as relevant for the introduction of ADAS

The Common set of Measures, as proposed in the ADVISORS methodology was applied (Table 1)

### 7.6.2 Interurban ACC

Please refer to Annex 14

The ACC was assessed in a simulator study. The ACC had two operative modes:

1. speed control (= ordinary cruise control)
2. speed control extended by distance control. The ACC controlled the speed of the host-vehicle in a way that kept it at a fixed distance from a vehicle ahead on the trajectory, based on a set minimum time headway.

The simulated test route contained rural road sections and motorway sections. One section on each of the two road types was driven with ACC support and the other without ACC support. Along the route "normal driving" as well as "more critical" situations occurred. The test scenarios could be characterised as low to medium traffic density with certain events occurring.

### 7.6.3 Urban ACC & Stop and Go

Please refer to Annex 18

The ACC with S&G was assessed in a simulator study. The ACC+S&G had two operative modes:

1. speed control (= ordinary cruise control)
2. speed control extended by distance control.

The ACC controlled the speed of the host-vehicle in a way that kept it at a fixed distance from a vehicle ahead on the trajectory, based on a set minimum time headway. The S&G function was capable of automatically braking and accelerating the vehicle more heavily in response to stop-start situations.

The simulated test scenario was one route in an urban environment. The route contained roundabouts, junctions and traffic lights. Heavy and light traffic conditions were employed, during which the speed of the lead vehicle changed according to relevant traffic patterns. Triggered events (traffic light changes) occurred during each drive.

### 7.6.4 Lane Support Systems

Please refer to Annex 13

The Lateral Support System (LSS) was assessed in a real road study. The LSS, contained two different support functions:

1. a forward-looking Lateral (Lane departure) Warning (LW) that presented a tactile and/or an acoustic warning in case of an involuntary lane departure.
2. a backward-looking Lane Change Warning (LCW) or Blind Spot (BS) function that informed the driver in case other vehicles were coming along the lateral lanes, and warned the driver by an acoustic warning if s/he started to overtake when another vehicle was approaching from behind.

The test route was driven twice; once in high traffic density, once in low traffic density. Each driving session contained three phases, driving with the LSS system OFF (9.5 km), driving with the LW function ON (10,5 km), and driving with both the LW function and the BS function ON (17 km).

### 7.6.5 Driver Monitoring System

Please refer to Annex 15

The DMS was assessed in a simulator study. An EyeLid Sensor in the DMS measured the driver's eye blinks and eyelid closure, predominantly the duration of them. The resulting data were classified on-line into three driver states, fully awake, drowsy, and sleepy. The DMS supported drowsy drivers by presenting a warning (brief beeps) with the intention to avoid acute risk.

The simulated test scenario was a motorway environment. No other traffic appeared.

### 7.6.6 Board Computer in trucks

Please refer to Annex 17

The board computer was assessed in a laboratory setting. The support system is a device for improving the route and time planning as well as the information transfer and communication between planners at a transport company and the truck drivers. The device enables an *automatic* back coupling of the drivers'

activities to the planning department. As a result, drivers themselves don't need to inform the planners by sending a message via their board computer or by phoning

### 7.6.7 Lane warning and Collision warning system

Please refer to Annex 16

The different warning concepts were assessed both in a laboratory setting and in a simulator. Three different types of systems (warning types) were assessed: Collision Warning (CW), Lane departure Warning (LW), and combined collision warning and lane departure warning.

In the assessment of CW features the participants were confronted with the following *situations*:

- Sudden appearance of a car driving ahead with small distance
- Required immediate and strong actuation of the brake pedal to avoid a crash

In the assessment of LW features the participants were confronted with the following *task*:

- Sudden and unexpected lateral off-set of the car
- Immediate actuation of the steering wheel and/or simultaneous braking is required

### 7.6.8 Microscopic Modelling

Please refer to Annex 19

In order to extend the breadth of the modelling effort and capture a larger set of scenarios and situations, three microscopic models are used, in particular the Dutch model SIMONE (Minderhoud, 1999, and Minderhoud and Bovy, 1999) from the TRAIL/University of Delft, the English model SISTM of TRL (Stevens et al, 2000), and the Finnish model HUTSIM (Kosonen, 1999) developed by the University of Helsinki. All these models simulate traffic conditions, while SISTM and HUTSIM also simulated environmental conditions, based on the traffic simulation that they performed.

The following ADA systems were selected based on the finding of earlier work-packages as the most desirable to be simulated:

1. Intelligent Speed Adaptation (ISA) (Oei, 1998b; Davison et al, 1997)., and
2. Adaptive Cruise Control (ACC) (Hayward et al, 2000; Oei, 1998a).

In order to examine the interaction of these two systems, and the marginal benefits that each of these has to offer to the users, the expected impacts of the combination of these systems have also been simulated (ACC+ISA). Several penetration levels (ranging from 5% to 100% have been modeled, while the no-ADAS base case has been included in the modelling and is used as the reference scenario. A number of urban and interurban network configurations have been used in the microscopic modeling simulations in order to gain intuition on the sensitivity of the ADAS impact with respect to several physical characteristics of the network.

### 7.6.9 Macroscopic Modelling

Please refer to Annex 20

The macroscopic network efficiency model [SATURN, see Hall et al (1980) and Van Vliet (1982)] uses the microscopic traffic estimates to simulate the sensitivity of traffic impacts of the introduction of ADAS. Similarly, the macroscopic environmental model (TEMAT, see MEET, 1999) combines macroscopic traffic information (from the macroscopic network efficiency model) with fleet and emissions information to estimate the macroscopic environmental impacts of the introduction of ADAS.

The macroscopic models accepted as input and exploited the output of the microscopic models (described in Section 7.6.8). To facilitate this information flow, the same ADAS were modeled (i.e. ACC and ISA, as well as their combination). Furthermore, the urban network of Athens, Greece, has been used for the macroscopic simulations.

### 7.6.10 Brief Overview of the Pilot Results

(Refer to Annexes 21 to 25)

#### **Conclusions on the Interurban ACC Study**

Short term, initial effects revealed that the assessed ACC system yielded positive acceptance rates, drivers found motorway driving with ACC less loading, but they tended to drive more often on the left lane, and their own preferred headway (in the non-ACC condition) was larger than the ACC headway. All these effects are very dependent on the actual parameters of the system and the fact that the system functioned without fault.

#### **Conclusions on the Urban ACC with Stop & Go Study**

Short term, initial effects revealed that the assessed ACC+S&G system yielded negative acceptance in busy urban traffic conditions, the system was found to reduce the joy of driving especially by young drivers. The system was overridden frequently by the drivers, the headways were shorter and the speeds were higher than the drivers would have preferred themselves. Drivers, especially the young, indicated that the system reduced workload. However, lateral deviation was increased with ACC, indicating reduced attention. No differences in the vehicle measures between younger and older drivers were found.

#### **Conclusions on the Lateral Support System Study**

According to the judgement of the users, the LSS (consisting of a lane keeping, LW, and a blind spot, BS, function) is imposing very low load, and is also useful, satisfying, and user-friendly although there might be the risk of over-reliance on the system. The LW function interrupted about 40% of started driver manoeuvres, while the corresponding proportion for the BS function was about 20%. The BS also delayed lane changes, more frequently in dense traffic conditions. On the other hand vehicle data, as well as observations by the test leader, revealed a very high frequency of the warnings, and many 'false alarms' occurred that were seemingly ignored by the drivers. Further technical development of the LSS is necessary to increase system reliability and to ensure the long-term acceptance of the system by the users.

#### **Conclusions on the DMS Study**

DMS have a high acceptance and perceived usefulness, in particular with those drivers who needed a warning by the system because they were drowsy and swerved on the road. The usefulness of the system was rated highest for motorways and rural roads.

#### **Conclusions on the LW and CW study**

The acoustical warning is perceived as most effective and reasonably pleasant, as well as to evoke fast reaction times, in comparison with the visual and the metaphorical warning. A multi-modal warning is not judged better (accepted) than single mode warnings. The acoustical warning is preferred over all other types.

#### **Conclusions on the Board Computer study**

The truck drivers perceive the real time back coupling of their navigation activities to the operators room positively in the sense that it will improve the equilibrium between workload and efficient labour. However, there are some problems with regard to the HMI, e.g. in sharing tasks, user latitude, feedback. Drivers who are on the road for a long trip prefer oral communication to written messages from the operators, because they enjoy some personal contact. Older drivers prefer visual communication. Young drivers seem to be able to drive and communicate at the same time in contrast to older drivers.

**Conclusions on the Microscopic Simulation studies – ISA**

Where the ISA speed limit is above the average traffic speed, there are minimal traffic effects. However, for lower ISA limits (or higher speeds) an impact is observed, which forces the average speed towards the ISA limit as system penetration increases. ISA has produced limited reductions in short headways, which increase slightly with penetration. Finally, the introduction of ISA has either none or small negative effects in the capacity, depending mostly on the considered speed limit.

In terms of environmental impacts, the introduction of ISA led into a small reduction in the emissions of various pollutants. As extreme speeds are eliminated, and the speed profiles become, such an impact is consistent with the expectations.

**Conclusions on the Microscopic Simulation studies – ACC**

Simulation results suggest that for high speeds and low traffic volumes, the impact of ACC is hardly noticeable. As traffic volume and ACC penetration increase, the speed at capacity (so-called critical speed) is higher than for the reference case.

Headway distribution becomes more uniform with the introduction of ACC, and more so as the system penetration increases. Capacity is improved by the introduction of ACC, but was found to decline when the penetration increases above 50%.

Similarly to the ISA case, the introduction of ACC led into a small reduction in the emissions of various pollutants. As speed profiles may increase and become smoother with the introduction of ACC, such an impact is intuitive.

**Conclusions on the Macroscopic Simulation studies – ISA**

The traffic impacts of ISA increase proportionally to its penetration level, and the average speed increase is lower at higher traffic flow levels. Furthermore, the impacts of ISA were small, compared to those observed when ACC was modeled (see below).

The environmental impacts of the introduction of ISA are clearly positive, as the fuel consumption and most emissions are decreased. The most significant emission reduction is observed in PM, followed by CO<sub>2</sub> (and fuel related emissions Pb and SO<sub>2</sub>) and THC, CO and NOx.

**Conclusions on the Macroscopic Simulation studies – ACC**

The traffic impacts of ACC in the macroscopic simulation studies were similar to those observed by ISA, but of a higher magnitude. Also, a combination of ACC and ISA was found to be practically equivalent to ACC alone.

In terms of environmental impacts, ACC leads into reductions in fuel consumption and most pollutants, which increases with the penetration. The combination of ACC and ISA has only an advantage compared to ACC alone for a penetration of 100%.

**7.6.11 Inferences for the ADVISORS methodology, Discussion and Conclusions, Recommendations****General**

If an ADAS has more than one function (like the LSS), in a first step, each function should be assessed separately before the combination of functions is evaluated, because the results for the different functions might differ.

For the assessment of an ADAS in a simulator or on the road, the driving time has to be sufficiently long to produce potential positive or negative effects of the ADAS, e.g. reduced subjective workload of the driver on the one hand or annoyance of the driver because of the system warnings on the other hand.

### Measurement Methods

A measurement method comprises experimental procedures that use tools within environments. Data generated using tools is processed to yield indicators. The choice of assessment method (and the techniques and tools used) will depend on the indicators previously identified (for example, whether qualitative or quantitative data are required).

The principal relevant characteristics of measurement methods and the indicators produced are:

- Validity – extent to which the indicator is diagnostic for the concept being investigated
- Reliability – reproducibility of measurements over time
- Sensitivity – ability to measure small changes in an indicator

In addition to validity, reliability and sensitivity the choice of a measurement method will be influenced by other practical factors including the cost and availability of environments and tools, and the time and effort required for data gathering and processing.

Although this section has mainly discussed measurement methods for driver safety, comfort, user acceptance and risk, network efficiency/travel time reduction and environmental effects, measurement methods may need to be chosen for a wider range of criteria such as:

- User cost
- Public expenditure
- Third party effects
- Social/political acceptance
- Technical feasibility

### Tools and environments

Measurement methods use tools to obtain data. Example tools include:

- Video recorder
- Eye tracker
- Vehicle data recorder
- Questionnaire
- PC-simulator

There are advantages and disadvantages of each:

- Video recorder: video data can be a useful method of capturing participant behaviour throughout trials. However, participants may find video cameras intrusive and analysis of video data is time consuming and subjective.
- Eye tracker: the use of an eye tracker is an effective method of capturing participants' visual behaviour. Eye tracker data can provide an indication of participant situation awareness, arousal and workload. However, equipment is expensive, not always reliable and can be effected by changes in sunlight. Remote equipment can lead to loss of data and head mounted equipment can be intrusive.
- Vehicle data recorder: the advantage of a vehicle data recorder is that it allows quantitative measures to be taken whilst a real vehicle is being driven on either test tracks or on the road, allowing realistic data to be captured. Generate large amounts of data, which can be time consuming to analyse. Also, logging and analysing the data may generate problems.
- Questionnaires / surveys: the subjective view of the users can provide valuable information that cannot be easily captured by other measurement methods. Stated Preferences (SP) and Revealed Preferences (RP) questions should be combined to extract optimal information from the respondents.
- Computer simulation: running the appropriate simulation models it is possible to estimate the traffic and environmental impacts of the introduction of several ADAS. Furthermore, by recording useful/appropriate information, a number of other secondary or collateral impacts can also be

estimated. Computer simulation can also be used to estimate the impact of systems that have not been fully developed yet, as well as penetration levels that can not be simulated in any test environment.

Measurement methods use environments within which data is captured. Example environments include:

- Road
- Test track
- Driving simulators
- Mathematical simulation
- Expert panels

Again these environments have advantages and disadvantages:

- On-the-road-trials: These situations potentially provide a more realistic environment for system assessment but are more difficult to create and instrument, as well as costly and time consuming. Finally, as the environment is not fully controlled, such trials are potentially less safe, and need more driving sessions to reach statistical power in the results, than driving simulator studies. However, as these trials may be more realistic than driving simulator studies, there may be benefits.
- Test track: Again a more realistic environment than simulator studies can be provided on test tracks. However, test track trials are expensive particularly if traffic conditions are to be simulated. Test track trials are safer than on-the-road trials, however an element of risk is still involved.
- Driving simulator studies: These can be used to examine the reaction of drivers to hypothetical scenarios and new systems (from early simulated system concepts to fully developed ADAS). Studies can also evaluate potentially unsafe conditions, without actual risk. The experimental environment and scenarios are fully controlled exposing all participants to identical and intended conditions. Modern driving simulators provide extensive and elaborate monitoring facilities for driving and other conditions, as well as monitoring the physiological condition of the driver (e.g. reaction to driving conditions).
- Mathematical simulation: These are particularly useful for simulating the effect of systems on traffic flows etc. and can be realistic indicators.
- Expert panels: While the end-user information is central to the assessment of new systems, there are dimensions and issues that only experts and stakeholders can weigh appropriately. All indicators should be reviewed by experts. Furthermore, there are dimensions, particularly in relation to planning and implementation of the systems that should be measured by experts.

The specific methods and tools used during the ADVISORS pilots are described in deliverable 5.

### **Experimental procedures**

The experimental work needs to be planned. Therefore, each trial should follow a project plan that details:

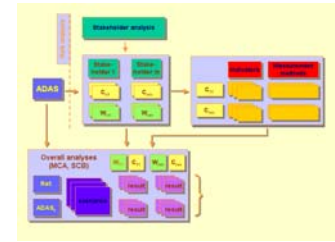
- The parameters of the system being tested  
This depends on the nature of the ADAS. For each ADAS being tested a description of how it will work and the exact parameters should be detailed.
- Participant characteristics  
Participant characteristics and therefore participant selection needs to be decided and clearly stated. Participants may be chosen for characteristics such as age, gender, driving experience and ADAS experience. A full description of participant selection criteria is provided in ADVISORS deliverable 5.
- The type of testing to be conducted  
This includes the environment and measurement methods being used during the trials. Measurement methods have been discussed in the previous section and trial environments are detailed in the section below.



- **Test scenarios to be used**  
Different test scenarios may be considered and compared during pilot trials. Test scenarios might include the type of traffic, for example light or heavy or the road type, for example urban, motorway or rural. These scenarios need to be decided upon and detailed in the plan.
- **Experiment design**  
The design of the pilot trials needs to be carefully considered. For example a repeated measures design might be used where all participants experience all test scenarios or an independent measures design might be used where each participant only experiences one of the test scenarios.
- **The test procedure**  
The test procedure needs to be detailed. This might consist of a breakdown of the trial timetable. For example, the trial might begin with a familiarisation drive so that the participant can get used to the vehicle and ADAS. This may then be followed by a drive and then the participant may be asked to fill in a questionnaire. Each step during the trial should be listed.
- **The instructions participants will receive at each stage during the trial**
- **The statistical analysis to be used**  
For each measurement method, the type of value to be taken should be specified. For example, whether a mean or overall score will be taken. Further detail should be given as to how this data will be analysed and the statistical analysis which will be used.
- **A health and safety risk analysis**  
A health and safety risk analysis should be performed to ensure that participants will not be at any risk and to identify any areas in which the trial could be at risk of failing or not being completed. Where areas of risks are identified possible back-up plans or solutions should be detailed.

The advantage of producing a plan is that consistency between trials can be maintained when considering more than one ADAS. An example of an experimental pilot plan used in ADVISORS can be found in deliverable 5.

**7.7 Multicriteria analysis (MCA) on a set of ADAS, revealing a rating of ADAS for which relevant criteria were considered most favourable.**



This work has been performed under Workpackage 6 and is reported in the deliverable:

ADVISORS_Del 6.pdf	CBA criteria and methodology for ADAS assessment. Potential funding mechanisms and incentives
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**7.7.1 Approach**

After reviewing several MCA methods, finally the specific MCA-tool chosen by the authors of this paper was the AHP-method developed by Saaty (1982, 1988 and 1995). The general idea of the stakeholder approach can be summarized as indicated in Figure 6.

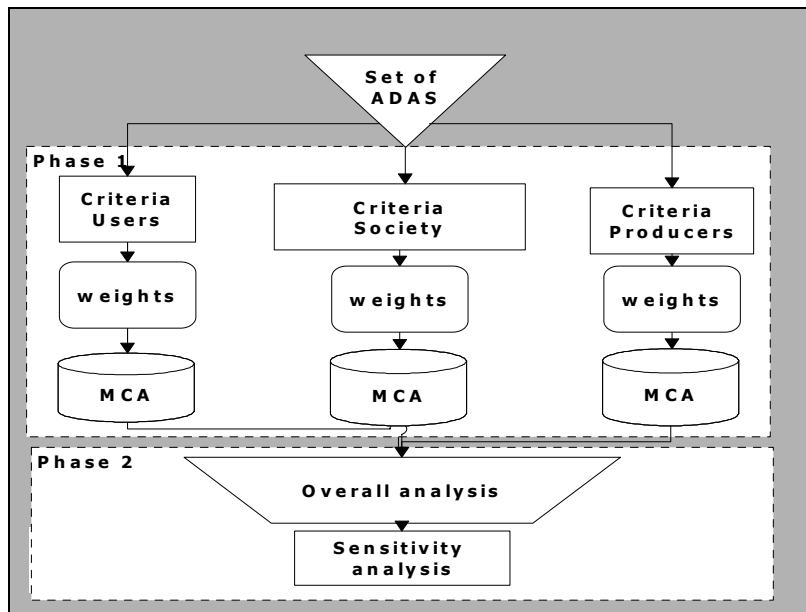


Figure 6 Overview of the stakeholder approach.

Three stakeholders can be distinguished who each develop their own criteria for the evaluation of the ADAS, namely the users, the producers and society as a whole. Each stakeholder in fact performs an evaluation of the ADAS in terms of his own objectives. Since not all criteria are equally important to the stakeholders, the stakeholders therefore use weights, which together with the different ADAS and the criteria developed by them are used as inputs to their own MCA. This means that three different MCAs are performed, which each have a limited focus, namely a stakeholder-specific focus. The users are concerned by the full user cost, driver comfort, driver safety and travel time duration. Society is concerned with public expenditure associated with ADAS introduction, the environmental effects (impacts on emissions, noise, etc.), overall safety, full social implementation cost (incl. e.g. subsidies), network efficiency and acceptability. Finally, the producers are interested in innovation cost, sales volume, internal spill-over effects, profitability and company status. In the second phase, an overall socio-economic MCA evaluation is to be performed. This is an overall MCA which integrates all points of view and encompasses all stakeholders. The result of this analysis is subject to sensitivity analysis.

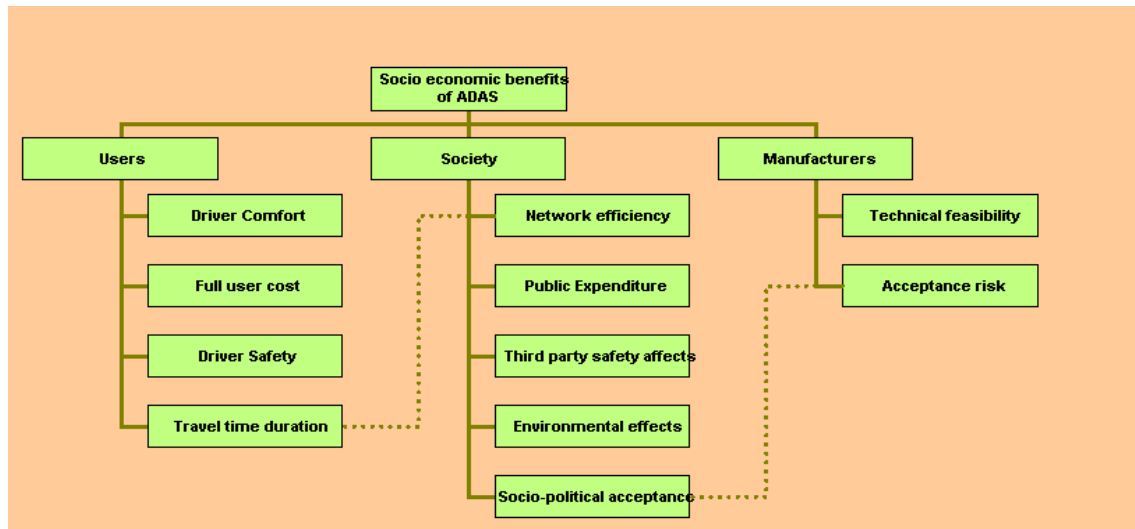


Figure 7 Decision tree for the evaluation of ADAS.

The decision tree developed here (Figure 7) was the result of initial development and refinement: operational criteria were developed which make it possible to measure the impacts of each separate ADAS on these criteria.

Figure 7 represents the hierarchical decision tree and also shows the linkages between the criteria (dotted line). For example, there is a link between the effect of ADAS on network efficiency and user travel time. Similarly, the manufacturers and society at large share a similar interest, namely the risk of low societal acceptance. In order to avoid double counting, these criteria were represented only once in the final evaluation table and placed under the heading of the stakeholder group that would likely attach the greatest importance to them. The criteria are further specified in the table in the Annex 26.

### 7.7.2 Weights of the criteria

The weights were determined by expert evaluations (experts in the field of ADAS research). The relative “priority” given to each element in the hierarchy is determined by comparing pair-wise the contribution of each element at a lower level in terms of the criteria (or elements) with which a causal relationship exists. The resulting list of weights in order of importance was: (see Annex 26) driver safety (denoted by DRISAF) and third party safety effect (THIRD SA) received the highest weights. A second group of criteria with still relatively high weights consists of travel time reduction/network efficiency (TRAVEL) and the environmental effects (ENVIR), i.e., two key mobility problems. Technical feasibility (TECHN FE), the full user cost (USER) and the socio/political acceptance (SOCIO/PO), received more moderate weights. Finally, the last group includes criteria viewed as somewhat less important, such as public expenditures (PUBLIC) and driver comfort (DRCOMFOR).

#### Step in the evaluation framework of the ADVISORS Assessment Methodology: Criteria, indicators and measurement methods

In this stage, the previously identified stakeholder criteria are “operationalised” by constructing indicators (also called metrics or variables) that can be used to measure whether, or to what extent, an ADAS contributes to each individual criterion. Indicators provide a “scale” against which a project’s contribution to the criteria can be judged. Indicators are usually, but not always, quantitative in nature. More than one indicator may be required to measure a project’s contribution to a criterion and indicators themselves may measure contributions to multiple criteria. On the basis of their work in the technical studies, the technical experts within the ADVISORS project were asked to evaluate the 22 scenarios in a pair-wise fashion. For each criterion, three or four experts completed the table. The evaluations were compared and any differences were then discussed among the experts. As a result, a number of experts changed their evaluations after these discussions. After this phase of discussions and some changes in scores, the

geometric mean of the expert evaluations was calculated. The overall analysis was then performed based upon these tables.

### 7.7.3 Overall analysis and ranking

In the work of WP7, a list of future priority scenarios was produced (Annex 27). This list of scenarios forms the basis of the overall ranking.

In the Annex, the final ranking of various scenarios is given. The Integrated Scenario is ranked first, well before the other ones. This implies that overall (i.e., taking into account all relevant criteria) this scenario is clearly the best as compared to all other ones. The two driver monitoring system (DMS) scenarios are in second and third place. The fifth Intelligent Speed Adaptation scenario (ISA5), which is the control scenario, is ranked fourth. Finally, the first advanced cruise control system (ACC1) is ranked fifth.

The ADAS chosen were types of: ACC, ISA, Driver Monitoring System (DMS) and Integrated ADAS system (IAS). The scenarios were identified on the basis of reasonable expectations derived from risk analyses, pilot studies, implementation issues and barriers. The scenarios of one type of ADAS differs from the other scenarios of the same type of ADAS with respect to expected effect on driver behaviour or implementation opportunity.

An extensive sensitivity analysis of these evaluations obtained can be found in Del 6.1 Its aim is to investigate whether the ranking would change when other sets of policy weights would be used. This analysis is called sensitivity analysis, because it examines to which extent the final ranking is sensitive to changes in the input data (c.q. the policy weights).

The stakeholder analysis revealed that users do not seem to be in favour of ISA5, ISA4<sup>2</sup> and ISA3<sup>3</sup>, but rather prefer the INTEGRATE<sup>4</sup>, DMS1<sup>5</sup>, STOP3<sup>6</sup> and DMS3<sup>7</sup> scenarios. Society appears to prefer ISA5 and ISA4, in addition to the INTEGRATE scenario. Manufacturers, however, are not in favour of ISA5, which is similar to the users' perspective. They rather prefer the NAVI<sup>8</sup> and STOP3 scenarios. They do not highly appreciate the INTEGRATE scenario either, an ADAS scenario that was ranked first in all earlier rankings (both when assessing the basic scenarios and the additional scenarios resulting from the sensitivity analysis). If society chooses to promote the use of ISA5, both substantial incentives and a media campaign may be necessary.

### 7.7.4 Sensitivity analyses

Three types of sensitivity analysis have been performed in this part, namely (1) sensitivity analysis for each criterion separately, (2) scenario analysis and (3) stakeholder analysis. In each of these types of sensitivity analysis a basic scenario is compared to an alternative scenario. The basic scenario contains nine types of ADA scenarios carefully selected by the Advisors team which were analysed through multicriteria analysis (MCA). In the alternative scenarios the policy weights used in the basic scenario were changed in order to test the sensitivity of the final ranking.

In the first type of sensitivity analysis (namely sensitivity analysis for each criterion separately), the sensitivity of the final ranking was tested for each of the nine criteria separately. It was tested whether the final ranking would be different from that obtained in the basic scenario when the weight of one separate criterion would be increased or decreased, while the relative weights of all the other criteria remained the same.

In the second type of sensitivity analysis, namely scenario analysis, a different policy scenario was defined. A policy scenario is a scenario whereby specific policy objectives are given extra emphasis. In that case several criterion weights may need to be changed at the same time, depending on the objective emphasized. The scenario analysis examines to which extent the ranking obtained in the alternative

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<sup>2</sup> Urban, Dynamic, Intervening

<sup>3</sup> Rural, Dynamic, Intervening

<sup>4</sup> Integrated ADAS

<sup>5</sup> Warning only, professional drivers

<sup>6</sup> Stop and Go, Peri-Urban, High Flow

<sup>7</sup> Warning only, all drivers

<sup>8</sup> Navigation and Fleet Management

scenarios is different from that obtained in the basic scenario.

Five alternative policy scenarios were taken into account, namely (1) a policy scenario with emphasis on safety (both driver safety and third party safety effects), (2) a green scenario with emphasis on both safety (driver safety as well as third party safety effects) and the environment, (3) a policy scenario with emphasis on external effects (i.e. the environment and third party safety effects), (4) a scenario with emphasis on risk (socio-political acceptance and acceptance risk, as well as technical feasibility) and (5) a scenario with emphasis on comfort (driver comfort and travel time).

The third type of sensitivity analysis was the so-called stakeholder analysis. In this type of sensitivity analysis several points of view are defined, each corresponding to a specific stakeholder in the policy process. In this analysis the weights of the criteria relevant to that specific stakeholder were maximised, whereby the other criteria were ignored, i.e. their weight was set equal to zero. Three stakeholders have been taken into account, namely (1) the users, (2) society and (3) the manufacturers. It was then analysed whether the ranking based on a specific point of view, corresponding to a specific stakeholder, was different from the ranking obtained in the basic scenario.

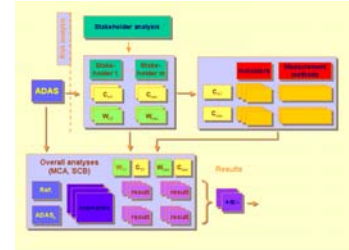
The first and the second types of sensitivity analysis yielded results that were comparable to a large extent. Both in the sensitivity analysis for each criterion separately and the scenario analysis, two often three ADAS were always ranked on top of the ranking and their internal position within the ranking always remained the same. This was true resp. for INTEGRATE, DMS1 and, to a lesser extent, also for ISA5. The latter ADAS received, however, a worse position in the comfort scenario and in the risk scenario. Additionally, in both types of sensitivity analysis, there was always one ADAS that was always ranked at the end of the ranking, namely DMS4. As regards the other ADAS, the so-called "intermediate alternatives" or the "intermediate ADAS" (namely ISA4, NAVI, STOP3, ISA3, DMS3 and DMS4) the ranking was, however less stable. Their relative priorities were lying close to each other. For some of them the sensitivity was rather low, for other ADAS, the sensitivity was rather high, depending on the criterion studied. This was illustrated by various sensitivity graphs shown in §3.1 - §3.9.

The results of the third type of sensitivity analysis, namely the stakeholder analysis, were completely different from the two former types of sensitivity analysis. Nor could a parallel be found among the three points of view analysed within the stakeholder analysis. This may be due to the fact that the weight set, in the latter analysis, was really strongly different from the weight set used in the basic scenario as well as from those used in the former types of sensitivity analysis. Only the criteria considered relevant for a specific stakeholder were taken into account and their weight was maximised. The weights of the other criteria was set equal to zero.

The stakeholder analysis revealed that users seem not to be in favour of ISA5, ISA4 and ISA3, but rather prefer the INTEGRATE, DMS1, STOP3 and DMS3. Society seems to prefer ISA5 and ISA4, next to the INTEGRATE. Manufacturers, however, are not in favour of ISA5, just like the users. They rather prefer NAVI and STOP3. They even do not highly appreciate the INTEGRATE, an ADAS that was ranked first in all former rankings (both in the basic scenario as well as in the various alternative scenarios analysed in the sensitivity analysis).

### 7.8 Identification of a set of multidimensional future priority scenarios for ADAS developments

This work has been performed under Workpackage 2 and 7 and is reported in the deliverables:



ADVISORS_Del 2.pdf	A priori user acceptance of ADA systems, user implementation priorities, a user friendly ADAS terminology and the decision framework
ADVISORS_Del 7.pdf	Priority implementation scenarios, and schemes regarding equity, insurance policies, legislation, incentives and organisational consequences for ADAS deployment. Overview of state of the art regarding standardisation issues

#### 7.8.1 Approach in formulating the future scenarios

Before preparing the scenarios, a scenario definition (scenario template) listing all the key parameters was made. This ensured that all the prepared scenarios included comparable information in similar parameters. The working method is presented below (Figure 8). The scenarios were made as preliminary most preferred ADAS scenarios. The scenarios are developed further in continuing work in the workpackages on MCA and Implementation strategies.

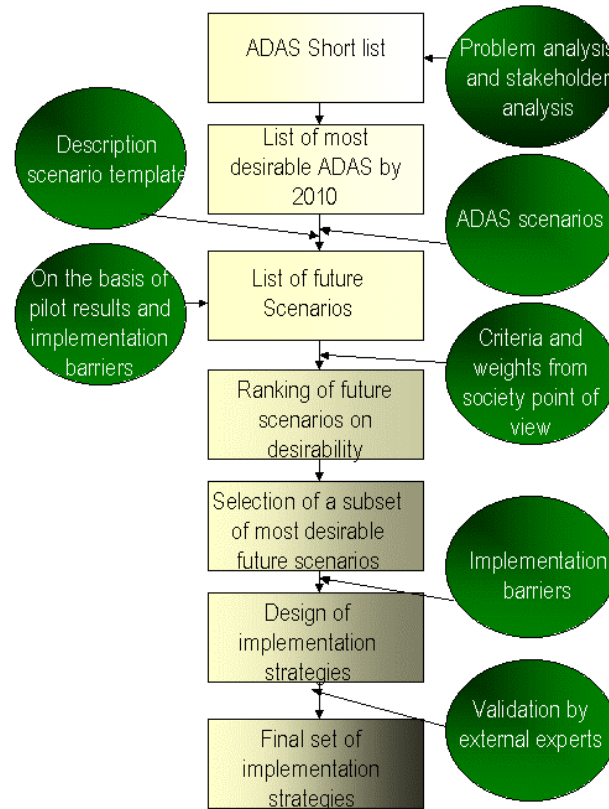


Figure 8 Working method for defining the preliminary most desirable and likely ADAS scenarios.

### Scenario definition - important factors

A scenario was defined to be a *snapshot* view of a possible (usually future) set of circumstances. In this project, scenarios are created so that predictions can be made about the effects of introducing new ADAS in road transport.

The important factors in any scenario of this type are the driver, his vehicle, other vehicles (which compose the traffic), the road infrastructure and the other environmental conditions. This is depicted in Figure 2.

Scenarios may be described at various levels of detail. An overview may consist of just a paragraph of text containing the main idea. Scenarios may be described with dynamic components, being composed of a series of events, which may also be thought of as different scenes in a play or film. For modelling purposes, some aspects of a scenario must be described in great detail. In general, the focus of the description and the level of detail will depend on how the scenario is going to be used.

The future implementation and adoption of new ADA systems will depend on many actors and a wide range of factors. Key actors are User, vehicle and system manufacturers and authorities and administrations (refer to paragraph 7.5).

However, one needs to keep in mind, that in addition to the listed actions, there are numerous factors directly or indirectly affecting the implementation of new technology. The users' willingness to pay is not the only thing affecting the release of new technologies. There might be bottlenecks in the domain of regulations, insurance or standards or it might be even forbidden to release certain ADA products under the current laws. Also the lack of regulations might cause some limitation to the ADA systems that are introduced to the market - the manufacturers can perceive substantial litigation risks due to missing rules, guidelines or definitions of system characteristics. For example, at the moment ADAS that provides information or warnings, or for systems that are capable in practice of being overridden by the driver, the

user is responsible for control of the vehicle, but this might change in future if users' judicial relief is improved. In addition to mentioned factors, also the type of ADAS systems (open and closed ADAS and autonomous and dependent ADAS) affects the implementation speed and manufacturers' interest to develop the ADAS system.

The Actor Analysis showed that the estimated utilities indicate that the **navigation** attribute is most important, which indicates that the availability of navigation support within future ADAS applications can have a considerable effect on preferences for ADAS. As such, the implementation of navigational aids, preferably as part of an integrated system, should be stimulated. **Price** is the second important attribute. This implies that financial incentives can improve the preferences for ADAS. This would require, however, some additional research on how respondents expect that ADAS might be implemented. In the study no specifications were given if the ADAS were available for new vehicles only (like current distance keeping) or might be installed in existing vehicles also (like current speed adaptation devices and navigation systems). Purchase prices of vehicle equipment for new vehicles are perceived as relatively low as compared to the price of the new vehicle itself. These perceptions might have influenced the importance of the attribute price and will be subject of our future research.

With respect to distance keeping and speed adaptation, the **warning level** is more preferred than the other levels. These findings suggest that it has to be tried to implement systems that have a warning functionality. In addition, regarding speed adaptation, warning support is preferred to no support. Hence, there appears a need among drivers for speeding warnings. Regarding navigation, the **dynamic route info level** is more preferred than the other levels. As such, an effort should be undertaken to (further) implement systems which couple actual traffic information with in-vehicle navigation support.

The systems of the ADVISORS Shortlist Table 6 are subject to the analysis. Of the six systems under review, Stop & Go can be considered as an operational extension of ACC. All the systems except Driver Monitoring and Lane Keeping are considered for integration, using as common denominator locating the vehicle by GPS and later by Galileo/GPS. Presumed is that for lane keeping the accuracy to locate a vehicle by Galileo/GPS is too small.

## 7.8.2 Scenarios

A number of future scenarios have been selected on the basis of the following considerations: The scenarios should be distinguished on key factors for which it is to be expected that they have differential impacts on one or more of the criteria determined in the MCA. Furthermore, practical implications and realism in possible developments in the near future have played a major role. A short description of the scenarios are listed below and the complete descriptions are listed in Annex 27.



## Stop and Go

### **Scenario title: Stop&Go (urban ACC)**

(ADAS) function: Vehicles are equipped with STOP&GO (urban ACC).

Stop & Go - A vehicle system which controls vehicle speed even in the low speed range (congested roads) and enables the vehicle to automatically adjust speed and stops according to the vehicle in front.

However, the function does not include so called emergency braking function, which could prevent a crash by forceful braking. It will not detect the possibility of a collision (for example obstacles on road) and either warn a driver or even automatically control the vehicle's movements if the collision is otherwise unavoidable.

Level of operation: Drivers have the option to switch on/off Stop&Go and select a time-headway to the vehicle in front. The Stop&Go functions even when the vehicle slows to a stop and re-starts.

Penetration: One penetration level will be explored – 25% of the vehicles having (and using) Stop&Go.

#### Important parameters:

- Road type: urban OR peri-urban roads (rings etc.)/motorways
- Traffic density: Two traffic density situations will be explored – one congested situation (80% or 100% of the lane capacity) and one free-flow situation (60% or 40% of the lane capacity). The traffic flow values might be about 1200 and 2000 vehicles per hour per lane).
- Penetration level: only one penetration levels will be explored – 25% of the vehicles having (and using) STOP&GO.
- Traffic characteristic: High level of pedestrian activity; wide variation in vehicle speed

#### Intended benefits:

- Safety: Reduction in accidents.
- Network: Improvements in traffic flow.
- Environmental: Reduction in noise, fuel consumption and exhaust output.

#### Scenarios:

Combining the different values of the key parameters results in the following appropriate implementation scenarios:

Scenario No:	Scenario name:	Road Type:	Traffic Flow:
1	Stop&Go1	Urban	High Flow
2	Stop&Go2	Urban	Low Flow
3	Stop&Go3	Peri-Urban	High Flow

*Table 19 Implementation Scenarios for Stop and Go*

## ISA

### **Scenario title: Intelligent Speed Adaptation (ISA)**

(ADAS) function: Five ISA types are ordered chronologically - from phase [A] the present state to the last phase [E] the mandatory type after some 15 years. The ISA types are progressive in development and sophistication.

Level of operation: The ISA system can give a) a warning or can b) intervene to prevent speeding. For safety reasons overruling is possible by kick-down for all ISA types. ISA types A up to D can be switched on/off by the driver. This is not the case for the mandatory ISA[E].

Penetration: The penetration level depends on the car manufacturer: installing ISA as standard equipment at an early stage will increase the penetration level.

Important parameters:

Road type: urban OR rural roads

Traffic density: All traffic densities

Communication features: Data on which ISA is based can be stored on an in-car CD-ROM or DVD or can be transmitted from a regional centre having the most up-to-date data. Combinations are also possible, e.g. road network stored on CD-ROM/DVD and road works, traffic and weather data being sent from regional centre.

Intended benefits:

Safety: Reduction in speed and accidents/road casualties.

Scenarios:

Combining the different values of the key parameters results in the following appropriate implementation scenarios:

Scenario No:	Scenario name:	Road Type:	Implementation mode:	Communication mode:
1	ISA[A]	Rural/urban	Information	Dynamic
2	ISA[B]	Rural/urban	Information	Static
3	ISA[C]	Rural	Assisting/intervening	Dynamic
4	ISA[D]	Urban	Assisting/intervening	Dynamic
5	ISA[E]	Rural/urban	Controlling	Dynamic

*Table 20 Implementation Scenarios for ISA*

## Inter Urban ACC

### Scenario title: *Inter-urban ACC – Adaptive Cruise Control*

(ADAS) function: Vehicles are equipped with ACC (Adaptive Cruise Control), a vehicle system that will automatically (when engaged by the driver) control vehicle cruising speed and as necessary, operate the throttle and brakes to maintain a safe distance to the vehicle in front. However, the function does not include so called emergency braking function, which could prevent a crash by forceful braking.

Level of operation: Intervention – however, drivers have the option to switch on/off ACC and select the time headway to the vehicle in front.

Penetration: One penetration level will be explored – 25% of the vehicles having (and using) ACC.

Important parameters:

Road type: motorway/ highway

Traffic density: Two traffic density situations will be explored – high flow (80% or 100% of the lane capacity) and lower flow (60% of the lane capacity). The traffic flow values might be about 1200 and 2000 vehicles per hour per lane).

Intended benefits:

Safety: Reduction in accidents.

Network: Improvements in traffic flow.

Environmental: Reduction in noise, fuel consumption and exhaust output.

Combining the different values of the key parameters results in the following appropriate implementation scenarios:

Scenario No:	Scenario name:	Road Type:	Traffic density:
1	ACC1	motorway	High flow
2	ACC2	motorway	Lower flow

Table 21 Implementation Scenarios for the ACC

## Navigation

### **Scenario title: Extended (integrated) navigation**

(ADAS) function: The function of this ADAS is to provide advice, warning or intervention/control in the following scenarios: route guidance, over speeding, approaching a location (such as a sharp bend on an intersection) with too high speed, as well as in the case safe headway is jeopardised or imminent risk of collision arises. It merges the functionalities of ACC, collision avoidance, navigation and route guidance.

Level of operation: It has three main levels of operation:

- Driver advice.
- Driver warning (one or two levels).
- Intervention (control).
- 

Penetration: No data exist on the impact of such a system according to penetration level.

Important parameters:

Road type: Mainly for highways and rural roads, including city peripherals, and interurban arterial roads

Driver type: All drivers but especially those over speeding, young drivers, drivers with an aggressive driving style. System algorithms may need to calculate different reaction times per driver age (i.e. 0,8s for young, 1,2s to 1,5s for older), to result in a system that is comfortable for older drivers, while not irritating (not producing too many alarms) for younger drivers.

Traffic density: All traffic density conditions.

Communication features: The data are transmitted from a regional centre having the most up-to-date data.

Vehicle: This system is intended for all vehicles, while it is expected to be first implemented in high-class vehicles.

Intended benefits:

- ➔ Road safety enhancement, especially through reduction of curve departures, led to tail accidents and intersection accidents in rural roads.
- ➔ Environmental benefits through small average speed reduction (reported in all traffic density conditions and driver types).
- ➔ Traffic situation improved through less accident causing traffic jams. Small average speed reduction effects are not yet calculated but are expected to be small.

Potential hazards:

- ➔ Drivers using the system as aim indicator when to overtake or relying on the control function to prevent them from colliding with the vehicle in front (case of misuse).
- ➔ Drivers over relying on the system's information and not checking properly traffic risks such as hidden intersections, curves or road works, that may eventually not be included in the system database (over relying on the system).
- ➔ Unless trustworthy and highly reliable dynamic navigation maps are available, several new traffic hazards may emerge, of which the system is absolutely unaware. This fact renders the system a comfort rather than a safety related device.

Table 22 Implementation Scenarios for the Integrated Navigation

**DMS****Scenario title: Driver Monitoring System**

(ADAS) function: Its function is to monitor the driver physical status, in order to alert the driver in case "driver impairment" is detected or is estimated to be imminent..

Level of operation: Warning / intervention

Penetration: Penetration level is based on the estimated average percentage of people that works in a nightshift. The US Bureau of Labour statistics show that 2 to 10 percent of all occupation involve working evening, night, or rotating shifts. Therefore, in order to limit the total of scenarios, two penetration levels of 5 and 10% are chosen.

Important parameters:

Road type: DMS will first work on highway, then on rural roads and much later in urban environment, due to the different complexity levels of these environments in relation to traffic risk estimation as well as the users priorities, which are higher for highway/rural environments.

Vehicle type: This system will be more accepted and economically viable as support to professional drivers (mainly application in trucks), people suffering from sleep disorders (who would not be allowed to driver otherwise) and maybe shift workers. Rest users (general public) will follow.

Communication features: It is mainly an on-board type of system. Nevertheless, integration of dynamic data (i.e. on traffic levels, road-works, weather conditions and other road risks) may improve the reliability of the system, and especially its Traffic Risk Estimation module. Such a communication will be based on standard TMIS transmissions, using GPRS or UMTS for message delivery.

Intended benefits:

It is estimated that sleepiness, drowsiness or fatigue plays a causative role in approximately 10% of all accidents. On motorways this percentage is approximately 20% (Brown, 1997, Maycock, 1997).

Fatigue affects safety as it has a negative effect on the ability and speed of decision making, and on hazard perception (Brown, 1994). The directly measurable cost of fatigue-related road accidents is estimated at EUR 4.5 billion (EC White Paper, 2001). Therefore, the intended benefits of the introduction of a drowsiness monitoring device are twofold:

- (1) Reduction of the number of accidents;
- (2) Reduction of fatigue-related health costs, associated with (1)

These benefits are based on the assumption that the DMS functions with a low number of false alarms, i.e. has a sufficiently great predictivity. In order for the DMS to function properly, the face must be in-focus of the camera, and the eye detection software must be able to locate the eyes within the camera image of the face. In this eye detection process two important sources of noise (artefacts) can be identified: postural changes, and reflection of glasses. Both issues may be solved by technical refinements (e.g. eye detection algorithm improvements) Next to this, the DMS can be used independent of the environmental or situational conditions (weather, illumination, road type).

Potential hazards:

Related to predictivity, the more general issue of sensitivity must be questioned. It is doubtful if the use of a single variable (blink duration) has a sensitivity that is sufficiently great to predict fatigue. It seems therefore advisable to follow a multivariate approach, using state change indicators that can be non-intrusively assessed (e.g. eye blinks), vehicle or sensor measures (e.g. swerving behaviour) and time parameters (e.g. travel time, time of day) to increase the total explained variance, i.e. enhance the system's predictivity.

Another potential hazard is complacency, i.e. the use of a DMS as a kind of "snooze device". In other words: the presence of the DMS could potentially justify or even stimulate irresponsible, drowsy driving behaviour. However, the DMS pilot study pointed out an important argument that contradicts this supposition. A lot of drivers of the DMS target group are well-aware that fatigued driving is associated with a higher risk on accidents. Many of them have experienced fatigue-related (near-)accidents, and therefore know that their ability to assess one's own (fatigued) state is inaccurate. Judging from the willingness-to-pay questionnaire, they generally have a positive attitude towards the DMS, which is probably generally seen as an aid (not a substitute) for their own state assessment.

Combining the different values of the key parameters results in the following appropriate implementation scenarios:

Scenario No:	Scenario name:	Implementation mode:	Driver type:
1	DMS1	Warning	Professional driver
2	DMS2	Intervention	Professional driver
3	DMS3	Warning	Private driver
4	DMS4	Intervention	Private driver

Table 23 Implementation Scenarios for the Driver Monitoring System

## LS

### Scenario title: Lateral Support System

(ADAS) function: Two modes of function:

- 1) lane support / lane keeping: warning in case of involuntary lane departure; acoustical and / or tactile warning
- 2) lane change support / blind spot function: warning in case of other vehicles coming along the lateral lanes and in case of an overtaking manoeuvre having been started when other vehicles are approaching; acoustical and / or visual warning

The first mode has the aim to support the drivers in case of involuntary lane departure, by means of a tactile and/or an acoustical warning. The second one, instead, informs the driver in case of other vehicles are coming along the lateral lanes; moreover, it warns the user if an overtaking maneuver is started when other vehicle – not seen by the driver – are approaching by means of an acoustical warning.

A combined vibration of the steering wheel and acoustical alarm reduces the reaction time of the driver compared with an acoustical warning only (Miichi et al., 1999). The reaction time is reduced even more if a corrective steering torque is applied in addition.

The results of the ADVISORS pilot study show that subjects prefer equally the acoustical and the tactile warning for the lane warning function and that they clearly prefer the acoustical warning for the lane change support function.

Level of operation: Perception enhancement, warning

Important parameters:

Road type: Currently motorways; future development: for urban roads and rural roads.

Driver type: All drivers, especially elderly, disabled and professional drivers.

Traffic density: All traffic conditions, especially for high traffic density.

Vehicle: All vehicles, for high class vehicles, trucks and buses first

Weather: All weather conditions; attention must be paid to snow, rain, fog etc. In fact, too bad weather conditions could damage the sensorial system (based on ordinary cameras).

Intended benefits:

- 1) improved safety: reduction of lateral vehicle collisions
- 2) enhanced driving comfort especially for elderly and disabled drivers

Indeed,

- between 10 and 30% of the accidents (depending on road type) are caused by lane departures (ROSETTA project)
- in Germany, 15.5% of the accidents in the year 1999 are caused by lane departure (Bubb, 2002)
- lane keeping can reduce the number of accidents by 1-2.5% (PROMETHEUS project, quoted according to ADVISORS D2)
- A simulator study by Fastenmeier et al (2001) showed that a Lane Change Support System was

able to reduce the risk related to lane changes.

Potential hazards:

Some drivers may be willing to take risks voluntarily that will trigger the alarm function of the system thus annoying the driver. To detect unintended lane departures, lateral support systems should be combined with driver monitoring systems (ROSETTA project).

Some drivers will rely on the information given by the system and stop looking back over their shoulder Fastenmeier, Gstalter & Zahn (2001).

Usual road marking is necessary; further technical development necessary to solve this problem.

Possible problems if the lane borders are not clear or not marked.

Combining the different values of the key parameters results in the following appropriate implementation scenarios:

Scenario No:	Scenario name:	Function:	Road type:	Intervention level:
1	LS-LK1	lane keeping	motorway	warning
2	LS-LK2	lane keeping	motorway	intervention
3	LS-LK3	lane keeping	rural	warning
4	LS-LK4	lane keeping	rural	intervention
5	LS-BS1	blind spot function	motorway	warning
6	LS-BS2	blind spot function	rural	warning

*Table 24 Implementation Scenarios for the Lane Support*

## IAS

### Scenario title: **Integrated ADAS**

(ADAS) function: Informing and warning, dynamic, for all vehicles.

We suppose the integrations of the following ADAS scenarios in one:

- [ACC1]: Highway ACC, operating also in high flows.
- [STOP1] and [STOP4]: Urban and peri-urban Stop & Go functions, operating in high flows, to complement the ACC function in these environments.
- [LS4]: Lateral Support on motorways and rural roads, limited to driver warning.
- [LC2]: Lane change support on motorways and rural roads, limited to driver warning.
- [ISA1]: Informatory ISA, based on dynamic info, transmitted by the infrastructure, operating in rural and urban roads.
- [NAV1]: Dynamic navigation and route guidance, based also on extended navigation maps (including the road marks), that are dynamically upgraded.

The overall functionality is as follows:

The integrated ADAS builds a detailed Traffic Risk Estimation, by merging longitudinal and lateral movement related info and identified risks, and fusing multi-sensor and multi-source data. Key to it is the control processing module and the ability of all sensors to provide synchronised info, of comparable reliability levels. Also a common, harmonised user interface is needed, towards which COMUNICAR project has already contributed. The driver will be warned, with 3 warning levels: informatory, cautionary and imminent risk levels. Audio, visual and haptic warning means will be combined for it.

Warning functionalities will include various traffic risks, such as obstacles/vehicles ahead, excessive

speed, approaching sharp curves or intersections with too high speed, predicted movement of vulnerable road users or animals at the vehicles trajectory, lane deviation, obstacles/vehicles at the adjacent lane when the vehicle is entering it, road works ahead.

Intervention may be included in urban environments, as Stop & Go function.

Level of operation: Warning / intervention

Penetration: The penetration will start from luxury cars and is expected to reach 10-15% after its first 3 years of marketing

Important parameters:

Road type: All road types, although some functionalities may be limited to specific types of roads.

Driver type: All drivers.

Weather conditions: All weather conditions. It might be needed to be switched off in specific adverse weather conditions, unless integrated also with vision enhancement systems.

Traffic density: All traffic densities.

Communication features: Will need to receive dynamic info on temporal traffic risks, conditions, density and weather from a Traffic Information and Management Centre (TIMC), most probably through mobile communication (i.e. UMTS), including the interaction with beacons at the road side (short-range communication) or even car to car communication.

Vehicle: All motorised vehicles. Initially, luxury ones, due to cost of the system.

Intended benefits:

- Reduction of accidents and road casualties. Still, behavioural adaptation of drivers and accident types migration should be very carefully studied.

*Table 25 Implementation Scenarios for the Integrated ADAS*

### 7.8.3 Discussion and Conclusions, Recommendations

The elementary analysis shows that the conditions for vehicle-related telematics to be developed, tested and implemented further are favourable. An important driving force behind this is the car industry, being supported by the EU by subsidising research and individual countries conducting research.

ISA will be developed step by step with increasing functionality. The building of Galileo satellite system will increase the precision of the location of vehicles and will be stimulating for the further improvement of enhanced navigation and ISA.

Although subsystems often are being developed and implemented separately, integration of hard- and software (when possible) is to be expected and also a must. The same applies to the integration of information to be presented to the driver. Standardisation is also needed.

The expectation is that in future an integrated system can be reached, after the needed research, testing and evaluation have been conducted. The question is whether a mandatory system such as ISA is needed. This depends among others on the penetration and use of voluntary ISA in practice and the effect on traffic speed. Further research on it is recommended.

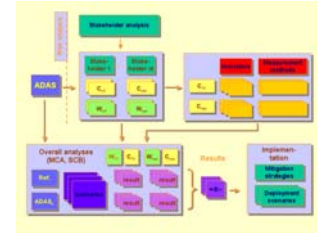
In the period 2002-2005 in new cars of certain brands installation of manual ISA and ACC will continue, further testing of subsystems will be done, speed limit data of all roads need be collected and criteria for critical locations formulated. Experiments with regional centres sending up-to-date data to vehicles driving in the region.

2006-2008: speed limit data will be incorporated in the software of navigation systems, when ISA is switched on speeding is not possible (except by kick-down), collection of dangerous locations on the European road network and the desired maximum speed, research to integrate navigation, ISA and ACC, research to integrate the information on behalf of the driver of all the subsystems, lane keeping and driver monitoring systems are installed in (some) new vehicles. UMTS operational, regional centres operational, sending the most up-to-date road and speed data to vehicles driving in that region.

2009-2012: Galileo operational. Hard and software of ISA, enhanced navigation and ACC+S&G are integrated in one system. Information of all the subsystems are integrated for the aural and visual display.



**7.9 Formulation of implementation strategies to overcome implementation barriers for priority future scenarios for: ACC, ISA, DMS and IAS.**



This work has been performed under Workpackage 7, on the basis of earlier work in workpackages 2 and 6 in particular and is reported in the deliverable:

ADVISORS_Del 7.pdf	Priority implementation scenarios, and schemes regarding equity, insurance policies, legislation, incentives and organisational consequences for ADAS deployment. Overview of state of the art regarding standardisation issues
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**7.9.1 Approach**

According to the previous sections, the Table 33 in Annex 27 summarises the Consortium decision on the final ADAS priority implementation scenarios. For the Stop and Go system, three scenarios are presented, which differ in terms of the road type (urban or peri-urban) and the density of the traffic flow. For Advanced Cruise Control (ACC) systems, the scenarios differ in terms of traffic density. We also consider four scenarios for Lateral Support systems, two scenarios for Lane Change Support systems, five scenarios for Intelligent Speed Adaptation (ISA) systems, four scenarios for Driver Monitoring systems, a single scenario for navigation systems and finally an “integrated” scenario, whereby various ADAS are introduced.

This set of Implementation Scenarios defined previously, was then prioritised through Multi-Criteria Analysis in WP6.

For this, evaluation criteria were chosen and defined, based primarily on the identified stakeholder objectives and the purposes of the ADAS considered. The users are interested primarily in the full user cost, driver comfort, driver safety and travel time duration. Society is concerned with public expenditures associated with ADAS introduction, the environmental effects (impacts on emissions, noise, etc...), third party safety, network efficiency and acceptability. Finally, the manufacturers are interested in the technical feasibility and the acceptance risk, as a proxy for the economic viability of the systems considered. The criteria are further specified in the table below.

<b>Criteria</b>	<b>Criteria description</b>
<b>Full user cost</b>	Monetary cost of the ADAS to be paid by the user (includes purchasing cost and operating costs)
<b>Driver safety</b>	Safety effects for the user of the system
<b>Driver comfort</b>	Changes in driving comfort from the point of view of the driver
<b>Network efficiency/travel time reduction</b>	More efficient performance of the road transport network and increased capacity
<b>Public expenditure</b>	Money outlay necessary to implement the ADAS, including investments in infrastructure and support measures
<b>Third party safety effects</b>	Overall change in safety from a societal point of view, i.e. the safety effects for the non-user of the system
<b>Environmental effects</b>	Effects on the environment (noise, emissions, etc.)
<b>Socio/political acceptance</b>	Societal acceptability of the ADAS by the users/decision makers
<b>Technical feasibility</b>	Technical/innovation risk: the risk of failure to develop the desired system

Table 26 Criteria description of the elements in the MCA

According to the MCA methodology, a pair-wise comparison of all the future scenarios was performed by

10 experts (internal and external members of the ADVISORS consortium, each focusing on those ADAS for which one had special expertise). The relative “priority” given to each element in the hierarchy is determined by comparing pair-wise the contribution of each element at a lower level in terms of the criteria (or elements) with which a causal relationship exists.

The geometric mean of all the scores provided by the experts was taken. The resulting ranking of future scenarios is shown below. (highest score is highest priority).

	<b>System</b>	<b>Overall score</b>
<b>1</b>	INTEGRATE	0,114
<b>2</b>	DMS1	0,068
<b>3</b>	DMS2	0,053
<b>4</b>	ISA5	0,050
<b>5</b>	ACC1	0,049
<b>6</b>	ISA4	0,048
<b>7</b>	NAVI	0,047
<b>8</b>	LS4	0,046
<b>9</b>	LC1	0,044
<b>10</b>	ACC2	0,041
<b>11</b>	STOP3	0,041
<b>12</b>	LC2	0,041
<b>13</b>	DMS3	0,040
<b>14</b>	STOP1	0,039
<b>15</b>	ISA1	0,039
<b>16</b>	LS2	0,039
<b>17</b>	ISA3	0,039
<b>18</b>	STOP2	0,038
<b>19</b>	ISA2	0,034
<b>20</b>	DMS4	0,033
<b>21</b>	LS3	0,030
<b>22</b>	LS1	0,026

Table 27 Ranking of future scenarios according to MCA

It was decided to start drafting Implementation Strategies on the scenarios ranked highest: the integrated scenario, the Driver Monitoring System, warning type, the intervening ISA, but not focusing upon the mandatory type, because of the specific implementation problems (liability, user acceptance, position of the industry), ACC.

Please refer to Annex 29 for a detailed description of the procedure.

## 7.9.2 Implementation Strategies for ACC

### Objectives of implementation strategies for ACC

In the strict sense of the word, there is no need for implementation strategies for ACC, because this ADAS is already on the market. However, what is important, is to ensure implementation of the ACC system to induce higher road safety, the reader will recall the various behavioural risks and negative effects ACC may have on driver behaviour, next to the positive effects. Therefore, the focus lies on driver training and awareness enhancement. Currently, mainly high class vehicles are equipped with it. One aspect facilitating the implementation of ACC is the fact that this ADAS is autonomous and not depending on infrastructure devices. ACC is designed and sold as a comfort system and not as a safety system, but some studies have shown that there is the risk of drivers expecting ACC to work like a collision-avoidance system and therefore reacting too late to stationary objects on the road, for example. Furthermore, the comfortable driving with ACC may reduce driver vigilance. Most of the implementation strategies for ACC that are described in the following aim at minimising the risks connected with its implementation as it is at the

moment. Another objective of the implementation strategies is the technical and technological development of ACC to enable the integration with other ADAS.

#### Development of implementation strategies for ACC

According to the above mentioned aims, 4 strategies were chosen to improve the implementation of ACC. These are:

##### *Strategies for ACC implementation*

1. Development of guidelines for driver instruction / training
2. Further research on the behavioural effects of driving with ACC
3. Further technical / technological development of ACC
4. Standardisation / Type approval

Most of these activities are already ongoing. Car manufacturers and electronic suppliers are working on the technical development of driver assistance systems and research is done on behavioural effects of ADAS (for example within the scope of the ADVISORS project). Furthermore, there are standardisation activities for ACC that have yielded a draft international standard for ACC, but currently, many points for discussion are left open and further research is needed to decide on these open questions, for example which acceleration and deceleration rates are acceptable. This shows that although the chosen implementation strategies are working in parallel, they are related to each other.

#### Timeframe of the implementation strategies for ACC

The following chart shows the expected timeframe for the implementation strategies that are described in detail in the following.

Strategy step	2002	03	04	05	06	07	08	09	10	11	12
1.1 driver instruction											
1.2 driver training											
2.1 research on behavioural adaptation											
2.2 research on driver-monitoring											
3.1 technical development of integrated systems											
3.2 enlargement of ACC functions											
4.1 standardisation of ACC											
4.2 type approval for ACC											

Figure 9 Timeframe for the implementation strategies for ACC

In the Annex 30 the four implementation strategies are described in detail, each strategy consisting of two steps. Note that 'steps' does not mean that the two parts of the implementation strategy must follow on each other.

### 7.9.3 ISA

#### Objectives of implementation strategies for ISA

Five different types of ISA are defined; ordered chronologically - from phase [A] the present state, to the last phase [E] the mandatory type after some 15 years. The systems increase in functionality and flexibility and sophistication.

Intended benefits for ISA: to reduce speeds and accidents/road casualties

Communication: data on which ISA is based can be stored on an in-car CD-ROM or DVD or can be transmitted from a regional centre having the most up-to-date data. Combinations are also possible, e.g. road network stored on CD-ROM/DVD and road works, traffic and weather data being sent from regional center.

For several reasons ; the problems identified earlier: the resistance from industry and users, the legal problems, the behavioural adverse effects and socio-political issues, ISA-E is *not* considered as the intended end-result. ISA-D is the system to aim for.

- ISA [A]** Present available ISA, warning and voluntary intervention  
Speed limit can be adjusted manually. Either just information or warning is given when speed exceeds the set limit or speeding is not possible (except by kick down). It depends on the carmaker which feed back type is given. The last system is an intervening system.  
For all road types. Exp. time frame: since a couple of years already fitted in some car types. Stimulation by EU governments so other car makers will fit ISA [A] too.
- ISA [B]** Informing or warning or intervening ISA; static speed limits  
This ISA system operates conforming to the static speed limits of the roads (CD-ROM).  
When the driver switches on ISA, the system can give either information or a warning when the vehicle is about to speed or it can intervene making speeding impossible.  
Fit for all road types. Possible coupling with in-car rain sensor for lower limits. Integration with navigation system. Exp. time frame: 2003-2006. Collection speed limit data and adding to navigation software(road authorities, software maker). Stimulation by EU governments to fit, accept and use of ISA[B].
- ISA [C]** Informing or warning or intervening ISA, also at dangerous locations  
The ISA system is based on the static speed limits [B] and on maximum safe approach speeds of dangerous locations [C], e.g. curves, intersections, and railway crossings.  
When the system is switched on, it can give just information or a warning or can intervene. Fit for all road types. Possible coupling with in-car rain and light sensors for lower limits. Exp. time frame: 2007-2010. Research on criteria risky locations and maximum speed (research institutes), collection data risky locations, determination max. speed and adding to software (road authorities, software makers), standardisation data bases, HMI & interfaces and liability issues (EU, car makers).
- ISA [D]** Informing or warning or intervening ISA, also for road/traffic/weather conditions.  
The ISA system is based on static speed limits ISA[B], safe approach speed of dangerous locations ISA[C] and safe speed at dangerous road, traffic and weather conditions ISA[D] (dynamic). A regional center sends the dynamic up-to-date information to the car. Fit for all road types. Possible coupling with in-car light and rain sensors for lower limits. Integration with navigation.  
Exp. Time frame: 2011-2014. Criteria for risky conditions and maximum speed (research institutes), setting up data collection network and regional centres, (road authorities, industry), standardisation (EU), stimulation fitting and use of ISA [D] (governments), integration longitudinal control {industry}.
- ISA [E]** Mandatory controlling ISA  
ISA [E] is a mandatory controlling system and can not be switched off by the driver. Fit for all road types. Exp. Time frame: never, or after 2018. Liability issues (car makers, EU governments).

### Development of implementation strategies for ISA

According to the above mentioned aims, 3 strategies were chosen to improve the implementation of ISA. These are:

#### Strategies for ISA implementation

1. Research and Development
2. Development and Implementation: Data Collection and Transmission to vehicles
  - 1 for ISA [B]
  - 2 for ISA [C]
  - 3 for ISA [D]
  - 4 for ISA [E]
3. Standardisation and Type approval

The activities for ISA [A] are completed: the system is already on the market.

**Timeframe of the implementation strategies for ISA**

The following chart shows the expected timeframe for the implementation strategies that are described in detail in the following.

Strategy step	2002	03	04	05	06	07	08	09	10	11	12
1.1 Research and Development											
2 Data collection and transmission to vehicles											
2.1 for ISA [B]											
2.2 for ISA [C]											
2.3 for ISA [D]											
2.4 for ISA [E]											
3. Standardisation and Type approval											

Figure 10 Timeframe for the implementation strategies for ISA

In the Annex 31 the implementation strategies are described in detail.

7.9.4 DMS

**Objectives of implementation strategies for DMS**

Naturally, full integration within a vehicle-control-system is aimed for. The development and implementation of the Driver Monitoring scenario is both a national and international (European) case, as it is not developed for particular traffic or special environments. The first application is expected to be on highways / motorways, as this is technically feasible and relatively easy to organize, and most relevant: reduced vigilance is a problem particularly for motorways/highways and rural roads. The Driver Monitoring scenario is developed for all types of motor vehicles, although cost considerations might lead to a first application of all functionalities in professional vehicles, in particular from the heavy goods transport sector. Application to trucks is more profitable and easier to realize from a legal and organizational point of view. The consequences of truck accidents as a consequence of driver impairment are probably unbalanced with respect to seriousness. From the stakeholder analyses it appeared that companies are interested in these systems.

**Development of implementation strategies for DMS**

According to the above mentioned aims, 1 strategy was chosen with four steps for the coming decade to improve the implementation of DMS. This is:

Strategy for DMS implementation	
1. Research and Development of the DMS	
1.1 R&D for Professional driver monitoring, warning only	
1.2 R&D for Professional driver monitoring, warning and intervening	
1.3 All drivers monitoring, warning implementation	
1.4 All drivers monitoring, warning and intervening implementation	

**Timeframe of the implementation strategies for DMS**

The following chart shows the expected timeframe for the implementation strategies that are described in detail in the following.

Strategy step	2002	03	04	05	06	07	08	09	10	11	12	13
1.1 R&D professional warning only												
1.2 R&D professional warning intervening												
1.3 R&D all drivers warning												
1.4 R&D all drivers warning intervening												

Figure 11 Timeframe for the implementation strategies for DMS

In the Annex 32 the implementation strategies are described in detail.

### 7.9.5 Implementation strategies for Integrated ADAS

Within ADVISORS MCA as scenario of highest score (first priority) has been selected the so called “ Integrated ADAS ”, combining functionalities of dynamic navigation, ACC, S&G and ISA. More precisely, it combines the functionalities of the following ADAS scenarios from:

- ACC1 (Motorway, High flow).
- STOP1 (Urban, High flow).
- NAVI (Dynamic Navigation).
- ISA (Rural / Urban, Information, Dynamic)`.

Such an ADAS would fully cover the longitudinal control of the car, but mainly at the warning level, with few interventions from S&G system in the urban environment. The next logical step will be its integration with lateral support aids (i.e. LS2, LS4, LC1, LC2), to develop a virtual electronic cushion around the car. This version is also considered.

The following figure presents a first vision towards such a car in the future:

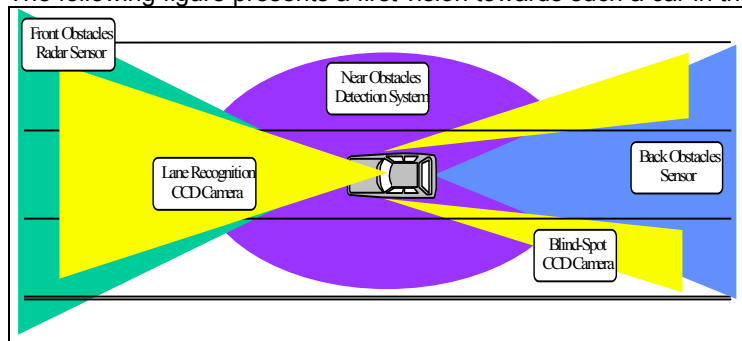


Figure 12 Integration of longitudinal and lateral ADAS for an extended IAS scenario in the future

The development and implementation of the integrated ADAS scenario is international (at least pan – European) , as it is not aimed for particular traffic or weather environments. The first application is expected to be on highways/motorways, as this is technically easier and organizationally simpler (move all infrastructure can be put in place by the road authority, where as in rural /urban areas various Municipalities may also need to be involved).

The ultimate goal is the application in a rural, peri-urban and urban environment and, even more, the seamless operation of the system across different environments and territorial/country borders. Such an application has as critical parameters the following:

- **Signalization of the road type:** As different system parameters or even systems may operate in different road types, there need to be appropriate signals (i.e. through beacons) letting the system to understand in which type of road it is operating.
- **Interoperability of services:** Different areas may be mapped digitally by different developers. Seamless service requires full compatibility and automatic transition from the one to the other. The project NEXTMAR is the first step towards this direction.
- **Service Roaming:** Different service providers are expected to exist in different countries/ areas. Service roaming, in the form of telecommunication services roaming, is still lacking in the areas of infomobility and driver support and needs urgently to be established.

Regarding the type of vehicle, the integrated ADAS scenario is for all types of motor vehicles, although cost considerations might lead to a first application of all functionalities in luxury cars. Also application on trucks might be easier from a legal and organizational point of view, but any technical problem remaining may have more serious impact in this domain.

	2003	04	05	06	07	08	09	10	11	12
R&D on ISA, ACC, S&G, NAVI										
Standardization and fusion between them										
ACC in the market										
S&G in the market										
ISA in the market										
Dynamic navigation in the market										
NAVI Integrated TMCs										
Infrastructure development for highways										
Infrastructure development for rural environments										
Infrastructure development for urban environments										
Integrated ADAS in the markets										

	13	14	15	16	17	18	19	20	21
R&D on ISA, ACC, S&G, NAVI									
Standardization and fusion between them									
ACC in the market									
S&G in the market									
ISA in the market									
Dynamic navigation in the market									
NAVI Integrated TMCs									
Infrastructure development for highways									
Infrastructure development for rural environments									
Infrastructure development for urban environments									
Integrated ADAS in the markets									

In the Annex 33 the implementation strategies are described in detail.

### 7.9.6 Validation through the workshops

Rating on how realistic the scenario is.

is this scenario realistic (scale 1-5, 1 = not realistic at all)?

System	Mode	Median	Average	Range
ISA	2	3	3.0	2-5
ACC – Stop & Go	4	4	3.7	2-5
Driver Monitoring	4	4	3.4	2-4
Lane Keeping Support	4	4	3.8	2-5
Navigation	5	5	4.6	4-5

Those systems that are already available receive a high rating on reality with respect to scenario development. The experts are most sceptic about ISA, all other scenarios are rated neutral to likely.

Rating on how desirable the scenario is.

is this scenario desirable (scale 1-5, 1 = not desirable at all)?

System	Mode	Median	Average	Range
ISA	4	4	3.8	2-5
ACC – Stop & Go	3.5	4	3.6	2-5
Driver Monitoring	3	3.5	3.6	1-5
Lane Keeping Support	3.5	3.5	3.5	2-5
Navigation	4	4	3.8	3-5

All scenarios are rated as desirable (median 3 – 4)

#### Rank order systems

Systems Rank ordered:

System mentioned	1 <sup>st</sup>	2 <sup>nd</sup>	3 <sup>rd</sup>	4 <sup>th</sup>	5 <sup>th</sup>
ISA	5 x	2 x	1 x	0 x	0 x
ACC – Stop & Go	0 x	3 x	1 x	4 x	0 x
Driver Monitoring	0 x	1 x	4 x	1 x	1 x
Lane Keeping Support	1 x	2 x	0 x	1 x	3 x
Navigation	2 x	0 x	1 x	1 x	3 x

Systems Rank ordered (cumulative):

System mentioned	1 <sup>st</sup>	1 <sup>st</sup> + 2 <sup>nd</sup>	1+2+3 <sup>rd</sup>	1+2+3+4 <sup>th</sup>	(total)
ISA	5	7	8	8	8
ACC – Stop & Go	0	3	4	8	8
Driver Monitoring	0	1	5	6	7
Lane Keeping Support	1	3	3	4	7
Navigation	2	2	3	4	7

At the end of the workshop, the five systems were ordered on importance.

- ISA was considered no. 1 in terms of priority.
- With respect to desirability of the scenario, ISA also received high ratings, although the scenario is not expected to be highly realistic.

## 7.9.7 Discussion and Conclusions, Recommendations

The procedure for ranking the future scenarios and development of the implementation strategies has worked, although the validation is still limited. More feedback from experts, maybe through a questionnaire method would be advisable. Still, the experts who participated in the workshops were highly valued members of the community, with respect to knowledge, experience and position in the field of ADAS.

### **Approach for defining policy measures**

The type of actions that can be undertaken by the public authorities in particular, will be defined according to the FANTASIE framework, e.g. described in van Zuylén and Weber (2002). Some elements are the following:

The following successive phases can be distinguished in the development of innovative products: Invention, Test, First application, market introduction, Maturity, Decline and Replacement.

According to the authors, in general, the best steering opportunity for governments is in the Invention phase and in the transition phase between R&D and Market introduction. These are the phases in which the ADAS of interest are positioned, momentarily (ISA-A: Market introduction; ISA-B, C, D: First application, Test/Invention; ACC: Test/First application; DMS: Test; Integrated ADAS: Invention)

The types of measures governments can take are the following:



Types of measures:	Explanation
<b>Structural measures</b>	adaptation of legal and regulatory framework conditions (e.g. taxation issues).
<b>Technology measures</b>	these involve research, development and experimentation
<b>Compatibility measures</b>	standardisation issues, either for increasing compatibilities between technologies or for increasing critical weight for introducing these measures
<b>Cultural measures</b>	Government policy can play an important role in influencing attitudes.
<b>Institutional measures</b>	Sometimes parties have to cooperate in order to enable e.g. multimodal transport. Competitive pressure in the market determines innovative investments.

### Roles of the Industry

In several phases and with regard to several actions, it is regarded essential that Industry will have to invest.

The relevant model for prediction of *willingness to invest*, based on the common widely excepted theories of business and investment theories (e.g. Brealy and Myers, 1988) state the following:

The willingness to invest in the ADAS product by the industry is primarily determined by the market expectations and the cost price of the investment (=profit).

The influence of the role of the public authorities on willingness to invest is fourfold.

- (1) It can influence the price through funding mechanisms by subsidizing or tax reductions for ADAS. This is particular relevant in the initial product phase.
- (2) The image of the product can be influenced by the public authorities.
- (3) There is an evident role for the public authorities with regard to the availability and
- (4) the cost price of infrastructural and dynamic traffic data.

### ISA Facilitation

As followed from the future scenario prioritisation procedure, ISA-D is considered the goal to aim for.

Industry has to perform, or contribute to actions, according to the analyses:

- (1) Collecting data and transmitting to vehicles (ISA-B - ISA-E)
- (2) Standardisation and type approval (all ISA types)
- (3) Research on setting criteria for safe speed (ISA-C-ISA-E)

The experts considered all these actions relevant, but there is a preference for the actions 1 and 3, and also a higher urgency in time.

Therefore, public authorities could facilitate introduction of ISA by improving the individual willingness to invest by the industry by making available infrastructure at low cost and especially dynamic traffic data (for increasing safe speeds).

Furthermore, other, supporting institutional measures can be taken.

In addition, market expectations can be raised by installing funding mechanisms for the start off of investments needed for the development of ISA.

Public Authorities could in principle also play a role in the product image, but this may be a tricky business and may be best left for the commercial parties, who are best equipped to do so.

**ACC**

Actions related to the promotion of ACC use by the Industry and the Authorities include:

- (1) Reach a commonly agreed Technical Standard and Homologation procedure.
- (2) Clarify and extend its functionality, taking into account possible driver behaviour adaptations (further research; emphasis on driver behaviour issues).
- (3) Development of driver training schemes for optimal ACC use.

Authorities should initiate the above procedures and partially fund them (especially the further research), but it is the Industrial sector who has to perform most of the actions.

ACC products exist already in high-end vehicles, it may be the decisive ADAS to either pave the way for the rest or to doubt their usefulness and traffic safety enhancement potential.

Therefore, the unstructured and multi-brand based policies of today seem to be dangerous for ACC success and fast market penetration rate.

**IA**

An Integrated ADAS needs still to be developed and optimised by the Industry, before being promoted. Nevertheless, public sector funding needs to be streamlined towards this direction, as only an integrated application will be finally viable in the market and will cover the actual user needs. Thus, the Industry needs to:

- (1) Work towards sensor fusion and HMI integration for the realisation of multi-ADAS integrated applications.
- (2) Start working early on their interoperability and standardisation.

Relevant authorities on the other hand (including EU) should prioritise to:

- (1) Provide the necessary infrastructure, or at least provide incentives for its realisation (i.e. digital maps of high accuracy).
- (2) Promote the subsystems standardization (especially on the HMI level) with the issue of statements of principles, guidelines and, eventually, recommendations to the Industry; as well as the definition of a proper evaluation framework for them.

## 7.10 Dissemination of the results through various channels and production of the user-friendly terminology

This work has been performed under Workpackage 8 and is reported in the deliverable:

ADVISORS_Del 8b.pdf ADVISORS_Del 8b Annex.pdf	Dissemination report and exploitation plans
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### 7.10.1 Leaflet and poster production

The objective of Leaflet and Poster production was to distribute information about ADVISORS scope and objectives during conferences, events.

Around 2500 leaflets and 500 posters have been produced and distributed at conferences, workshops, through individual contacts.

### 7.10.2 ADVISORS WEB site

The ADVISORS web site has been deployed at an early stage of the project, in June 2000. From this period it was under continuous development and improvement.

The following sections give information about the WEB site organization, management and implementation process. A specific paragraph is dedicated to the User Forum. The last section presents statistics about the use of the WEB site from June 2000 until September 2002. The address: [www.advisors.iao.fhg.de](http://www.advisors.iao.fhg.de)

#### Web site general organization

The ADVISORS Web site contains the following pages:

- **General Information page:** this first page includes the Project acronym signification, specific news about the update of the ADVISORS Web site and the link with the other pages:
  - **Project:** contains information about ADVISORS project management, the consortium, the work-package structure, a sample of ADVISORS leaflet
  - **Reports:** contains the executive summary of the various deliverable as well as the full public deliverables. It also includes the ADVISORS workshop venues scopes and minutes and at last the list of the ADVISORS publications in congresses and journals and their related abstracts.
  - **Tools:** Contains the ADAS QuickCheck that is a checklist for checking the human-machine interface (HMI) of advanced driving assistance systems (ADAS). It includes anthropometrical, biomechanical and perceptive/cognitive aspects.
  - **Virtual driving lab:** The Virtual Driving Lab provides a virtual "driving simulator" for demonstration of ADAS systems. It is used to
    - ❖ demonstrate ADAS functions via the Web
    - ❖ perform ADAS experiments at distributed locations
  - **Links:** contains links with other related project
  - **Forum:** A discussion forum, which objective was to guide the user needs, acceptances as well as dissemination activities of the project. The discussion forum is organized around several conversations
  - **Comments**
  - **Internal:** For internal purposes a password protected internal site was also established, which allows the online reading of agendas and minutes of consortium meetings and to download important documents. The internal web-site also allows the access to the ADVISORS internal ftp server, which hosts all important ADVISORS documents.

#### Documents and reports

The exploitation manager, in relation with the technical board and WEB administrator, decides which documents should be implemented on the WEB server, taking into account the confidentiality requirements, but also the usefulness of the document for public use.

#### Papers in conferences, journals and chapters in books

In order to ensure the coherence of the publications, with respect to the publication plan and to avoid any papers duplication an abstract of papers to be presented or published and the conference or journal

references is sent to the exploitation manager. Then the selected paper is administered by the WEB administrator.

#### **Events (Workshop cycle)**

Scope and information about organized events is provided to the WEB administrator, when available.

#### **Demos/simulations**

The appropriateness of the demo is to be decided by the project's technical board.

##### **Virtual driving lab:**

The Virtual Driving Lab provides a virtual "driving simulator" for demonstration of ADAS systems. It is used to

- demonstrate ADAS functions via the Web
- perform ADAS experiments at distributed locations

#### **Links**

The Links page contains a useful

- selection of European projects about Advanced Driver Assistance Systems
- selection of national projects about Advanced Driver Assistance Systems
- European organizations and services
- Other international references
- Publications and Journals

### 7.10.3 Workshops

Within ADVISORS project duration, several Workshops have been organized.

Their objectives were:

- To communicate with the different communities :
  - Insurance companies;
  - Legal authorities;
  - Customers / transportation operators / users;
  - Car manufacturers and suppliers;
  - Scientific community experts.

The aim of these workshops was:

- to discuss about users awareness;
- to identify critical problems;
- to make potential users (customers) aware of ADVISORS work;
- to get information and recommendation from the different communities;
- to give the opportunity to these different communities to establish a dialogue;
- to extract information about potential exploitation from these different communities;
- to present ADVISORS work -methodology and results.

These workshops contributed to the dissemination process, user awareness and exploitation plans, but also provided support for the achievement of several project milestones.

The attendance to these workshops was mainly based on: ADVISORS partners, Invitations based on the key contact list used for WEB diffusion, External attendance (from WEB information) and local diffusion Experts not involved within ADVISORS.

- Early in the project, a first set of Workshops was organized simultaneously in several countries. These first workshops were organized in relation with milestones M1 and M2. It was the first occasion to meet ADVISORS key contacts and to establish or reinforce links. During them, a global presentation of ADVISORS objectives and expected outcome was delivered. In addition, the main objective was to present the results of the State of the Art analysis and the identification of high potential ADAS (milestone M1). It was also used as an additional information poll for the identification of major socio-economic, financial and user acceptance barriers, as well as for market analysis. Some presentations of the former experience in terms of ADAS market introduction from different socio-economic actors were included.
- In the framework of work package 7.3 several Expert Workshop were organised, in Netherlands by RUG, in Germany by BAST and by the end of the project in conjunction with the final dissemination workshop in Lyon. The objectives of these workshops were to assess and to discuss organisational

consequences and way to overcome all kind of hindrances regarding the implementation of ADAS.

- The Final dissemination Workshop was held in Lyon in September 2002. Its objective was to present the final ADVISORS results on: ADAS methodological assessment, ADVISORS exploitations plans (results from questionnaire), ADVISORS pilot results.

In addition several presentations of ADVISORS project have been done at other EU projects. The table in the Annex 36 summarizes these different workshops and related dissemination activities.

#### 7.10.4 CD-ROM

The objective of the ADVISORS CD-ROM is to give the reader the opportunity to have a short and good overview of the ADVISORS goals and achievements. Part of the CD-ROM is dedicated to the video of the various experiments performed during the project. They should be used to highlight the recognized problems and enhance relevant users' / actors' awareness.

The ADVISORS' CD-ROM includes 5 different parts. Parts 1, 2, 3 and 5 are in PowerPoint form and give in a few slides a synthesis of the ADVISORS project objectives and results. Part 4 includes video of the various test pilots performed during the project.

The CD-ROM is organized in a hierarchical manner. Thanks to menu and sub-menus readers can have a direct access to their point of interest.

#### 7.10.5 User Friendly terminology

The work has been performed in Workpackage 2 and is reported also separately in a document:

ADVISORS_UFTerminology.pdf	User Friendly ADAS Terminology
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##### **Main aims**

ADA systems may help to make the entire driving experience safer for consumers. They gear to reduce vehicle collision, to enhance occupant protection and to assist post event (crash etc.) rescue. However, it is common knowledge that the implementation of a lot of ADAS is not based on users' expressed wishes but rather on the manufactures considerable technological push. Furthermore misunderstandings between developers technical terms and users' expectations and assumptions are making the conversation between the providers and the end users irrelevant and even impossible. As seen in previous chapters, there are also differences between authorities'/administrations' (i.e. policy makers') and users' expectations and preferences. By developing a user-friendly ADAS terminology, it is possible to enhance system acceptance and public awareness, and to prevent false assumptions and expectations of the end users. It is important in both marketing and public information campaigns that the used terminology is understandable for the end-users.

The main aim of this part of the study was to define a user-friendly ADAS terminology to some of the most important ADA systems selected during the first year of the ADVISORS-project. The further development of user-friendly terminology needs to be done by testing the comprehensibility of defined terms with actual drivers (pilot studies etc.).

##### **Methodology**

The exhaustive table of user-friendly terminology of several ADA systems and their technical parts (presented in Deliverable D2.1, and *the setup* is shown in Annex 37) is based on literature and standards review done by Dr. Alan Stevens from TRL. In addition to the review, the ADVISORS Deliverable D2.1 was used to describe the technical functions of different ADA system, especially those of system manufacturers. In addition, the previous findings in work package 2 were taken into account while planning especially the system specifications.

##### **Results**

In different ADA systems there are various functions (such as ACC, ISA etc.) that are designed to reduce crash risk and enhance driving comfort. In addition, in individual ADA functions it is very common that

different levels of intervention exist, ranging from informative to intervening systems. In other words, some systems are designed to reduce crash risk by providing support to drivers in a number of ways, by even taking over control of the driving task and intervening in situations of increased crash risk to eliminate or at least reduce risk to an acceptable level. Some systems aim at reducing crash risk by informing or warning drivers of imminent hazards, like following the vehicle in front too closely, hazards to be expected ahead on the route or incidents blocking the road or causing some time delays.

The expectation concerning these informing or warning systems is that road users utilise this information by adapting their behaviour to account for the hazard and thus decrease the crash risk and avoid a collision. To gain the best safety effects of ADA systems, it must be ensured that the drivers understand the technical capability and the level of intervention that the system he or she is using is capable to offer. This is possible only if the functions and level of intervention of different ADA systems are described with terms that are understandable to the end user.

In the relevant table some of the most important ADA systems in near future, or most often concerned ADA systems in ADVISORS project are presented in three categories: longitudinal systems, lateral systems and other systems. In each category the individual ADA systems are described by their basic function idea, technical definition and definition that should be used, when discussing with the end users. The systems are divided to lateral support systems (lane keeping, blind spot detection), longitudinal support systems (headway control, collision avoidance, intelligent speed adaptation, platooning) and others.

## 7.11 List of deliverables: Public and Restricted Deliverables

	<b>Deliverable details</b>
<b>WP:</b>	<b>1, 2</b>
<b>Deliverable Id:</b>	<b>D1/2.1 v4 Public Deliverable</b>
<b>File name:</b>	<b>ADVISORS_Del 1a.pdf</b>
<b>Title:</b>	Problem identification, User Needs and Inventory of ADAS
<b>Responsible authors:</b>	T.Heijer, H.L.Oei, M.Wiethoff (SWOV), S.Boverie (Siemens), M.Penttinen, A.Schirokoff, R.Kulmala (VTT), J.Heinrich (CDV), A.C.Ernst, N.Sneek, H.Heeren (JDR), A.Stevens (TRL), A.Bekiaris (AUTH), S.Damiani (CRF).
<b>Deliverable date:</b>	November 2000
<b>WP:</b>	<b>1</b>
<b>Deliverable Id:</b>	<b>D1.2 Public Deliverable</b>
<b>File name:</b>	<b>ADVISORS_Del 1b.pdf</b>
<b>Title:</b>	Inventory of ADAS and User Needs. Update 2002
<b>Responsible authors:</b>	H.L.Oei, M.Wiethoff (SWOV), S.Boverie (Siemens), M.Penttinen, A.Schirokoff, R.Kulmala (VTT), J.Heinrich (CDV), A.Stevens (TRL), A.Bekiaris (AUTH), S.Damiani, F. Tango (CRF)
<b>Deliverable date:</b>	15 December 2002
<b>WP:</b>	<b>2</b>
<b>Deliverable Id:</b>	<b>D2 V2.0 Public Deliverable</b>
<b>File name:</b>	<b>ADVISORS_Del 2.pdf</b>
<b>Title:</b>	Actor interests, acceptance, responsibilities and users' awareness enhancement.
<b>Responsible authors:</b>	E. Mankkinen, V. Anttila, M. Penttinen (VTT), V. Marchau (TRAIL) and A. Stevens (TRL)
<b>Other authors:</b>	S. Boverie, N. Mallet-Lamandin (SIEMENS), M. Dangelmeier (IAT), J. Heinrich (CDV), A. Bekiaris (AUTH), S. Damiani, F. Tango (CRF), A.C. Ernst, N. Sneek, H. Heeren (JDR), A. Heino (Achmea) and M. Wiethoff (SWOV)
<b>Deliverable date:</b>	4 <sup>th</sup> May 2001 and accepted 16 <sup>th</sup> May 2001.
<b>WP:</b>	<b>3, 8</b>
<b>Deliverable Id:</b>	<b>D3/8.1 Public Deliverable</b>
<b>File name:</b>	<b>ADVISORS_Del 3a8a.pdf</b>
<b>Title:</b>	Compendium of existing Insurance schemes and Laws, risk analysis of ADA systems and expected driver behavioural changes. User awareness enhancement, dissemination report, market analysis and ADAS marketing strategy.
<b>Responsible authors:</b>	E.Bekiaris, Ch. Papakonstantinou (AUTH), A.Stevens, A. Parkes (TRL), S. Boverie (Siemens), L. Nilsson (VTI), K. Brookhuis (RUG), K. Van Wees (TRAIL), M. Wiethoff (SWOV), S.Damiani, F. Lilli (CRF), A. Ernst (JDR), A. Heino (Achmea), H. Widlroither (IAT), J. Heinrich (CDV)
<b>Deliverable date:</b>	May 2001
<b>WP:</b>	<b>3</b>
<b>Deliverable Id:</b>	<b>D3.2: Public Deliverable</b>
<b>File name:</b>	<b>ADVISORS_Del 3b.pdf</b>
<b>Title:</b>	Framework for Insurance and related liability issues, gaps and barriers for the implementation and Expected organisational changes.
<b>Responsible authors:</b>	E. Bekiaris, Ch. Papakonstantinou (AUTH), A.Stevens, A. Parkes (TRL), S. Boverie (Siemens), L. Nilsson (VTI), K. Brookhuis (RUG), K. Van Wees (TUDelft), M. Wiethoff (SWOV), S.Damiani, F. Lilli (CRF), A. Ernst (JDR), A. Heino (Achmea), H. Widlroither (IAT), J. Heinrich (CDV)
<b>Deliverable date:</b>	16 July 2002

- WP: 4**  
**Deliverable Id: D4.1 Public Deliverable**  
**File name: ADVISORS\_Del 4a.pdf**  
**Title:** Development of Multi-Parameter criteria and a common impact assessment methodology.  
**Responsible authors:** N. Brook Carter, A. Parkes, A. C. Ernst, I. Jaspers, L. Nilsson, K. Brookhuis, D. De Waard, S. Damiani, F. Tango, S. Boverie, M. Danglemaier, A. Knoche, G. Yannis, J. Golias  
**Deliverable date:** August 2001
- WP: 5**  
**Deliverable Id: D5.1 v3 Public Deliverable**  
**File name: ADVISORS\_Del 5a.pdf**  
**Title:** Pilot plans  
**Responsible authors:** L. Nilsson (VTI), A. Parkes (TRL), M. Dangelmaier (IAT), K. Brookhuis (RUG), C. Gelau (BAST), F. Tango (CRF), S. Damiani (CRF), A. Ernst (JDR), S. Boverie (SIEMENS) and M. Wiethoff (SWOV)  
**Deliverable date:** September 27, 2001
- WP: 4, 5**  
**Deliverable Id: D4/5.2 Public Deliverable**  
**File name: ADVISORS\_Del 4b\_5b.pdf**  
**Title:** An integrated methodology and evaluation checklist and ADA design. Pilot Evaluation Results  
**Responsible authors:** Part I: (tasks 4.1-4.5)  
 N. Brook-Carter, A. Parkes, (TRL), M. Dangelmaier (IAT), K. Brookhuis (RUG), C. Gelau (BAST), F. Tango (CRF), S. Damiani (CRF), A. Ernst (JDR), S. Boverie (SIEMENS) and M. Wiethoff (SWOV)  
  
 Part II: (Task 4.6)  
 N. Brook-Carter, A. Stevens (TRL), A. Bauer (BAST), K. Brookhuis (RUG), M. Danglemaier (IAT), S. Hoogendoorn (TUDelft), C. Macharis (BIVV), L. Nilsson (VTI), F. Tango (CRF), G. Yannis (NTUA)  
  
 Part III: (Tasks 5.2 and 5.3)  
 L. Nilsson, J. Törnros (VTI), A. Parkes, N. Brook-Carter (TRL), M. Dangelmaier (IAT), K. Brookhuis, A-J. Roskam, D. De Waard (RUG), A. Bauer, C. Gelau (BAST), F. Tango, S. Damiani (CRF), I. Jaspers, A. Ernst (JDR), G. Yannis, C. Antoniou (NTUA), M. Wiethoff (SWOV)  
  
**Deliverable date:** December 15, 2002
- WP: 6**  
**Deliverable Id: D6.1: Public Deliverable**  
**File name: ADVISORS\_Del 6.pdf**  
**Title:** CBA criteria and methodology for ADAS assessment. Potential funding mechanisms and incentives  
**Responsible authors:** A. Verbeke, C. Macharis, K. de Brucker  
**Deliverable date:** December 15, 2002
- WP: 7**  
**Deliverable Id: D 7.1 v4: Public Deliverable**  
**File name: ADVISORS\_Del 7.pdf**  
**Title:** Priority implementation scenarios, and schemes regarding equity, insurance policies, legislation, incentive and organisation consequences for ADAS deployment. Type approval and standardisation recommendations.  
**Responsible authors:** E. Bekiaris (AUTH), A. Bauer, C. Gelau (BAST), A. Stevens (TRL) M. Wiethoff, L. Oei, C. Schoon (SWOV), K. Brookhuis, D. de Waard (RUG), V. Anttila, E. Mankkinen (VTT), C. Macharis, A. Verbeke (BIVV)  
**Deliverable date:** December 27, 2002



**WP:** 8  
**Deliverable Id:** **D8.2: Restricted Report**  
**File name:** **ADVISORS\_Del 8b.pdf**  
**ADVISORS\_Del 8b Annex.pdf**  
**Title:** Dissemination report and exploitation plans.  
**Responsible authors:** S. Boverie (Siemens), M. Wiethoff (SWOV), M. Dangelmaier (IAT)  
**Other authors:** All other partners  
**Deliverable date:** December 15, 2002

#### ADVISORS Pilot Reports Task 4.5 and 5.2

**Deliverable Id:** **ADVISORS: ID1/4.5 V2**  
**Title:** *Road network efficiency and environmental impact assessment of Advanced Driver Assistance Systems.*  
**Responsible authors:** *Authors: J. Golias, G. Yannis, C. Antoniou, S. Pelantakis (NTUA), A. Stevens, E. Hardman (TRL), C. Cuypers, R. Dieleman (IBSR-BIVV), H. Bruneel, M. van Poppel (VITO), S. Hoogendoorn, M. Minderhoud (TU Delft), M. Penttinen, V. Anttilla (VTT), J. Niittymaeki (HUT)*  
**Other authors:**  
**Deliverable Date:** *Deliverable Date: July 2001*

**Deliverable Id:** **ADVISORS: TRL\_4\_5\_2**  
**Title:** *Microscopic traffic and environmental modelling using SISTM*  
**Responsible authors:** *A. Stevens, E. Hardman (TRL)*  
**Other authors:**  
**Deliverable Date:** *Deliverable Date: May 2001*

**Deliverable Id:** **ADVISORS: HUT4\_5\_1**  
**Title:** *ADAS-Vehicles Microsimulation Using HUTSIM-simulator*  
**Responsible authors:** *J. Niittymaeki, M. Granberg (HUT)*  
**Other authors:**  
**Deliverable Date:** *Deliverable Date: June 2001*

**Deliverable Id:** **ADVISORS: TRAIL4\_5\_1.**  
**Title:** *ADAS Impacts Assessment by Microscopic Simulation*  
**Responsible authors:** *S. P. Hoogendoorn (TU Delft)*  
**Other authors:**  
**Deliverable Date:** *Deliverable Date: May 2001*

**Deliverable Id:** **ADVISORS: Vito4\_5\_1.**  
**Title:** *Subtask macroscopic environmental modelling. Model: TEMAT*  
**Responsible authors:** *H. Bruneel, M. Van Poppel (Vito)*  
**Other authors:**  
**Deliverable Date:** *Deliverable Date: May 2001*

**Deliverable Id:** **IAT ID 5.2 Internal deliverable**  
**Title:** *Pilot results Lane Warning and Collision Warning*  
**Responsible authors:** *M. Dangelmaier, H. Widlroither*  
**Other authors:**  
**Deliverable Date:** *October 2001*

*Deliverable Id:* **TRL ID 5.2 Internal deliverable**  
*Title:* *Urban ACC and Stop and Go results*  
*Responsible authors:* N. Brook-Carter et al (TRL)  
*Other authors:*  
*Deliverable Date:* May 2002

*Deliverable Id:* **BASt ID5.2 Report LSS Internal deliverable draft 1**  
*Title:* *An Evaluation Study of the Lateral Support System (LSS)*  
*Responsible authors:* A. Bauer (BASt), F. Tango (CRF)  
*Other authors:*  
*Deliverable Date:* October 4, 2002

*Deliverable Id:* **VTI ID5\_2\_1.DOC Internal Deliverable**  
*Title:* *Effects of ACC on driver behaviour, workload and acceptance in relation to minimum time headway*  
*Responsible authors:* J. Törnros, L. Nilsson, J. Östlund, A. Kircher  
*Other authors:*  
*Deliverable Date:* March 2002

*Deliverable Id:* **RUG ID5\_2\_3 Internal Deliverable**  
*Title:* *Pilot test 3*  
*Responsible authors:* Albert-jan Roskam, Dick de Waard, Karel Brookhuis  
*Other authors:*  
*Deliverable Date:* March 2002

*Deliverable Id:* **JDR ID 5.2 Internal deliverable**  
*Title:* *Task Report Task 5.2 Pilot Results JDR*  
*Responsible authors:* I. Jaspers et al (JDR)  
*Other authors:*  
*Deliverable Date:* September 2002

## 8 Results and Conclusions

The Common Assessment Methodology, is an approach for choosing the relevant ADAS effects, assessment of the ADAS effects, prioritization of implementation aims and devising implementation strategies. The approach has been developed in the ADVISORS project, and therefore applied (to a limited degree; naturally, because the development process took place during the project). However, the approach developed here, is to be considered as a comprehensive approach. Although the approach is developed in the field of ADAS research, one could imagine that the approach can be transferred to other fields for which new (technological) developments take place. Naturally, some of the specific ADAS elements have to be replaced.

One of the elements of the Common Assessment Methodology is the review and listing of pilot testing methods and the overview of measurement methods. This is a very practical tool for many researchers in the field, or even other fields in which operator behaviour is important. A first set of criteria has been defined for evaluating whether a measurement indicator shows a result which is outside acceptable boundaries or not. However, the problem is usually that the effect of an ADAS gives rise to a pattern of behavioural effects, and that the pattern itself is conclusive. Certainly, more research is needed here, and a database of criteria should be developed, as part of a meta-project.

The empirical studies gave rise to many behavioural results; most importantly the direct behaviour of the driver, as well as the problems still involved in the parameters of the ADAS. For instance, the urban ACC system was not very much liked by the drivers. Partly, the setting of the parameters (pre-set speed too high), partly the fact that a system interferes is the cause of the problems. The option of being able to adjust the parameters is to be considered. Both the urban ACC and the interurban ACC reduce driver workload.

The ACC was generally accepted by the drivers, but only by younger drivers; a bit more left lane driving and smaller time headways were observed; the DMS is certainly worth developing further, especially for professional drivers. The HMI studies revealed that people do not like warning signals which represent a "crash" sound, but they do prefer acoustical warning signals only.

The board computer study revealed that reading the board display is problematic, especially during driving, but that in general, the older drivers prefer visual information. However, most drivers enjoy spoken contact with the operators, especially during long trips.

The simulation tests, both microscopic and macroscopic are very revealing in their effects on traffic flow and environmental load. For instance, ACC effects for traffic flow increase at higher penetration rates and lower speed. The reduction in emission levels for ACC is higher than for ISA, especially with higher penetration levels. The effect of ISA on traffic capacity is minimal.

The Multi Criteria Analysis revealed a prioritisation of criteria in which two safety criteria come first, and then after a large distance environmental effects and travel time, then technical feasibility, user costs, socio-political acceptance, driver comfort and public costs.

Integrated ADAS, the Driver Monitoring system for professional drivers, intervening ISA in urban areas and ACC on the motorway with high flow have come out as the most important, high priority ADAS.

The Implementation Strategies reveal that different issues are to be solved for each ADA system. ACC, a system that typically is approaching the market now, bears some safety problems. Implementation strategies have to address these problems. Driver training, standardization are important, inquiring after the options of manual adjustment of the settings. ISA is a growing scenario, in which the functionality and sophistication is gradually increasing over time. The link with the navigation system, especially with the *dynamic* navigation system is of utmost importance. Cooperation between authorities and a commercial partner is important here. The Driver monitoring system could be a welcome system to support professional drivers. Still, research and development need to be done to increase the number of people for which the system can be helpful. The Integrated ADAS system is still far away, and safety implications are still very uncertain.



## 9 Acknowledgements

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We would also like to thank all the drivers who participated in the pilot studies, the scientific colleagues from other institutes, members of the public authorities, colleagues from industry, the legal experts and all the other experts who contributed to the interviews, the questionnaires and the workshops so actively. Also, we like to thank the experts who took part in the Quality Board and reviewed the deliverables.



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## 11 Glossary

Ability	Demonstrable knowledge or skill
Affect	The emotional response to e.g. software.
Arousal	To rouse or stimulate to action or to physiological readiness for activity.
Attitude	Measures are quantified and standardised reports on an individual's opinion towards something, for example the individual's evaluation of the comfort of use of a particular software package.
ACC	Adaptive cruise control consists of 'traditional' cruise control settings with an additional time-headway feature, associated with the vehicle in front. With 'traditional' cruise control, the driver selects a cruising speed and the vehicle then maintains this speed unless the driver over-rides it with brake or accelerator. With time-headway the driver also selects a time-distance to the vehicle in front. The ACC vehicle will then adjust its speed to maintain this headway even when the vehicle in front slows to a stop and re-starts. When the vehicle in front is travelling faster than the selected cruising speed or when there is no immediate vehicle ahead, the equipped vehicle will switch back to 'traditional' cruise control. When the equipped vehicle approaches a vehicle in front too fast, the ACC will slow the equipped vehicle down by either braking, de-accelerating, or changing down gear (if the vehicle has an automated gearbox). It must be noted that ACC is not a collision avoidance system, and driver intervention is required for hard braking situations.
Blind Spot	To resolve blind spot by means of visual sensors located on stern of vehicle would be appropriate put to use in the first place when reversing. To realise potential of camera when reversing enhances broadly safety mainly for heavy vehicles. Stern camera should compensate also missing rear-view mirror in interior.
CAS	CAS may have different features. One feature is rear end collision avoidance or longitudinal CAS, where the presence and speed of other vehicles and objects in the vehicle's lane of travel will be sensed, and warnings and/or interventions (coasting, downshifting, or braking) will be provided. Another feature is obstacle detection, where the system will warn the driver when pedestrians, vehicles, or obstacles are in close proximity to the driver's intended path. A third feature is intersection collision avoidance, where the driver will be warned when the potential for a collision exists at an intersection.
Criteria	Principles or standards of judgement that should be met by ADAS during their assessment. Note: They are the basis on which the ADAS is assessed and appropriate indicators and corresponding measurement methods of the defined criteria should be used accordingly
Cognition.	An individual's thoughts, knowledge, interpretations, understandings, or ideas.
DMS	This feature provides a monitoring and warning capability to alert the driver to problems such as drowsiness, or other types of impairments. These systems support drivers in identifying when they are too impaired to drive. The term "driver impairment" encompasses all the situations in which the driver's alertness is diminished to the extent that an adequate level of driving performance cannot be maintained. It is a consequence of stress, fatigue, alcohol abuse, medication, inattention, or effects of various diseases.
Electroencephalogram (EEG).	A record obtained by attaching electrodes to the scalp. Among the brain waves observed are alpha waves (8-13 Hz), characteristic of relaxed wakefulness; delta waves (1-3 Hz), a slower wave of high amplitude that occurs during deep sleep and theta waves (4-7 Hz), a pattern characteristic of the EEG of the hippocampus and indicative of behavioural arousal

Extroversion	The act, state or habit of being predominantly concerned with and obtaining gratification from what is outside the self.
Fatigue	Weariness or exhaustion from labour, exertion or stress
ISA	ISA systems can operate in a number of ways. They can provide advice and warnings to the drivers regarding the speed limit for the road on which they are travelling. They may also provide the option to the drivers to engage a voluntary ISA that intervenes and prevents the drivers from exceeding the speed limit. There are also mandatory versions of ISA, which do not allow the driver to disengage the system. Finally, a dynamic ISA could limit the maximum speed of the vehicle using real time information concerning the appropriate speed limit for the road and weather conditions.
Environment	All surroundings and circumstances affecting ADAS and ADAS implementation
Future scenario	A snapshot view of a possible future set of circumstances. Scenarios are developed and used in implementation, in overall analysis, in measurement methods and in deployment. Note: The important factors in any scenario of this type are the driver, his vehicle, other vehicles (which compose the traffic), the road infrastructure and the other environmental conditions
Goal (stakeholder)	Relatively high level or abstract objective or quality that a stakeholder desires as part of their experience of ADAS. Note: goals can be operationalised in terms of one or more criteria
Headway	The time interval between two vehicles travelling in the same direction on the same route.
Heart rate	The number of heartbeats per time interval.
Heart rate variability	The heart rate is not consistent over time: it varies, also if the individual is resting. This variation origin from several sources: e.g. blood pressure regulation, temperature regulation and respiration.
Implementation strategy	All the steps that need to be taken to bridge the strategic gap between the current situation (or projected future situation without special action) and the desired future scenario
(Implementation) tool	A specific device or measure that can be used by one or more stakeholders as part of an implementation strategy. Note 1: An example of a tool is “press briefing pack”.
Indicator	Variables (metrics) that measure whether the ADAS meets given criteria
Individual workload	Describes aspects of the interaction between an operator and an assigned task: it denotes the extent of the demands in comparison to the individual's capacity to deliver. Here, the term has the same meaning as ‘workload’.
Introversion	A state or tendency towards being wholly or predominantly concerned with and interested in ones own mental life
ISO standards	standards as defined by the International Standards Organisation. These standards may be adopted by national or international authorities and be legally binding.
Likert Scale	A rating scale in which the strength of agreement with a clear statement is measured.
Mental Workload	Has been defined as the “degree of processing capacity that is expended during task performance” (Eggemeier, 1988)
Metric	A scale of known reliability and validity
Mitigation	Strategies to make implementation less intense, severe or disruptive
Mood	A conscious state of mind or predominant emotion.
Movement Time	Defined as the time to complete the movement once initiated.

Navigation Systems	This ADAS system will give to the driver intelligent information, advice and warning. Navigation systems aim to improve driving safety and should be used in passenger and heavy vehicles. Navigation by providing location and route guidance to the drivers and supports the various collisions avoidance capabilities with road geometry and location data at every moment of the day and during all traffic and weather conditions. It will also provide the necessary capability RDS-TMC <i>Radio Data System/Traffic Message Channel</i> to filter traffic information to select those messages that are applicable to the vehicle location and route of travel. It will also offer the capability to recommend optimal routing based on driver preferences. More advanced versions of this service may integrate real-time traffic conditions into the calculations of optimal routes. An extra module will enable the receipt of information via GSM. The navigation display can also be used helping the driver when parking, using a camera viewing backwards.
Objective measures	Quantified and standardised indicators that are independent of the perception of the individual, and can not easily be consciously controlled
Physiological measures	Measures of bodily processes and states e.g. hormone excretion levels, measures of cardiovascular functions, indicators of activity in the brain, muscle contractions etc.
Psychophysiological measures	Indicators of psychological processes and states, by measuring physiological determinants. In the end, the outcome of the physiological measures need to be interpreted psychologically, and often related to psychological measures.
Questionnaire	A psychological measurement instrument that is constituted from questions. These questions may have open response categories or multiple choice response categories, or it may be that the individual can respond by indicating a location on a line with ascending or descending responses.
Reaction Time	The elapsed time between the presentation of the stimulus and the initiation of movement.
Reliability	The extent to which a measurement procedure yields the same result if carried out on different occasions, possibly by different people on the same subject. In other words, the stability, accuracy and error associated with the measurement procedure.
Regulatory issue	All regulations and restrictions relating to ADAS and their implementation
Result	Finding for each criteria, i.e. whether each criteria is met by the ADAS as indicated by the value of given indicators
Results (+/0/-)	Overall finding for the ADAS + = ADAS is better than nothing, is safe and considered viable 0 = ADAS is no better than no ADAS and therefore not worth implementing - = ADAS is worse than nothing and is dangerous or not viable
Semantic differential scale	A scale with bi-polar adjectives at its end points, respondents rate an interface on a scale between these paired adjectives.
Sensitivity analysis	Analysis of the effect of making slight changes in variables (criteria and weights) on the overall result
Simulator	A device that enables the operator to reproduce or represent under test conditions phenomena likely to occur in actual performance.
Stakeholder	A person, group or organisation that has an interest in the future of existing system. Note: examples include individuals and organisations involved in the manufacture, implementation, legal issues, type approval, risk assessment, quality assurance, and use of the ADAS
Stakeholder analysis	The process of identifying stakeholders, recording their goals, and the perceived potential costs and benefits of the proposed system
Step (of a strategy)	One or more closely related actions designed to achieve a specified impact such that the current situation (scenario) moves closer to the desired future

	scenario. Note 1: Steps in an implementation strategy may be related in complex ways. Note 2: A strategy step may be composed of one or more actions. Note 3: An example step is “public information”.
(Strategy) action	A specific undertaking by one or more stakeholder, usually over a specific period, that contributes to one step in an implementation strategy. Note 1: Actions may make use of tools. Note 2: An example of an action is “briefing press concerning the measured benefits of the new ADAS system”.
Stress	A physical, chemical or emotional factor that causes bodily or mental tension and may be a factor in disease causation.
Task	An activity that a user of a computer system needs to do in order to achieve an objective.
Users	The population of individuals who work with a specific application.
Valid	Well grounded or justifiable, relevant and meaningful.
Weights	Degree of importance/influence allocated to each criteria by each stakeholder
Well-being	The state of being happy, healthy or prosperous.
Workload	Describes the interaction between an operator performing the task and the task itself. The term “workload” delineates the difference between capacities of the human information processing system that are expected to satisfy performance expectations and that capacity available for actual performance (Gopher and Donchin, 1986).