

# RESPONSE 2

Advanced Driver Assistance Systems: From Introduction Scenarios towards a Code of Practice for Development and Testing



## **RESPONSE 2 – Final Report: ADAS – from Market Introduction Scenarios towards a Code of Practice for Development and Evaluation**

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## Disclaimer

Opinions, findings and conclusions expressed by the consortium in this document do not necessarily reflect those of one of the partners including Ford Motor Company as prime contractor, or those of the EC. Most of the partners are not English native speakers, therefore please excuse language inadequacies.

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## Table of Content

Editors .....	ii
Revision Chart and History Log .....	iii
Table of Content .....	iv
Executive Summary.....	1
Foreword of the European Commission .....	3
Foreword of the Project Manager.....	4
<b>1 Introduction and Objectives .....</b>	<b>6</b>
<b>2 Market Introduction of ADAS.....</b>	<b>10</b>
<b>2.1 ADAS overview: Roadmap for ADAS Market Introduction .....</b>	<b>10</b>
<b>2.2 ADAS: Market Introduction Scenarios and Proper Realisation.....</b>	<b>11</b>
<b>2.2.1 Scenario Management: The Methodological Approach.....</b>	<b>11</b>
<b>2.2.2 The Market Introduction Scenarios: Introduction and Overview .....</b>	<b>16</b>
<b>2.2.3 Operational Framework of the Introduction Scenario.....</b>	<b>19</b>
2.2.3.1 Defining the research question.....	19
2.2.3.2 Finding descriptors .....	20
2.2.3.3 Evaluating the descriptors .....	46
<b>2.2.4 Extracting the major Descriptors of the Future and their Development.....</b>	<b>47</b>
<b>2.2.5 Four Alternatives of Market Introduction Scenarios .....</b>	<b>49</b>
2.2.5.1 Scenario 1: High Financial Risk for OEM, High Usability of ADAS .....	50
2.2.5.2 Scenario 2: High Financial Risk for OEM, Low Usability of ADAS.....	54
2.2.5.3 Scenario 3: Low Financial Risk for OEM, Low Usability of ADAS.....	56
2.2.5.4 Scenario 4: Low Financial Risk for OEM, High Usability of ADAS.....	57
<b>2.2.6 Market Introduction Scenarios: Strategic Options and Recommendations.....</b>	<b>59</b>
2.2.6.1 Regulators .....	60
2.2.6.2 Vehicle Manufacturer and Suppliers.....	61
<b>2.3 Summary and Prospect .....</b>	<b>62</b>
<b>2.3.1 Usability of ADAS.....</b>	<b>62</b>
<b>2.3.2 Financial risk for OEM .....</b>	<b>65</b>
<b>2.3.3 Prospect.....</b>	<b>66</b>
<b>3 Methods for Risk-Benefit-Analysis of ADAS.....</b>	<b>67</b>
<b>3.1 Risk Benefit Considerations in Non-Automotive Areas .....</b>	<b>67</b>
<b>3.2 Risk Benefit Considerations – the Micro Perspective .....</b>	<b>67</b>
<b>3.2.1 General Risk Consideration .....</b>	<b>67</b>
3.2.1.1 Hazard, Harm, Risk and Co.....	67
3.2.1.2 Risk of life.....	68
3.2.1.3 Risk Perception and Acceptance.....	70
<b>3.2.2 Risk Perception from the perspective of science, media and public .....</b>	<b>72</b>
3.2.2.1 Introduction.....	72
3.2.2.2 The Scientific-Technological View on Risks: Risk Assessment.....	73
3.2.2.3 The view of the media on risks: Risk Journalism .....	74
3.2.2.4 The view of the laymen on risks: Risk perception.....	76
3.2.2.5 Divergent risk concepts: Consequences for the political risk regulation .....	77
<b>3.2.3 Known Risk Benefit Considerations in Automotive Industry.....</b>	<b>78</b>
3.2.3.1 What has been done already.....	78
3.2.3.2 Risk assessment of hazardous goods transport.....	82
<b>3.2.4 Benefits of Driving with ADAS .....</b>	<b>83</b>
3.2.4.1 Retro Perspective Analysis of Accident Database – Example Benefits of ESP .....	84
<b>3.2.5 Risks of ADAS – Checklist for ADAS Design.....</b>	<b>86</b>
3.2.5.1 System / Sensor Limits.....	86
3.2.5.2 Test procedures of NHTSA and ISO .....	91
<b>3.2.6 Methods and procedures for the identification of risks and their classification .....</b>	<b>94</b>
3.2.6.1 Quantification of risk.....	94
3.2.6.2 Risk graph .....	97
<b>3.2.7 Legal Relevance and Legal Implications of a Risk-Benefit-Analysis.....</b>	<b>99</b>

3.2.7.1	Relevance of a Risk-Benefit-Analysis .....	99
<b>3.2.8</b>	<b>The Influence of Court Decisions regarding Product Liability on Public Opinion .....</b>	<b>107</b>
3.2.8.1	Media Coverage on Product Liability Cases .....	107
3.2.8.2	Influence of Media Coverage on Public Opinion.....	108
<b>3.2.9</b>	<b>Summary and Conclusions .....</b>	<b>109</b>
<b>3.3</b>	<b>Risk Benefit Considerations – Macroscopic Socio Economic Evaluation.....</b>	<b>117</b>
<b>4</b>	<b>Steps towards a Code of Practice for the Development and Evaluation of ADAS .....</b>	<b>119</b>
<b>4.1</b>	<b>Scope of a future Cop .....</b>	<b>119</b>
<b>4.2</b>	<b>Formal Aspects.....</b>	<b>121</b>
4.2.1	How does a CoP fit into the world of standards and regulations? - The legal perspective .....	121
4.2.1.1	European and national legislation.....	121
4.2.1.2	Safety levels according to the Old Product Safety Directive and the Product Liability Directive .....	121
4.2.1.3	Legislative developments .....	125
<b>4.2.2</b>	<b>Design, Performance and Process Standards.....</b>	<b>126</b>
4.2.2.1	Types of standards .....	126
<b>4.2.3</b>	<b>Formal Characteristics of a CoP .....</b>	<b>127</b>
<b>4.2.4</b>	<b>Synthesis of Formal Requirements .....</b>	<b>128</b>
<b>4.3</b>	<b>"Reasonable Safety": Design and Performance Aspects .....</b>	<b>130</b>
4.3.1	Relevant Aspects/Elements of existing design "standards" for ADAS concerning the development of a CoP .....	131
<b>4.4</b>	<b>"Duty of Care": Process Aspects.....</b>	<b>135</b>
4.4.1	Relevant Aspects/Elements of existing process "standards" for ADAS concerning the development of a CoP .....	136
<b>4.5</b>	<b>Stakeholders and Roles.....</b>	<b>138</b>
<b>4.6</b>	<b>Follow on Activities &amp; Implementation .....</b>	<b>141</b>
<b>4.7</b>	<b>CoP Consensus Formation Process .....</b>	<b>143</b>
<b>4.8</b>	<b>Research Needs.....</b>	<b>144</b>
<b>4.9</b>	<b>Synthesis of CoP Content and Structure.....</b>	<b>145</b>
<b>5</b>	<b>Evaluation of CoP Acceptance - Questionnaire at the Final Workshop of RESPONSE 2.....</b>	<b>148</b>
<b>5.1</b>	<b>Agreement with the CoP .....</b>	<b>149</b>
<b>5.2</b>	<b>Agreement with the planned content of the CoP .....</b>	<b>151</b>
<b>5.3</b>	<b>Missing Aspects .....</b>	<b>153</b>
<b>6</b>	<b>Relations to IST-Programme - CarTALK 2000.....</b>	<b>155</b>
<b>6.1</b>	<b>Introduction CarTALK 2000 .....</b>	<b>156</b>
<b>6.2</b>	<b>Summary: Legal and Liability Issues regarding Inter-Vehicle-Communication of CarTALK Systems .....</b>	<b>156</b>
<b>7</b>	<b>Final Recommendations of RESPONSE 2 and Outlook .....</b>	<b>159</b>
<b>8</b>	<b>References .....</b>	<b>166</b>
<b>9</b>	<b>Acronyms .....</b>	<b>170</b>
	<b>ANNEX I: Risk-Benefit Analysis - Macroscopic Perspective.....</b>	<b>173</b>
	<b>ANNEX II: RESPONSE2 Deliverables List .....</b>	<b>219</b>

## Executive Summary

Due to the new challenges of Advanced Driver Assistance Systems (ADAS) - characterised by intensive Human-Machine-Interaction, environmental "interaction" and safety relevance - it is necessary to manage not only the problem of specification, implementation or realization errors and failures but also to prevent from reasonably foreseeable operational errors and reasonably foreseeable misuse.

The importance of integrating the Human Factors science has to be realized – **Human Factors<sup>1</sup> integration** not only into the safety assessment process but also in the whole design and development process of ADAS.

Resulting from the previous Response 1 project the creation of a Code of Practice (CoP) for the development and validation of ADAS was proposed. This implies to establish "principles" for the development and evaluation of ADAS on a voluntary basis, as a result of a common agreement between all involved partners and stakeholders, mainly initiated by ADAS manufacturers.

In a first step (WP 2 **Market Introduction Scenarios**) RESPONSE 2 described market introduction scenarios analyzing the gap between technological possibilities and market introduction benefits and risks using typical scenario technique procedures. Enabling and disabling factors concerning market introduction have been identified and their interactions clarified. The in-principal technological possibilities of modern ADAS implying technical, human factors, and legal risks were outlined.

In a second step (WP 3 **Risk Benefit Analysis**) this deeper understanding of enabling and disabling factors was used for the definition of risk/benefit-assessment methodologies. This was done on a 'microscopic' perspective, where the risks for the whole Human-Machine-System had to be evaluated. Further a macro-economic approach for a combined risk-benefit analysis was developed.

In a third step (WP 4 **Towards a Code of Practice**) these risk identification and assessment strategies were translated into a requirements definition for a Code of Practice for development and testing of ADAS. This included the analysis of already existing procedures and standards as well as the derivation of need for additional ADAS-specific procedures. Content, structure and formal aspects of a future CoP was defined.

The approach was to translate the legal terms '**reasonable safety**' and '**duty of care**' into requirements for a Code of Practice by

- analysing existing automotive and non-automotive regulations, standards, rules, technical papers, guidelines and other relevant provisions as well as

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<sup>1</sup> The Human Factors concept was sometimes mistakenly reduced to the field of Ergonomics. Nowadays wider definitions are used, e.g. that the Human Factors discipline tries to optimize the relationship between technology and the human. Human Factors discipline is mainly studying the role of humans in man-machine systems and how systems can be designed to work well with people, particularly in regard to safety and usability.

- deriving the relevant design, performance and process aspects/elements by selecting, adapting and completing these requirements to special ADAS needs.

Eventually, in a consensus formation process between project partners it was defined

- what is **content and scope of the future CoP**
- what are the **formal requirements of the future CoP**
- which are the **steps towards a Code of Practice**.

The RESPONSE 2 project has been the first move towards agreed validation procedures to be incorporated in a Code of Practice. Further methodological developments for validation (of system safety and safety of usage) and the final definition of the CoP will be part of the follow-up activity in RESPONSE 3.

All in all the voluntary agreement towards a Human Factors based Code of Practice shall

- give guidance in the user centred ADAS design process, helping to accelerate safe ADAS development on a “state of the art” level,
- promote positive public opinion concerning ADAS technology and its corresponding safety benefits as well as
- provide the basis for market introduction of ADAS and therewith a significant reduction of accident rates in Europe.

## Foreword of the European Commission

It is now 2 and ½ years that the eSafety initiative has been launched in Europe jointly by the Industry and the European Commission. This initiative aims at bridging the gap between technology developments and their actual implementation in the market by fostering the introduction of new ICT technologies and systems in future motor vehicles and infrastructure. The eSafety initiative aims therefore to improve road safety and efficiency through intelligent vehicle safety systems. When the eSafety initiative was launched in April 2002, The EU had 15 members. On 1st May 2004, 10 new countries joined for a European Union with now 25 members and a population of 445 Million. This means new urge for all modes of transport, but in particular for road transport and road safety.

The European Commission, together with the European Governments has launched several initiatives to improve road safety and make the transport sector overall more sustainable. One example is the adoption in September 2001 of the Transport white paper that for the first time established a target to halve fatalities by 2010. In the EU with 25 members we have 50.000 fatalities a year (base year 2002 source Eurostat). By 2010 we target then a reduction of 25.000 fatalities which is an ambitious but not an impossible target. Several actions have been deployed at political level mainly based on strengthening enforcement rules and improving driver education and information through for example, prevention campaigns. These measures are proving to be useful and the number of fatalities is decreasing. To further reduce the number of fatalities and target the 50% reduction a more integrated approach is underway where the traditional “3Es” approach (Education, Enforcement and Engineering) is extended with a 4th “E” which is represented by “eSafety”.

As we know that between 90 and 95% of the accidents are due to the human factors and that in almost 75% of the cases the human behaviour is solely to blame, it is clear that our failings as drivers represent a significant safety risk to ourselves, and other road users. It is in this framework that within the eSafety initiative, Advanced Driver Assistant Systems and Intelligent Active Safety have a major role to play in reducing the number of accidents and their impacts. Unfortunately there is still an important gap between technology development and its implementation in the market. A clear assessment of these new safety systems in terms of their impact on the reduction of accidents and on legal and social aspects is part of the eSafety Forum activities where the results of the RESPONSE project have been widely used. The European Union and its Member States, have considerable responsibility together with the automotive industry and the equipment providers for encouraging this deployment of innovative in-vehicle safety systems also by addressing and finding solutions to the liability and legal issues that are a major barrier to the market introduction of Advanced Driver Assistant Systems. It is in this framework that the project RESPONSE II has been funded by the European Commission and that its results represent the necessary basis for the future realisation of a European Code of Practice for development validation and market introduction of ADAS.

André Vits  
Head of Unit

Fabrizio Minarini  
Scientific Administrator



## Foreword of the Project Manager

December 2000 in Munich we presented the results of the RESPONSE1 project at the final user forum workshop and almost the whole European ADAS - "scene" was present. The big number of attendees showed us that we posed the right, the "hot" questions that were coming up with ADAS development and market introduction.

Nevertheless, it was a bit unclear if we would continue the RESPONSE activities in the future.

RESPONSE1 could provide a lot of information regarding the legal and liability problems of ADAS market introduction and the relating Human Factors and system safety aspects. But it became more and more obvious that the RESPONSE mission was not completed. Not all questions could be fully answered. A lot of new questions were raised.

All in all it was more complex than expected to understand the links between system safety, human factors, and legal implications for a fast market introduction of user friendly and safe Advanced Driver Assistance Systems. We had to realize that we stood rather at the beginning of the work than at the end.

On the contrary it was also clear that the integrated, multiparty approach of RESPONSE was absolutely the right way to deal with the new challenges. And, although the industry partners were mostly competitors, it was an encouraging and motivating experience for me - and I think for the other RESPONSE colleagues as well - that within the consortium there was the strong will to go on and continue our activities. The idea of a Code of Practice for the development and evaluation of ADAS systems was born - RESPONSE had created a platform where an open exchange of ideas took place in a very pleasant and constructive atmosphere.

Furthermore these discussions were stimulated and accompanied by the European Commission and it was not least because of the close co-operation with the project officer Fabrizio Minarini which made it possible to go "into a second round" with the RESPONSE project.

In the meantime the RESPONSE2 project is coming to a successful end and RESPONSE3 is already planned and will begin in October 2004. Steps towards a Code of Practice for the development and evaluation of ADAS systems are already defined and an agreement about the main content could be achieved.

In 2006 the RESPONSE3 consortium will finalize the Code of Practice, which will help to reduce the existing uncertainties of ADAS developers, will provide a guideline to ensure a high safety level of ADAS functionality aspects and will accelerate the market introduction of user friendly ADAS systems.

Although there is still a lot of work to do until 2006, we are a little bit proud of our RESPONSE "success story".

All in all the self commitment approach of a commonly agreed CoP is a powerful strategy and a model for future arrangements between different stakeholders integrating industry, public authorities, society and users interests.

At the end of the RESPONSE2 I would like to say - on behalf of the whole consortium - thank you to the European Commission for funding this activity and personally to Fabrizio Minarini for his constructive support, contributions and critique.

Thank you very much to all partners within the consortium and the consulting team for their active involvement and professional input: Hideki Amemiya, Luisa Andreone, Edwin Bastiaensen, Prof. Dr. H. Baum, Elena Bianco, Richard Bishop, Dr. Paola Carrea, Jan P. van Dijke, Dr. Elmar Dilger, Eckard Donner, Dr. W. Fastenmeier, Dr. Joachim Feldges, Thomas Frese, Francis Frost, Dr. Herbert Gstalter, Dr. Joachim Irion, Dr. Wiel Janssen, Philippe Jarri, Dr. Christine Kanz, Dr. Matthias Kopf, Alain Risch, Dr. Wolfgang H. Schulz and Gerard Vassal.

A special address is going to the members of our so-called steering committee, doing the main work: Christoph Jung (BMW AG), Hans-Lothar Schollinski, Thomas Winkle (AUDI AG) and Dr. Jürgen Schwarz (DaimlerChrysler AG) for their significant contributions, their untiring activities and passionate discussions as well as their pleasant and friendly working style. Thanks also to my colleague Johannes Mihm (Ford Werke GmbH) and Martin Brockmann (Subcontractor) for supporting me substantially in managing this project and their contributions to the entire workpackages.

Also I have to say thank you to my company Ford Werke GmbH / Ford of Europe, especially to my Chief Engineer Mr. Christof Kellerwessel for supporting me and providing me the time which is needed to manage such a project.

During the last 6 years I coordinated the first 2 RESPONSE projects. Now a change in management will take place. The follow-on project RESPONSE3 will be managed by Dr. Jürgen Schwarz from DaimlerChrysler; Ford (with Johannes Mihm and me) will remain in the future project as an active project partner. Jürgen is an experienced project Coordinator and we are glad to have him continuing the project work successfully.

Dr. Stefan Becker  
Project Coordinator

# 1 Introduction and Objectives

In the last years, it became more and more obvious that passive safety systems alone cannot reach the proposed goal of 50% reduction of road fatalities in the EU by 2010. A new dimension of active safety systems to avoid and prevent accidents is needed, i.e. active and intervening ADAS-systems that may take over control from the driver in critical situations.

Overall objective of the RESPONSE projects is the fast and 'safe' development and market introduction of such Advanced Driver Assistance Systems (ADAS).

Beside the majority of national and European "technical" research projects in the field of ADAS, the RESPONSE approach aims to integrate the different aspects of human, system, and legal perspectives on ADAS.

The legal analysis on basis of the European Product Liability Directive – carried out in RESPONSE 1 (see Final Report RESPONSE 1 - Becker et al. 2001) project – was coming to the conclusion that „legal safety“ is depending not only on functional system safety but also on safety of system usage (safety of functionality).

Especially two key concepts came into the center of interest:

- The „**reasonable safety**“ of the product  
(Which are the requirements of a safely designed ADAS?) and
- The „**duty of care**“ of the development process  
(which are the necessary elements of the underlying development process?)

To meet the requirements of a "reasonable safe" product and a corresponding process, it is intended to compose a **Code of Practice** as guideline for a "**safe**" ADAS development and evaluation.

In the framework of the RESPONSE project this means to establish "principles" for the development and evaluation of ADAS on a voluntary basis, as a result of a common agreement between all involved partners and stakeholders, mainly initiated by ADAS manufacturers.

## What are the new challenges of ADAS technology?

The design and development process of new products in modern automotive industry is characterized by a mass of regulations, standards, rules, technical papers, guidelines and other provisions. Generating, implementing and following these "**standards**"<sup>2</sup> has led car manufacturers to a rather **high functional safety level** of its products – especially when comparing to most other industries.

Within the field of conventional automotive technology it is therefore "state of the art" to create "reasonable safe" products.

But with the **technology of ADAS**, manufacturers are faced with new challenges.

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<sup>2</sup> In the following, the expression of "standards" in quotation marks is used as a common topic for all regulations, (international and national) standards, rules, guidelines, technical papers, and other provisions.

These systems are **detecting and understanding the environment**. They are e.g. identifying lane markings, other vehicles or pedestrians.

And above that they assist the driver in his driving task and are therefore **interacting with the user of the system**.

#### How to ensure the safety of ADAS systems (functional safety)?

It is obvious that every additional subsystem (this also applies to active safety systems) in a vehicle increases the overall failure probability. Furthermore, every safety system has certain functional limits implying additional risks, which may increase the probability of creating difficulties associated with safety issues.

An **ADAS-specific functional safety process** has to be applied to minimize these risks to achieve “freedom from unacceptable risk” as it is defined in ISO EN 8402. It is aspired and achieved by fulfilling safety related requirements on correctness and reliability.

Objective is, that a vehicle function does not cause any intolerable endangering states, which are resulting from

- **specification-, implementation or realization errors** and failures while operation period
- **reasonably foreseeable operational errors**
- **reasonably foreseeable misuse**

So one major part of the development process of ADAS has to be the **proof of functional safety** by an extensive functional safety process containing safety and hazard analyses and risk evaluation methods as well as validation procedures.

Beside this, another major part of the ADAS development process has to be the proof of safety of functionality.

#### How to ensure the safety of ADAS usage (safety of functionality)?

System designers and developers are faced with the problems of

- **Functional restrictions** caused by i.e. **sensor limitations** regarding the environmental detection
- **Interaction between the “logically operating” system and the user** with his unpredictable, non-deterministic behaviour
- **Human failures and misuse**<sup>3</sup>

The importance of integrating the Human Factors science has to be realized – **Human Factors**<sup>4</sup> **integration** not only into the safety assessment process but also in the whole design and development process of ADAS.

#### Why the Human Factors approach?

<sup>3</sup> Misuse in this context includes also non-intended erroneous behavior in the common use/operation of ADAS e.g. caused by incorrect inputs, slips and errors.

<sup>4</sup> The Human Factors concept was sometimes mistakenly reduced to the field of Ergonomics. Nowadays wider definitions are used, e.g. that the Human Factors discipline tries to optimize the relationship between technology and the human. Human Factors discipline is mainly studying the role of humans in man-machine systems and how systems can be designed to work well with people, particularly in regard to safety and usability.

When an ADAS system shall support the driver also in safety critical tasks first of all the system has to be designed for usage, and its **functionality** (what the user is perceiving and experiencing) has to be tailored to human requirements of safe use.

The **driver is part of the safety concept** of an ADAS system and cannot be handled separately.

It is not enough to develop firstly just a system according to the newest technological capabilities and afterwards trying to set on top a Human-Machine-Interface (HMI) hoping the user would be able to operate the system safely and effectively.

The Human Factors approach has to begin already in the concept phase with a **user-centered system architecture design** and development. A Human Factors specification is an additional part of the process. In the ADAS realisation phase the **Human Factors specification** has to be validated regarding its requirements including e.g. usability, suitability and comprehensibility aspects as well as user-interface requirements.

#### Why RESPONSE2 ?

RESPONSE 2 contributes on a generic level to a fast and 'safe' market introduction of Advanced Driver Assistance Systems using its integrated perspective on human, system, and legal aspects.

This goal leads to the definition of the following three objectives:

(1) Scenario analysis describing the risks and possibilities of the market introduction of ADAS

(2) Transformation of this risk and possibility factors into methods for risk-benefit analysis on a microscopic and macroscopic level understanding individual risks for driver-system interaction and their consequences for the society in terms of cost/benefits on macro-economics

(3) and translating these results into a requirements definition for a Code of Practice for development and testing of ADAS. This Code of Practice has to ensure the market introduction of 'reasonable safe' products and the definition of 'duty of care processes.

#### The RESONSE 2 approach

The tasks of deriving consensus for a Code of Practice was carried out by an automotive industry consortium, and supported by independent research organisations, consumer organisations, and representatives of public authorities. The Consortium consisted of a Core Team, a Consulting Team and Subcontractors:

#### Core Team

Ford Werke GmbH, AUDI AG, BMW, Bosch, Centro Ricerche Fiat S.C.P.A. (CRF), DaimlerChrysler, PSA, ERTICO, Thomas Miller & Co., TNO;

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#### Subcontractors

Clifford Chance (CC), University of Cologne (UOC), Irion Management Consulting (IMC), Mensch Verkehr Umwelt, Institut für Angewandte Psychologie (MVU) and Martin Brockmann.

An industrial commitment like this was considered the most effective way of guaranteeing the market introduction of user-friendly and safe systems. To ensure an overall European (and wider) agreement, the methodological development and commitment process was based on a European Commission co-funded structure.

Therefore RESPONSE 2 was formally defined as a "Supportive Measure" for the European Commission. It belonged to the 5<sup>th</sup> Framework programme preparing the ground for activities in the 6<sup>th</sup> Framework. RESPONSE 2 launched its activities in September 2002, and finish with a final workshop in April 2004.

In accordance with the above project objectives, RESPONSE 2 consisted of three work packages:

- Market Introduction Scenarios,
- Risk / Benefit Analysis,
- Steps towards a Code of Practice.

In a first step (WP 2 **Market Introduction Scenarios**) RESPONSE 2 described market introduction scenarios analyzing the gap between technological possibilities and market introduction benefits and risks using typical scenario technique procedures. Enabling and disabling factors concerning market introduction have been identified and their interactions clarified. The in-principal technological possibilities of modern ADAS implying technical, human factors, and legal risks were outlined.

In a second step (WP 3 **Risk Benefit Analysis**) this deeper understanding of enabling and disabling factors was used for the definition of risk/benefit-assessment methodologies. This was done on a 'microscopic' perspective, where the risks for the whole Human-Machine-System had to be evaluated. Further a macro-economic approach for a combined risk-benefit analysis had to be developed.

In a third step (WP 4 **Towards a Code of Practice**) these risk identification and assessment strategies were translated into a requirements definition for a Code of Practice for development and testing of ADAS. This included the analysis of already existing procedures and standards as well as the derivation of need for additional ADAS-specific procedures. Content, structure and formal aspects of a future CoP was defined.

As result of a consensus formation process between all partners of Core and Consulting team the steps towards a Code of Practice were defined.

The RESPONSE 2 project has been the first move towards agreed validation procedures to be incorporated in a Code of Practice (CoP). Further methodological developments for validation (of system safety and safety of usage) and the final definition of the CoP will be part of the follow-up activity in RESPONSE 3.

## 2 Market Introduction of ADAS

This chapter describes the results of the activities within the Market Introduction Scenario work package.

After a short presentation of the roadmap for ADAS market introduction (chapter 2.1) the following chapter 2.2 describes firstly the methodological approach for the scenario analysis and then the market introduction scenarios developed during a special workshop of the RESPONSE 2 Core Team at DaimlerChrysler in November 2002.

The identified factors influencing the market introduction (so-called descriptors) have been clustered towards aspects related to society, macro economics, users, manufacturers, systems, and law. These factors were evaluated in the light of their influence on four elaborated market introduction scenarios.

Finally strategic options were discussed (chapter 2.3).

### 2.1 ADAS overview: Roadmap for ADAS Market Introduction

A roadmap, which lists the timing of market introduction for different ADAS systems, is currently under development within the ACEA (European Automobile Manufacturers Association) and shall be published in the near future. As long as this "official" roadmap is not available yet, another driver assistance roadmap can be quoted: The Driver Assistance Roadmap published in the ATZ (2003).

### *Advanced Driver Assistance Systems*

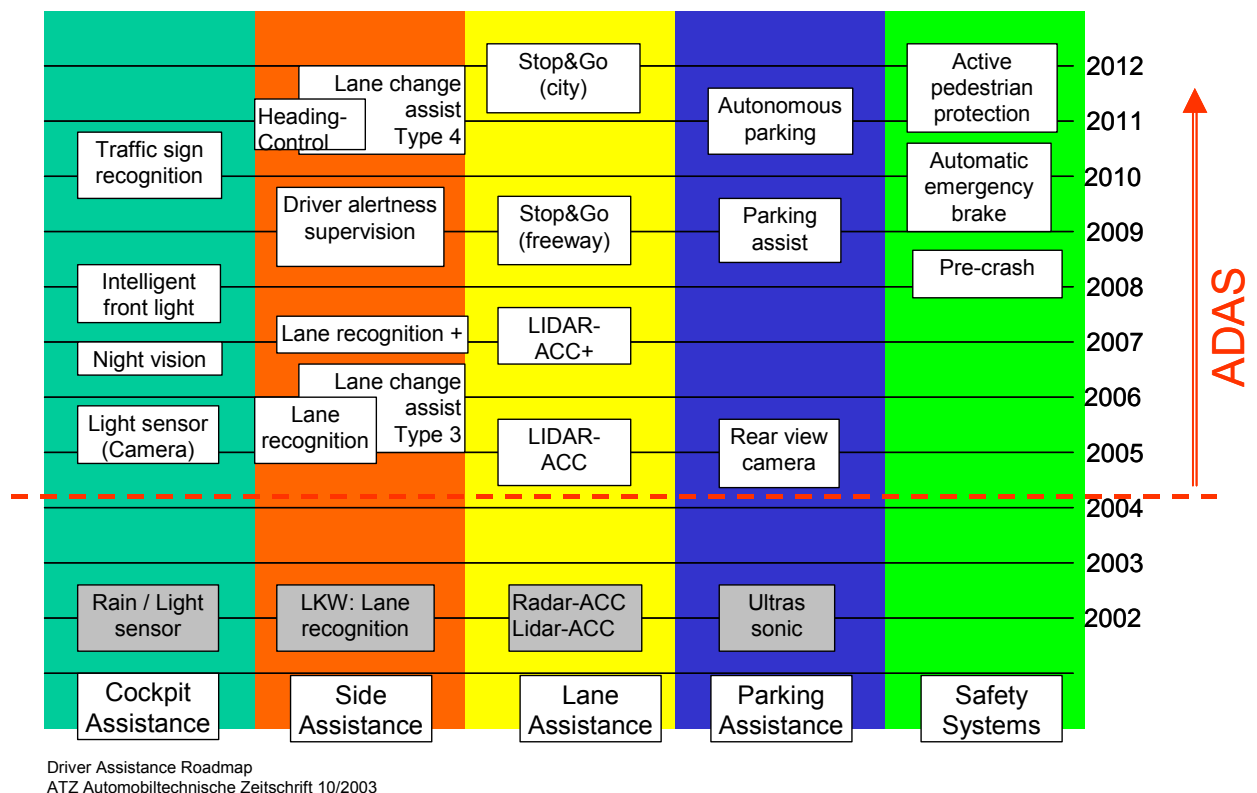


Figure 1: Driver Assistance Roadmap published in the ATZ (2003)

Those forecasts have always a certain level of uncertainty. The timing of ADAS marketing is influenced by various different factors, among others the competitive automotive market, customers preferences, public risk-benefit perception and media reaction.

Nevertheless, the ATZ (2003) roadmap represents the expectations of the RESPONSE2 project and is quite useful until there will be an ACEA publication in the future.

## 2.2 ADAS: Market Introduction Scenarios and Proper Realisation

The White Paper on European Transport Policy for 2010 calls for a 50 % reduction of road fatalities by 2010. That should bring the number of fatalities per year down from 40.000 to 20.000.

It is obvious that passive safety systems alone cannot achieve this goal. A new dimension of active safety systems helping the driver in critical traffic situations or even to prevent accidents is needed, i.e. active and intervening systems taking over control from the driver in critical situations. This is especially evidenced by the fact that about 95 % of all road accidents are caused by human error (see e. g. Karamitsos, 2001).

The development and introduction of these active safety systems (Advanced Driver Assistance Systems) offer great opportunities for the customer, society, and the manufacturer but may also introduce new risks. This is the direct consequence of the complex functionality offering on the one hand a real support for the driver in avoiding or managing safety critical traffic situations but on the other hand implying risks whenever operating beyond defined operational limits or in case of a system malfunction. For the vehicle manufacturer such electronic safety systems imply a possible business case, but also possible risks like product liability, criminal liability, and financial risks of e.g. a recall campaign. These risks could procrastinate or even block market introduction of features proving more attractive than essential.

The RESPONSE 1 project revealed that these risks are highly complex due to the fact that the term "defective product" used in the European Product Liability Directive not only has a technological meaning but also links to human factors covering system requirements such as dependability, controllability, comprehensibility, predictability and ability to withstand misuse.

Overall, these aspects have to be part of an industrial / societal consensus as to "reasonable safety" and the manufacturer's "duty of care," taking into consideration the fact that a risk-free technical product does not exist.

Accordingly, to achieve an effective market introduction of ADAS, an improved and agreed methodology for the definition and validation of safety-relevant automotive systems / active safety systems is needed, which may be achieved by combining legally robust technology and a perspective oriented towards human factors.

### 2.2.1 Scenario Management: The Methodological Approach

The desire to foresee what the future will look like is as old as mankind itself. There is still no method or procedure available,



which allows an exact prediction of the future, but it is the primary task of politicians and industrial management to shape the future. How can this dilemma be solved? How can the management of a company justify essential decisions that will only show their results many years hence? Only time will tell whether the decisions were right or wrong.

Before answering that question, we have to understand the following core statement:

**“The future cannot be foreseen, and will never be predictable”**

Numerous famous examples give proof of this. Two of them will be stated here, representing the type of prognoses that have been made in the past.

Examples:

“Man won't be able, within the next 50 years, to fly in an aircraft built out of metal“

Wilbur Wright; 1901

”I believe that on the whole world market there is a need for 5 computers, not more.“

Thomas J. Watson (Chairman IBM); 1943

Does that mean, that all actions are in vain? Not at all. A quotation by Perikles says it all: “It is not necessary to know the future, but important to be prepared for it.”

To put this in words readily understood by those involved with ADAS: “Nobody can drive to the future on cruise control“ (Figure 2).

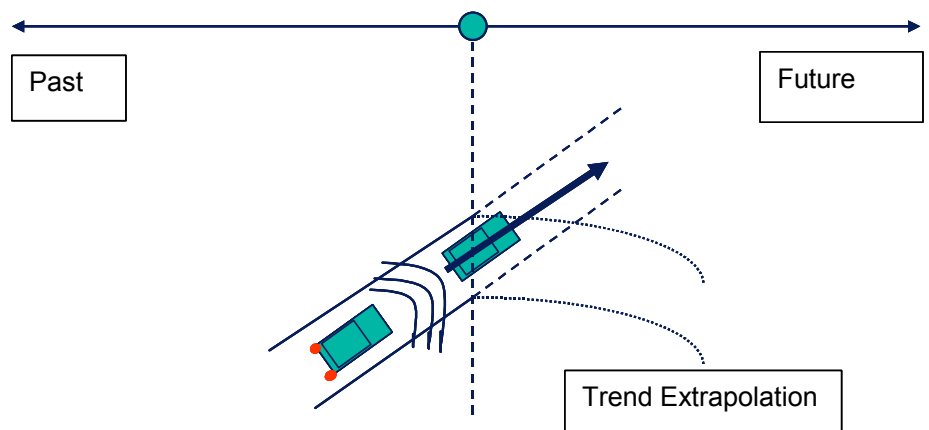


Figure 2: Model of Extrapolation

Furthermore, the meaning of “*being prepared for the future*” is best explained by the use of scenario techniques. This technique is today a well-known method to think about how future might develop and what could be done to be best prepared for it.

In general, the goal of the scenario process used for product planning can be described by listing the following points:

- Systematically compile all relevant information concerning the subject to be investigated, so that the complex problem of likely future realities can be investigated.

- Identify all factors, which might influence the future (we call them enablers and disablers), and perform an analysis of the interaction of these different factors by an extrapolation into the possible dimensions these factors could exhibit.
- Reflect on the effects of these factors on product requirements.

This can be done adopting the following steps:

### Step 1

**Clear Definition of the question to be investigated.** That means a focus with respect to

- subject,
- time,
- and space (regional boundaries).

### Step 2

**Identification of enabling and disabling factors and their possible developments and consequential premises.**

There are many different ways of collecting information that can influence your scenario, but it is essential that underlying processes allow a prioritisation of your information and also the possibility to project your information into the future. In order to compile the information using a list of influencing factors (enablers and disablers) requires a search for factors which are scaleable and thus may be projected into the future; e. g.

Factor: Average economic growth in the EU

Possible Developments: from “+ 0 - 1 %” up to “+5 %”

Not all of the factors will affect your analysis with the same impetus. But the question remains: How can we find the most important factors influencing the problem?

### Step 3

**Impact / Uncertainty Analysis**

The Impact / Uncertainty Analysis will focus on the prioritisation of the listed factors by using two dimensions in respect of each factor, i. e. how important is the factor? (does it have a high impact on the problem?); and how predictable is the factor? (is there a low or high uncertainty as to whether the factor will change in the future or not?).

In so doing, one encounters a common problem, namely that different people see different topics with different eyes and this can easily lead to evaluation finding only very important factors, which does not help at all. Therefore RESPONSE 2 used an assessment method, in which we derive a relative importance and a relative uncertainty. This can be achieved by limiting the score of the overall assessment. Example:

Let us suppose we want to assess 3 factors to find out which are the most important, and which are the most uncertain concerning the development of the subject being investigated. For assessing the importance and uncertainty we use the ranking with a system of points explained in Figure 3.

Value	Importance	Uncertainty
0	Factor is less important	Factor is quite certain
1	Factor is important	Factor is uncertain
2	Factor is extremely important	Factor is very uncertain

Figure 3: Importance / Uncertainty values

If we now have to estimate each factor as to its relative importance and uncertainty, we introduce another limit, namely, the average number of points for each factor estimation; for example, 1. This means that, in evaluating 3 factors, the sum of all their values for importance and also for uncertainty has to be 3. In this example this would mean that only one factor is extremely important.

Factors	Importance	Uncertainty
Factor 1	2	1
Factor 2	0	0
Factor 3	1	2
Sum	3	3

Figure 4: Example for evaluation of factors

Every participant of the scenario group now has to apply such an estimation to all the enablers and disablers. All estimations are then accumulated and displayed in an Impact / Uncertainty chart (see Figure 4).

Importance

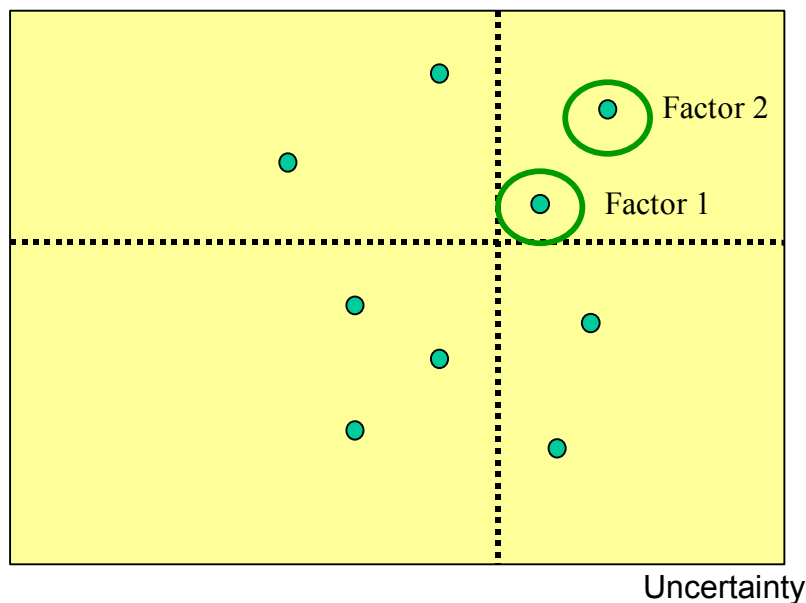


Figure 5: Impact / Uncertainty Chart

The accumulation now reveals the highest relative importance and the highest relative uncertainty of factors. The top right corner

shows the most interesting factors, because these are considered as very important, but also very uncertain. The corner can now be shifted with respect to the number of factors to which further process steps should be applied.

#### Step 4

#### Interaction Analysis

In preparing scenarios, we have to combine factors that are preferably of a very different kind. We also have to determine the dimensions that these factors could have. This could appear as in Figure 6, entailing four quadrants that build the basis for the “different worlds” that will be created using the various combinations of disabler / enabler developments.

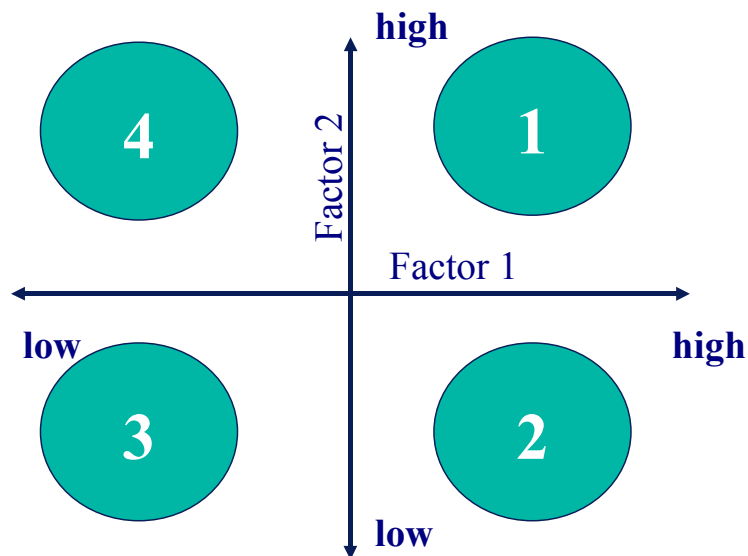


Figure 6: Interaction fields for selected factors

#### Step 5

#### Development of different scenarios

Most of the work is comprises establishing the different scenarios and creating the various possible “worlds” that can be created using the 4 quadrants.

4 teams are necessary for creating the scenarios, each taking a scenario with its corresponding core elements to characterise a world for the core elements. The task is to find a title for the chosen world, to define the most relevant aspects of this world, to make up a story or a picture and thus a presentation for it.

#### Step 6

#### Scenario Implications: what should we do today?

“The best way to predict the future is to create it” (Peter F. Drucker). We shall find worlds that are perfect for bringing our products into the market, but also worlds which are not. What then are the possibilities of influencing the way in which the future will be built? Who are the actors? We have to make proposals for the different actors (e. g. OEM, Regulators), consider what they should do and create an appropriate action plan for them. This has to be done for every scenario, no matter whether the scenario is good or bad for our products. In the end, all these results can be merged so as to derive a set of stable recommendations; namely, those

that appear to be the most robust in the light of the various specific developments predicted.

## 2.2.2 The Market Introduction Scenarios: Introduction and Overview

As described above, the “Scenario Management” procedure is based on the principle of “Thinking in Scenarios”.

A scenario is the description of possible situations in the future based on the development of a complex net of influencing factors. Therefore, this starting point for considering the future allows for several ways in which plausible scenarios could develop. Thus, the “Scenario Management” procedure justifies the insight that the future is not predictable.

In the context of RESPONSE 2, numerous factors with a diverse range of levels of consideration determine the future development of the market introduction of Advanced Driver Assistance Systems (ADAS). For instance, the key words “technology”, “environment”, “regulatory environment” or “consumer behaviour” may be singled out. None of these areas should merely be considered on its own; only together do they form a complex net of influencing factors. Through the aid of “Scenario Management” this situation is reflected by allowing, and even requiring, “network thinking”.

Various organisational patterns can be used to develop scenarios. For RESPONSE 2, a “Scenario Conference” was selected (Fink 2001, S. 107 ff).

In this organisational pattern a group of “competent knowledge carriers” get together to solve the tasks of selecting the key factors, which will then form the basis of the development of future scenarios in teamwork. In elaborating these work phases, presentations by small groups alternate with discussions involving all participants.

For dividing the team into appropriate groups it is important that knowledge carriers spanning the most diverse fields of relevant expertise get together in order to cover a wide and comprehensive spectrum of influencing areas.

The participants in the RESPONSE 2 project belong to various groups and take part in the project at various levels of intensity. Besides the Core Group there are the so-called Sub-Contractors of certain Core Group members and there is also an extended group of participants known as the Consulting Team. In all groups the most wide-ranging relevant fields of expertise, such as the automobile industry, the supplier industry or various research institutions, are represented. This ensures that in the RESPONSE 2 project every participant group provides input by a sound diversity of competent knowledge carriers.

In the first step of the scenario development the Core Group members and the sub-contractors met in a two-day workshop in Esslingen. Under the heading “A Field Trip in the Future – Advanced Driver Assistance Systems (ADAS 2010)” the participants developed 4 scenarios describing the possible ADAS market situation in the year 2010. In the second step of the scenario development this preparatory work was refined and

supplemented by participation of the Consulting Group in an Expert Workshop at Audi in Ingolstadt.

The results of the Workshop at DCAG in Esslingen from 07 – 08 November 2002 are shown in the following. Supplementary results from the Experts Meeting in Ingolstadt on 21 – 22 January 2003 are subsequently presented.

The systematic development of future scenarios at the Workshop in Esslingen was performed in three steps (see Figure 7 (Fink 2001, S. 75)).

In the first step, “Scenario Field Analysis”, the research question was defined and the significant influencing factors established and evaluated. Evaluation of the influencing factors, so as to select the most important ones, was the starting point for “Scenario Prognostics” (future descriptors). Here the major influencing factors of the given time horizon were projected into the future. From the combination of the future projections the “Scenario Development” was formed.

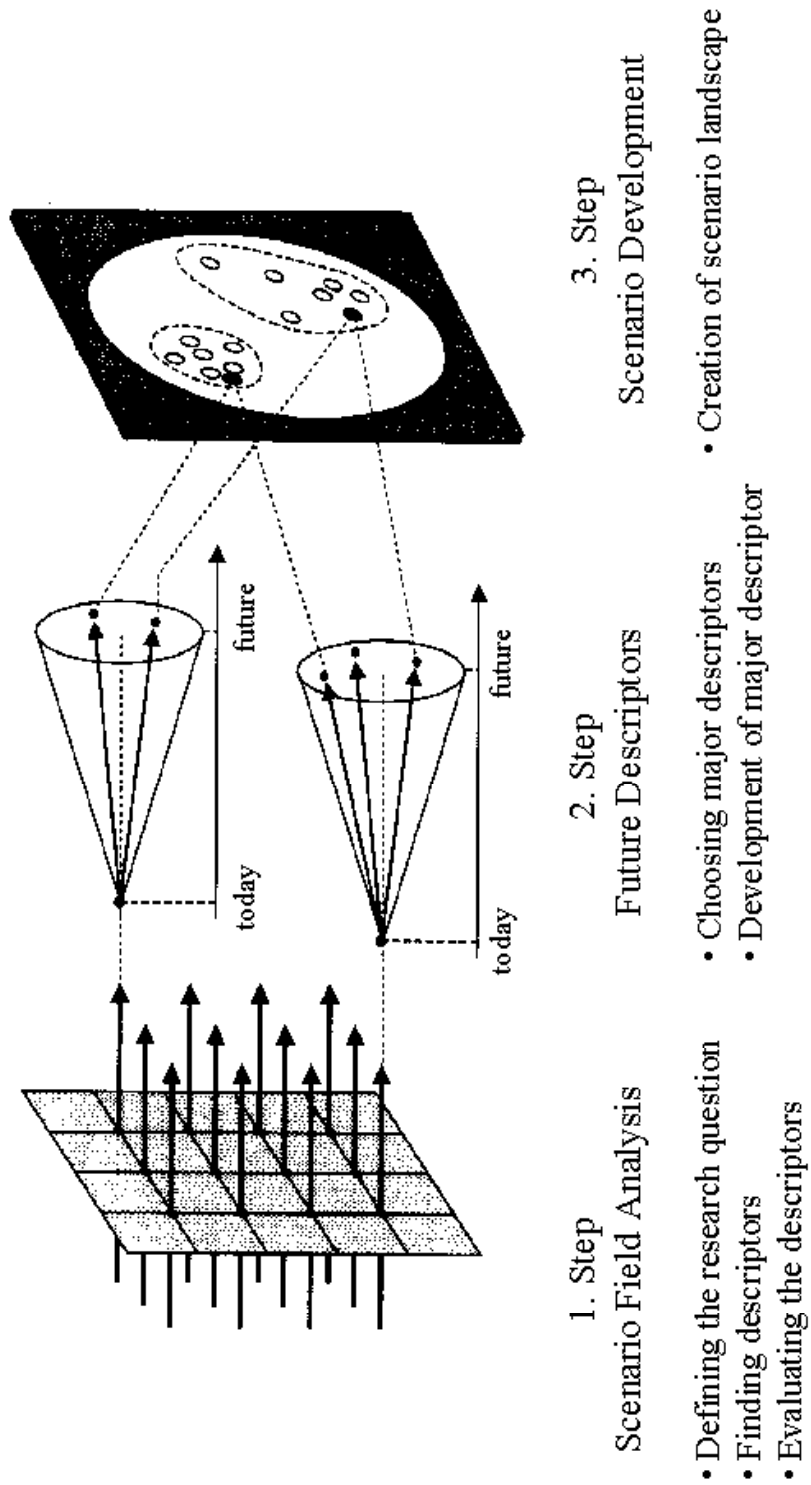


Figure 7: three steps of scenario development

## 2.2.3 Operational Framework of the Introduction Scenario

### 2.2.3.1 Defining the research question

The definition of the scenario field is the starting point of scenario development. The scenario field is the specific sector of focus, the future of which will be described by the scenarios.

The question: “Where are we going?” comprises the scenario field in respect to RESPONSE 2, combined with analysis of “future market situations of Advanced Driver Assistance Systems (ADAS)”. This field of focus combines activities of the participating groups which will be necessary in order to introduce ADAS into the market as early as possible. Stakeholders in this specific field of focus include, besides the vehicle industry, the regulatory environment, public opinion, the mass media, and consumers, i. e. the drivers themselves, who will operate vehicles in traffic with and without ADAS.

The year 2010 is considered a sensible horizon of focus for the analysis of the future. This selection is based on predictions of the so-called “White Paper”, “The European Transport Policy until 2010 – courses set for the future” In which, among other topics, the aim of future traffic policy to achieve a 50 % reduction of fatalities in traffic accidents is discussed.

Initially it is unrealistic to consider the ADAS market situation in one step worldwide. Based on the statements made in the “White Paper” of European traffic policy, it appears to make sense to refer at first to the “close area” of the European Union. This close area is defined as the EU market with a higher registration volume of new motor vehicles (EU<sub>v</sub>). In the second step the regional restriction will be extended to the total EU. In the third and fourth steps an extension to the markets of USA and Japan, as well as to the (not yet considered) rest of the world (ROW), shown in Figure 8, is performed.

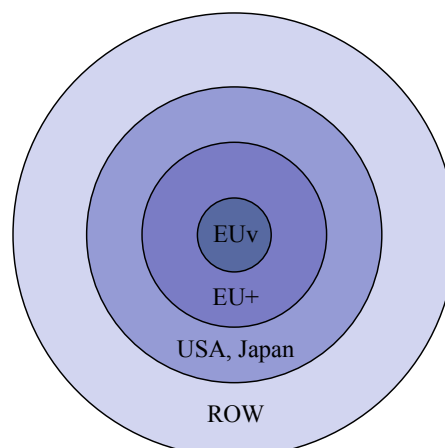


Figure 8: Regional focus



### 2.2.3.2 Finding descriptors

In order to describe the status and development possibilities of a scenario field it is necessary to determine the factors (descriptors) influencing the research question. These descriptors allow a description of the present state of a scenario field and its future development possibilities, as well as its present and future interactions with other influencing areas.

Descriptors may be found by means of reproducible processes or by creative procedures, for instance a brainstorming session or mind-mapping.

At the Esslingen Workshop, the descriptors had been evaluated according to the “intuitive procedure” (Gausemeier, 1996, S.174) This procedure emphasises creativity, i. e. the mental process of creative thinking, in which elements, aspects and experiences not usually connected are combined for a certain task or job. In six small groups, every group was assigned the task of choosing the three most important influencing factors in a brainstorming session. A total of 18 influencing factors were compiled, which included multiple selections. Table 3 shows the summary of the group work.

The compilation of the group work, when restricted to three selections each, resulted in no multiple inputs. At first, sight this appears to be an amazing outcome, because the six groups had been working separately and had not been discussing the matter together beforehand. The fact that there were no repetitions in the results appeared to be due to the heterogeneous profile of the workshop participants.

In preparation of the subsequent evaluation of the respective influencing factors it is necessary to describe the dimension of the possible future development of the individual factors (table 3 “possible developments”).

<b>Descriptor</b>	<b>Possible developments</b>
1. Marketing activities	Between high and low
2. Financial risk (Recall, Image Problems)	Between high and low
3. Cost / ADAS unit	Between increase and decrease
4. Economic volatility	Between high and low
5. Average economic growth in the EU	Between "0-1%" and "+5%"
6. Usability of ADAS systems	Between high and low
7. Consumer demand for safety	Between status quo and increase
8. Safety consciousness in public	Between growth and strong growth
9. Ageing drivers	Between homogeneous and heterogeneous
10. Customer acceptance threshold	Between lower and higher
11. Customer understanding of the system limits	Between lower and higher
12. Number of accidents with major injuries	Between increase and decrease
13. Compatibility of ADAS in integrated systems	Between integrated and not integrated
14. Risk of product liability	Between increase and decrease
15. Ownership of infrastructure	Between more public and more private
16. Regulatory environment	Between intervention and self-regulation
17. Amount of legislation	Between more and less
<b>Premise</b>	<b>Developments</b>
18. Premise: Technical performance of ADAS	Increase

Figure 9: Descriptors

With the exception of the selection "technical performance of ADAS", for every selection an area was found in which the respective selection could demonstrate itself in the future. Therefore, these selections are considered "real" descriptors with a development tolerance. In comparison to the real descriptors, there is a high degree of probability that the technical performance of ADAS will increase. Viewed from the present state of knowledge, no other possibility is plausible. Therefore, the selection "technical performance of ADAS" is not evaluated to be a descriptor, but as a reliable and predictable premise. So, for further scenario development it is not regarded as a descriptor, but as a fixed condition/circumstance.

In addition to the Esslingen Workshop, an Expert Workshop took place in Ingolstadt. Based on the presentations shown there and the subsequent discussions, each participant was asked to state

relevant influencing factors from his/her point of view. Figure 10 and Figure 11 show the collection of selections at the beginning of the workshop (first day) and at the end of the workshop (second day) influenced by all presentations and discussions.

The results from the Expert Workshop in Ingolstadt and the Esslingen Workshop are very similar. No significant deviations occurred. Therefore, it is considered sufficient to use the results from the Esslingen Workshop as the basis for further analysis.

### Descriptors Summarised 1st Day (#96)

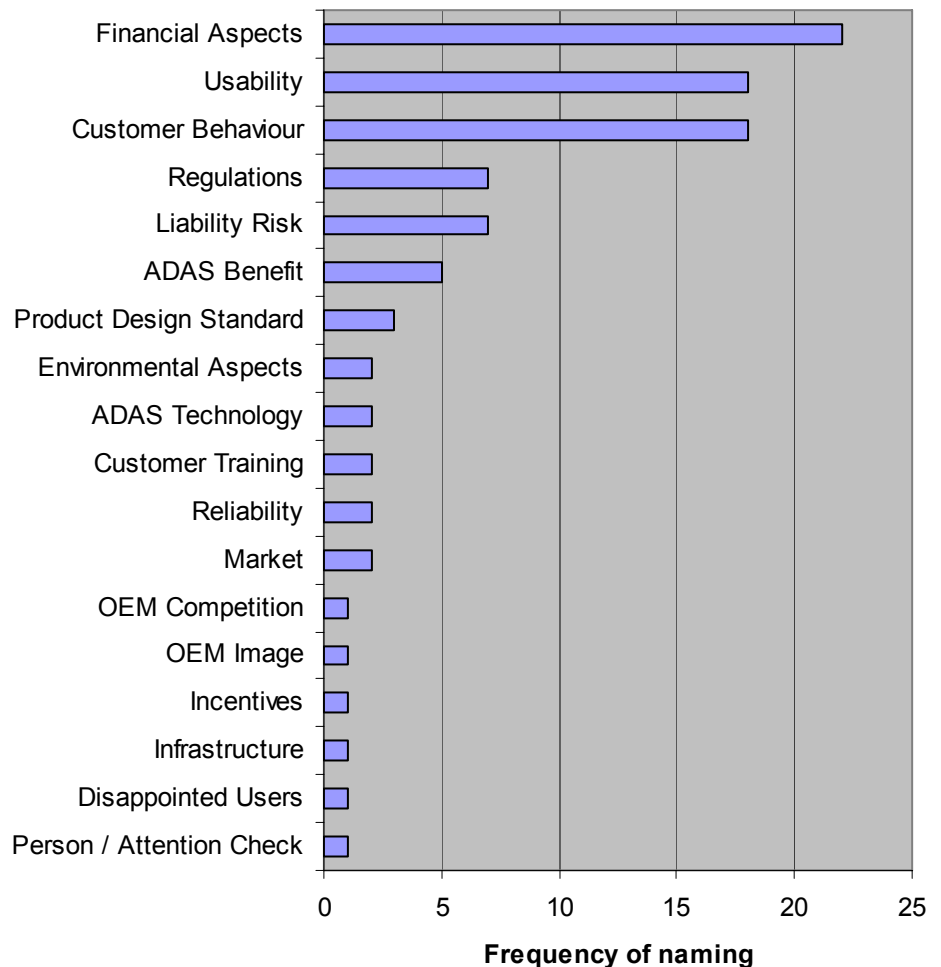


Figure 10: Descriptors Expert Workshop Ingolstadt; First Day

### Descriptors Summarised 2nd Day (#60)

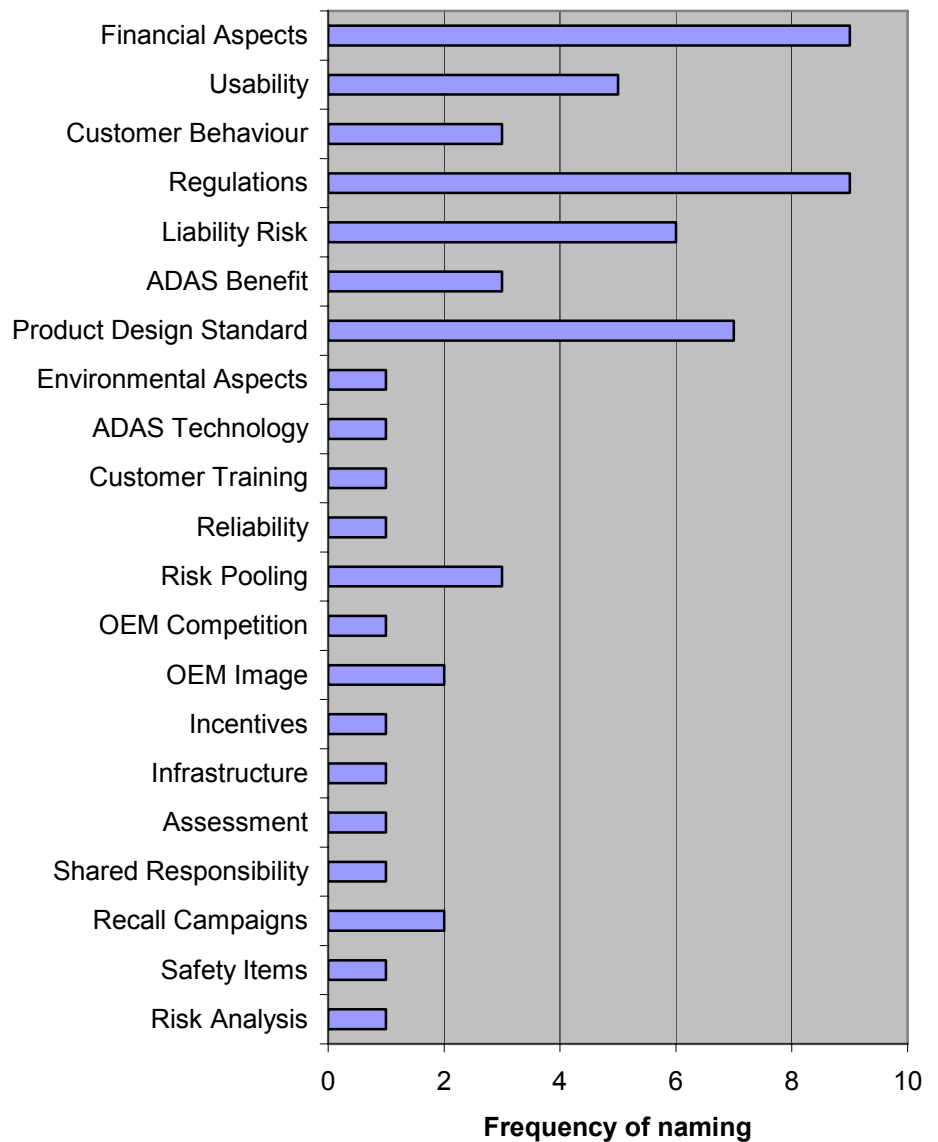


Figure 11: Descriptors Expert Workshop Ingolstadt; Second Day

The following chapters give a detailed overview of the found influencing factors of the topics.

1. Societal aspects
2. Macro economic aspects
3. User aspects
4. Manufacturer aspects
5. System aspects
6. Legal aspects

### 2.2.3.2.1 Societal aspects

#### *Ageing Drivers (no. 9)*

The ageing of the developed world's population is a well-known demographical issue. Older adults comprise the fastest growing segment of the population. As longevity increases and birth rates decline, one in every four persons will be aged 65 in 2030.

Scoping on the European Union states, the number of people aged 60 and over will double from 48 million in 1960 to 104 million in 2020 (from 15,8 % to 26,8 % of the population). The number of people aged 80 and over will quadruple, from 5 to 21 million (1,6 % and 5,5 % respectively) (EUROSTAT , 1997, p 2021)

The implications of this demographical issue for transport policies are huge. This significant increase in the adult population will indeed place new and growing demands on transport systems. Car driving and its new requirements for the future ageing driver will become a key aspect in the development of transport systems (Kraay, 2000).

Firstly, new technologies will have to contribute strongly to improving in-vehicle safety, but so also will the manner of use of roads. Vehicle manufacturers have to be encouraged to increase the protection of vehicle occupants in the event of a crash, but also to develop preventive applications to avoid crashes occurring. While each country may undertake efforts individually to face its challenge on its own, collaboration on research and sharing of best practice is critical. Co-operation and harmonisation can indeed make it easier to track shifts in transport patterns.

Secondly, one has to look at the new demands, needs and patterns of the ageing population in relation to their car use. To give an example, reallocation is a major issue for the ageing driver. In practice, older people are choosing to live away from inner urban areas. In many counties, the elderly population is becoming a suburban one. In the US in 1970, for example, the largest proportion of the elderly resided in the suburbs. By 1980, most urban elderly resided in the suburbs. In the new millennium, over 75% of the entire population will be living in low-density suburban or rural areas (Rosenbloom, 1991). This obviously means an increased use of the car, for longer trips. The ageing driver will thereby have more travel possibilities than now, as retirement will be delayed and physical capacities will be improving.

#### *Number of accidents with severe injuries (no.12)*

In the year 2000, road accidents killed over 40, 000 people in the European Union and injured more than 1.7 million. The directly measurable cost of road accidents is of the order of 45 billion €. Indirect costs are three to four times higher than that. The annual figure is put at 160 billion €, equivalent to 2 % of the EU's GNP.

In September 2001 the European Commission presented the White Paper on European Transport Policy for 2010 (White Paper, 2001). In this paper the Commission set a very ambitious target for road safety: a 50 % reduction of road fatalities by 2010, which should bring the number of deaths per year down to 20 000, and

simultaneously bring down the number of accidents and injuries. Many European countries have taken up this initiative. The Swedes even have the declared ambition of reducing the number of accident deaths to zero.

The use of new technologies cannot achieve this target alone, although they can make a significant contribution. Other measures, such as infrastructure improvements and enforcement of compliance with current safety measures, are still needed. The penetration of new technologies to the whole vehicle fleet will also take a long time and even in the most favourable projections will be incomplete by 2010.

#### *Customer acceptance threshold (no. 10)*

Customer acceptance of ADAS is necessary when the customer is expected to buy a system entirely as a volunteer and also when a system can be misused.

In literature we can find a multitude of definitions of acceptance. In many cases the sense is negative. In the context of ADAS, acceptance entails a positive attitude towards the system, as people have to spend money to obtain it and have to use the system in the manner intended and at the right moment. It is therefore not sufficient merely to accept the system.

Therefore the following definition is proposed:

*The level at which the targeted users see more advantages than disadvantages in buying and using the system in the manner intended.*

Research by the Dutch Ministry of Transport has elaborated 8 groups of factors, which influence acceptance according to the definition above:

- Price  
The cost for the customer can be reduced by incentives.
- Benefit  
It is important here to mention the customer's perception of the benefit. Issues such as risk-compensation may influence this benefit perception. Therefore, communication is crucial.
- Introduction scenario  
When the system is introduced to the market, the demonstrator must be credible and trustworthy. Transport authorities and user representation groups (such as ADAC, ANWB, AAA) and companies with strong positive image as to innovation may bring to bear strong benefits on user acceptance.
- Level of controllability  
Controllability is an essential issue. The driver must remain in control, and must perceive it this way. To make sure that a system will not be 'overruled' too often, there should be sufficient confidence by the driver in the proper functioning of the system. Bad experiences decrease this level of confidence.
- Image  
A system may provide a certain status to the user. Corporate Identity for fleet owners could play a role.

- Ease of use  
Before introduction or first use, the user must be well informed about the system's limits, human machine interface and performance. During driving, the system should give feedback on its performance ('situational awareness').
- Comfort  
The system should enhance the driver's comfort, by workload reduction. The HMI design is an important enabler.
- 'Joy of Controllability'  
This issue refers to the pleasure that many drivers have when driving. It is greatly dependant on the function for which the vehicle is used (commercial, private...)

*Source:* A qualitative analysis of Acceptance issues for ADAS. Dutch Ministry of Transport, AVV Transport Research Centre.

#### *Ownership of infrastructure (no. 15)*

The government/market interface is evolving. Government retains responsibility for urban/spatial planning, for meaningful regulation and for assessing preconditions in the widest community context. However, increasingly we shall see government creating frameworks for other players to select their own solutions and to offer services itself. Freeing up the situation for market forces, public/private joint enterprises and formulas for road operation and privatisation will be part of this move to business-oriented government. The government's internal decentralisation, by separating policy from road authority under central budget supervision, will be part of this.

The more business-oriented approach will give an impetus to the creative use, including dynamic traffic management measures. We can therefore expect a higher deployment of instruments such as the price mechanism (tolling). Secondly, we may expect more innovative types of road construction including tunnels. The organisational issues related to ownership of infrastructure will thus boost the deployment of more innovative traffic management systems and approaches.

#### *Safety Consciousness in public (no. 8)*

The level of safety consciousness within members of the public has increased since the launch of the EuroNCAP crash test programme in 1996. The aims of that programme were two fold:

- There was a need for objective consumer information
- There was a need for promoting the industry as one in which efforts are made to improve the vehicles manufactured beyond the demands of legislation.

EuroNCAP uses stars to indicate the safety level of a vehicle. A combined star rating shows the protection level in the front collision and side collision together. The intention of the scores is to give an indication to what extent best practice or benchmarking has been applied to an individual car model, and not to predict the real-life outcome. Whilst it is not possible to predict theoretically the outcome in all types of crashes there is a good correlation

between high scoring in the Euro NCAP and overall safety benefits in road accidents.

The EuroNCAP programme has been so successful in raising the awareness of the public that some manufacturers are basing their advertisement campaigns on the Star rating achieved in the EuroNCAP tests.

Research has shown (A Lie, C Tingwall 2000) that the reductions achieved in serious and fatal injuries are substantial through the EuroNCAP crashworthiness programme. It is to some extent surprising that it is possible to discriminate between cars built at the same time, and with differences that are at a level where they can influence safety. The magnitudes of the safety differences are at a level that they become one of the major instruments for the future of traffic safety. While there was no difference between cars that were ranked with 2 stars and older vehicles, four star cars seems to reduce the risk of serious and fatal injuries by more than 30%.

Work is currently in progress to extend the NCAP programme to cover other aspects of vehicle safety. Test procedures to assess primary car safety are currently being developed in the following areas:

- Braking and Braking Stability
- Lighting Quality
- Visibility
- Handling Behaviour

#### Ergonomics

With the introduction of ADAS systems which are “active and preventive” safety systems intended to assist the driver in the prevention and avoidance of accidents, it is likely that testing and assessment procedures will be developed to help the public understand and compare the performance of such systems.

This assessment procedure could help in the education of drivers to understand the limitations of new ADAS systems such as obstacle detection and collision avoidance systems.

EuroNCAP is an initiative to drive vehicle safety beyond current regulation, by offering the market more extensive information about adoption of best practice. While EuroNCAP is a process that should lead to car manufacturers aiming for best practice, and does develop and drive further development of best practice, it is of importance that the real life outcome is constantly monitored.

#### **2.2.3.2.2 Macro-economic aspects**

In the framework of the process to deduce the market introduction scenarios for ADAS macroeconomic aspects were identified as a crucial and important background phenomenon. As global descriptors economic volatility and the GDP growth were chosen. Like other investment decisions in industries the readiness of the automobile industry to spend money for the research and development of ADAS depends strongly on the overall economic situation. The willingness of industries to introduce new products



on the markets is, however, dependent on the market conditions related to the overall situation of a national economy. Furthermore, the overall economic situation also has a decisive influence on private households and more generally on the demand for ADAS. In particular, the growth rate of the GDP is directly linked with what people will spend -- for better equipment of vehicles. It is evident not only that the application ranges and technical equipment characteristics are relevant for the user acceptance and the decision to buy ADAS but that so also is the ability of the system users to pay for these additional elements.

#### *Economic Volatility (no. 4)*

Overall economic situations play an important role for the decision process of industries as to undertaking investments and introducing new products in the market. There is empirical evidence of the macro-economy volatility for the outputs and for the frequency and amplitude of business cycles. Massive drops in equity wealth and contraction in the economy lead, as a rule, to a decline in capital investments and to a lower willingness of industries to introduce new products in their markets.

The economic situation influences accordingly the decision of the automobile industry to introduce Advanced Driver Assistance Systems. The economic situation is particularly important because the market introduction is normally linked to the risks by ADAS. When using the term "risks" in this context we mean the risks of introducing ADAS on the vehicle market. "Market risks" is thereby a general term. It covers the risks that originate from the demand side (e.g. user acceptance, willingness-to-pay, price-elasticity of demand). Additionally, it includes the risks that the product "ADAS" will perform beyond consumer expectations. Unexpected costs such as costs for recall campaigns or monetary compensation demands can arise.

The wide range of possible advanced driver assistance systems means that differing extents of risks for the system provider are attached to them, and it may well be the case that some ADAS with higher expected benefits for the users are also more risky for the system provider than some with lower benefits. Therefore the economic situation is especially crucial in the case of an advanced driver system, which will lead to high benefits for the users (for example, lower rate of accidents and resultant accident cost savings for the user and society). However, introducing this system entails the industry taking a high financial risk. The willingness of industry to take that risk will be higher in a prosperous and flourishing economy. In contrast, in an economy with a downward trend or in a recession, the willingness of industry to introduce such a system will be low. Summing up, market introduction decisions on ADAS are strongly dependent on economic trends.

Understanding the linkage between market introduction of ADAS and the general economic situation is also relevant for the decision process of transport policy, and as to whether supporting actions and measures have to be undertaken to introduce advanced driver assistant systems, which offer a major benefit.

*Average economic growth in EU (no. 5)*

Long-term forecasts of GDP growth are difficult and uncertain. Therefore, short-term prognoses are preferred. The European Commission for, example, has developed an indicator-based model for quarterly GDP growth forecasts for the Euro area (Commission of the European Communities, 2002). In the first quarter of 2003 the forecasts of GDP growth have a range of -0.1% to 0.3%. Weak private consumption, contracting activity in the construction sector and a bleak international environment account are the driving forces for this forecast. For the second quarter of 2003, the model suggests growth in the range of 0.2% to 0.5%. The latter estimate is the result of a relative stabilization of the indicators used in the model.

For the market introduction process it is particularly of interest to determine, which variables are considered in the prognosis model. The model makes a distinction between real and financial variables. The real variables are:

- Car registrations in the Euro area.
- Private consumption in the Euro area, as reflected in the opinion survey on the current business situation in the retail sector.
- The construction sector in the Euro area, as reflected in the construction confidence survey indicator.
- The US ISM (Institute of Supply Management—previously National Association of Purchasing Managers) index of the manufacturing sector, which reflects the importance of economic integration at global level.

There are two financial variables:

- The relative yield spread between the Euro area and the US, which represents monetary conditions and international financial links.
- The real effective exchange rate, which is an indicator of the competitive position of Euro area exporters.

Reflecting the unavoidable uncertainty surrounding every prediction, the forecasts are presented as ranges rather than as point estimates. The in-sample mean absolute forecast error of 0.15% was used to calculate the ranges. For a better interpretation of the forecasts, it is useful to know that the average quarterly growth rate in the Euro area in the 1990s was 0.5%. The sharpest fall was 0.7% (first quarter of 1993) and the fastest increase 1.5% (first quarter of 1992). Tests suggest that the success rate in forecasting acceleration/deceleration/no change for the first quarter to be predicted is 76% and 68% for the following quarter.

For the long-term growth of GDP the principal factors taken into account are usually demographics (e.g. working age population), employment ratio (proportion of the working age population in work) and productivity growth. EU productivity growth has slowed markedly over recent decades. In the last ten years productivity growth has fallen to just 1 percent and seems to set continue. The employment ratio will not significantly increase due to higher tax

burdens for those who are in work. World Bank projections show that the working age population in Europe is only stable until 2010; thereafter it is set to fall over the next several decades. Without a significant improvement of productivity, the growth of the EU economy will be very weak over the coming decades. After 2010 it is possible that some countries, - such as Germany and Italy, will have a negative GDP growth.

*Recommendations for the market introduction scenarios:*

Prognoses on a long-term basis for economic volatility and economic growth are difficult and high uncertainty. However, market introduction scenarios have to focus on the general economic surroundings because the choice of market introduction strategies depends on general economic trends outside the original ADAS business. Therefore, the general expectations on economic volatility and economic growth have to be embedded in the market introduction scenarios.

It is useful to identify economic fluctuations to help predict whether distortions are possible or whether a more steady state and smoother development are more likely. In the same way the economic growth rate has to be described and estimated. Targeting on an expected number for the economic growth rate is not appropriate. It makes more sense to draw out the distinction that when economic growth is high there will be scope for consumers to expand their expenditure on mobility-related technologies. In contrast, when economic growth rate is low the current structure of mobility expenditure of system users must be considered as a factor, which will limit the demand for ADAS.

In that way two alternative development paths of the economy could be considered for the market introduction scenarios. Unfortunately a more pessimistic, but a more realistic, development path is that, as and when economic volatility becomes more stable, only showing some temporally limited distortions, the economic growth rate will be low. Significant increases of the economic ability of system users to buy ADAS will not occur. The implication of this development path is that the ADAS system providers definitely need support for all sorts of advanced driver assistant systems that can be justified by their overall benefits to society. A stand-alone market introduction of ADAS by the automobile industry is not likely to be successful.

Market introduction of ADAS without transport policy support would only make sense if a turn-around to higher economic growth rates could be expected. However, a higher economic growth will be linked to larger economic fluctuations. Therefore, it is crucial to understand how the business cycle of the automobile industry depends on the overall economic cycle. Advanced driver assistant systems, which do not carry high financial risks arising from system failure, could be introduced easily into the market because of the high economic growth rate. Market introduction problems still exist for such a system that would be highly beneficial for the users but would entail high financial risks for the system provider. The willingness of transport policy to support these systems might, in that case, be low. Therefore, due to the high economic growth rates, corporate actions between the system providers to share the financial market introduction risks play a more important role.

### 2.2.3.2.3 User Aspects

#### *Customer Understanding of System Limits (no. 11)*

Any ADAS has a working range, and – within that range – a certain way of operating. ‘Customer understanding’ refers to both aspects as follows:

- 1) Is it clear to the customer (driver) under what conditions a system gets into a different mode, including automatic shut-off or that the driver is handed over control, and how does the system indicate that this is going to happen?
- 2) Is it clear to the customer how the system will react when, within its operating range, certain unusual inputs are made?

Often only the first aspect is considered to be of importance. However, it appears wise to extend the issue to cover the second aspect as well. This includes situations the system is designed to handle, but that does not occur very often. In fact, for some ADAS (e.g. lane departure warning systems, collision avoidance systems) this is exactly the type of situations for which they are designed. Thus, for this type of system ‘customer understanding’ is critical even when the system is in a normal operating state.

Customer understanding today (2003):

A study by Hoedemaeker (1999) produced some useful evidence on how present-day drivers see a range of driver support systems. These included Obstacle Detection Systems, Collision Avoidance Systems, Adaptive Cruise Control, and the Automated Highway System. Figure 12 contains the results of this Questionnaire study on 1,000 Dutch drivers, minus those pertaining to the Automated Highway System. The collected opinions contain a number of items that can be considered to describe ‘understanding’ in the sense meant here.

Obstacle detection system			
Positive aspects		Negative aspects	
Increase of traffic safety	60%	Decrease of traffic safety	5%
Urges on changing behaviour	46%	Decreases attention	44%
Less attention to pay to traffic	5%	System is irritating	41%
Less risk of collision	42%	System can break down	39%
		System leads to shock reactions	25%

Collision avoidance system			
Positive aspects		Negative aspects	
Increase of traffic safety	42%	Decrease of traffic safety	12%
Less attention to pay to traffic	7%	Decreases attention	32%
Less risk of collision	58%	Takes over control	65%
		Brakes at dangerous moments	51%
		Brakes at unnecessary moments	43%

Adaptive Cruise Control			
Positive aspects		Negative aspects	
Increase of traffic safety	45%	Decrease of traffic safety	9%
Improves traffic flow	47%	Takes over control	56%
		Impossible to drive fast	15%
		Unwanted headway	27%
		Brakes at dangerous moments	70%

Figure 12: Opinions on driver support systems (from Hoedemaeker, 1999)

The most interesting aspect in these results, from the present point of view, is that many people appear to have an understanding of the way in which these systems work that is either exaggerated or wrong.

#### **Customer understanding in the year 2010:**

If left to itself, there is no reason to expect that the pattern that is visible in the present results on consumer understanding will have changed much by 2010. We cannot really expect users to learn the ins and outs of these systems just by everyday usage; the more so since new systems will come up between now and 2010. Active interventions, based on communicability and compatibility principles, are probably needed to achieve improvement here (Ortt, 1998).

#### *Consumer Demand for Safety (no. 7)*

The fundamental problem with the way ordinary people deal with (everyday) risks appears to be that people want to do whatever they please, and yet they feel they have to be protected against unacceptable risks by some form of authority. This is a general social development that will probably continue by itself in western countries over the years to come.

Separate from this, there is the specific question of traffic dangers, and the effects that the introduction of ADAS will have. This is what will be considered now.

- **Consumer demand for safety today (2003):**  
There is a growing awareness in policy-making circles that rigorous steps should finally be taken in order to reduce (road) traffic dangers. This is both an input to and a consequence of growing consumer uneasiness in this area. Although it is hard to provide an estimate of what an 'acceptable' level of risk for individual road users might be, it is therefore certain that this level will go down.
- **Consumer demand for safety in the year 2010:**  
What will the 'acceptable' level of traffic risk for consumers be in 2010? A few things should be kept in mind when considering this:
  - 1) Replacement of 'own' risk level by 'external' risk level. It is well known from the literature that one is willing to run a higher risk for activities that are under one's own control than for activities that are under someone else's

control. Mountaineers are, as it was, more afraid in the plane on their way to the Himalayas than on Everest itself. From this it follows that if consumers think the driving task will be taken over by machine they will want to run even fewer risks than they were already promised. This is a counterproductive result of automation in the driver support area.

- 2) Similarly, as a consequence of introducing advanced ADAS, we can expect, in regard to road traffic accidents, a shift away from high-frequency low-severity accidents to low-frequency high-severity accidents. In this respect, road safety will very much begin to resemble aviation safety. The point is, of course, that this latter pattern will generate more worries in the consumer's eye than the continuous trickle of injured persons that we have in present-day road traffic. Again, this is a potentially counterproductive effect that will have to be dealt with.

The conclusion is that, both because of a general societal trend and of the introduction of ADAS itself, consumers will have a very much bigger demand for safety in 2010 than they have now.

#### **2.2.3.2.4 Manufacturer Aspects**

##### *Marketing Activities (no. 1)*

The current scenario of the market introduction of ADAS systems is that for the first time the newly developed "active and preventive" safety systems are being introduced in the automotive market. So far all over Europe these systems have been introduced by car manufacturers in co-operation with system suppliers as "comfort" systems (e.g. ACC). The driver stays responsible for the driving tasks.

The reason for this marketing strategy is the fact that the systems offered in the market shall be positioned in balance between the aroused customer expectation and technical feasibility. The present state of the art, however, does not yet allow ADAS to take over complete driving tasks, and thus would discharge the driver from the responsibility for these partial tasks.

In spite of that, presently ADAS are being developed which head into the direction of systems, which will take over special driving tasks. In order to channel the customer expectations into the right direction at the time of market introduction of these systems, intensive support by means of marketing activities is required.

A basic understanding of basic ADAS functions should be developed on a European level.

Finding the appropriate name for the ADAS functions is the initial step. Names for ADAS should be simple, self-explanatory and most of all the name should be the same for all manufacturers. The customer should be able to recognise the function of ADAS from the name. Good examples are "navigation systems". Manufacturer related names are not very helpful here, because they are more likely to confuse the customer than lead to clarification.

However, concerning customer expectation a general understanding for the “limits of technical feasibility” should be provided. This includes the clarification that technical system may only take over a partial task for the driver to a certain degree. Furthermore, the customer must be made aware of the residual risk due to the technical design. An example is the introduction of airbag systems. Airbags contribute significantly to traffic safety by reduction of accident consequences for the persons involved. This positive influence on passive vehicle safety may be reversed if vehicle occupants react counterproductive at the time of the accident. An example is the positioning of the legs of the passenger on the dashboard during driving.

In view of these aims, the establishment of a task force inside every manufacturer should be promoted towards a common activity of the marketing and the technical departments. This would encourage a correct information flow from what is the new system really doing or not doing, to which are the potential risks of system misuse, and to which is the proper marketing strategy to perform. The advantages for the users then will be a correct understanding of the new functionality. The advantages for the manufacturers and for the suppliers will be the reduction of potential risk of “image” disturbances to a minimum.

In the vision of the foreseeable future it is important to take into account that new markets for mobility provisions will be established and the supply of mobility alternatives will be more differentiated. The possible dimensions of this competitive market are based on the fact that the market success of the various transport modes depends on their ability to satisfy the new mobility needs. Intermodal competition will be more present: public urban transport firms and operators in the field of long-distance passenger transport will develop more aggressive marketing concepts to engender a modal shift from car passenger transport and specific European and national policy will support these concepts by financial aids.

The marketing activities have to take into account the “cultural dimension”. As can be seen everyday, advertisement campaigns are not the same for given product throughout Europe. Therefore, the emphasis will be on different ADAS features, depending on the country in which it is to be sold.

### *Financial Risks (Nr. 2)*

#### OEM point of view

The financial risks of market introduction of ADAS and Active Safety Systems from view of an OEM are based on the following areas:

- Recall Campaigns
- Public Image
- Liability Claims

These areas are influenced by the following contributing factors:

- High Complexity of Systems

Advanced Driver Assistance Systems and, even more so, Active Safety Systems consist mainly of a bunch of sensors linked to a central processor and connected by data buses with a lot of other subsystems in the car (brakes, engine management, gears, power management etc.). Active Safety Systems are especially likely to have additional components by means of redundancy and fail- safe requirements, increasing the complexity still further.

- Short Product Lifecycles

There is a general trend in the car industry to shorten development cycles in order to accelerate the introduction of new products on the market. Although a lot of modern tools such as CAX, computer simulation and driving simulation enable shorter development time in principle, there could be a residual risk, namely that some product or process faults are not detected until the product is already in the market.

- Comprehensibility Problems of System Users

Not only in technical terms, but also in terms of functionality ADAS and Active Safety Systems show growing complexity. In particular, the system limits are often difficult to understand. In consequence, users may have wrong expectations towards the system and may operate the system in an environment, for which it is not designed.

- No standard test and validation methods for ADAS

In particular in passive vehicle safety, a magnitude of test procedures exists which a vehicle must comply with in the course development. These are for instance in Europe the so-called Euroncap and in the American market the so-called USNCAP. All these test procedures try to reproduce many traffic rep. accident situations in a laboratory. The conditions for these test procedures have been derived from the analysis of real accidents and their statistic distribution in the respective market.

For ADAS such a derivation from the real accident scenario does not yet exist. At present, no standard situations are defined which systems must comply with concerning factors from vehicle influencing up to accident avoidance. The main reason is that traffic situations in connection with ADAS are highly complex and involve a magnitude of variations.

These contributing factors influence the financial risks for the OEM as follows:

### **Recall / Warning Campaigns**

Marketing faultless products is of general interest to all manufacturers. In addition, customers are entitled to the right of purchasing a product fit for use. Increasing system complexity and non-standard test procedures make it increasingly difficult to comply with the requirement of a faultless product and a robust system at the same time. Should the manufacturer not be successful in meeting this requirement, he is then obliged to react accordingly, and in case the need arises warn the consumer and/or recall his products from the market.



## **Public Image**

The image of a product in public opinion and in the view of the customer provides a significant parameter for market acceptance of the product. This also applies to ADAS.

When new technologies are introduced, it is essential that customers and the public have confidence in the new technology. Confidence in a new technology is decisively influenced by the media. For market introduction this results in an opportunity as well as a risk. Gossip magazines may turn accident scenarios connected with ADAS into a major media event. A massive image loss for the respective manufacturer as well as for the new technology may be the outcome.

In this case, years of research and development will have been in vain and a lot of invested money lost.

## **Liability Claims**

In liability claims, elements such as the state-of-science and -the-art as well as existing and generated customer expectation of a product play a dominant role. One of the overriding maxims of a manufacturer is to market a faultless product. In the course of product development, the manufacturer must take care that the product complies with the current state-of-science and -the-art at the time of putting it into market. However, if such state of science and art does not exist, which might be especially true for ADAS, the manufacturer is obliged to develop risk analysis.

What may a customer expect from the product and which expectations are evoked in the customer? This question is significant for the manufacturer in the course of product development and advertising the product for sale. If the actual properties of the product deviate from the customer's expectation, this incurs the risk of product liability claims even if the product is not defective from a mere technical viewpoint. The respective system design as well as clear communication of the system function including its limits will reflect the interaction of technical feasibility and customer expectations, which need to be complied with.

## **Insurance point of view**

Insurers may be expected to gravitate towards two fundamental questions:

- 1) Will ADAS work?
- 2) What will it cost to put right if it does not?

The answer to the first question must lie in ensuring the highest-quality engineering, testing, monitoring, recording and technical integration. Such factors will form the basis of effective risk recognition, evaluation and minimisation. Insurers study the causes of previous engineering disasters. They will therefore need to see sound systems of design, development, quality-control and training; disciplined adherence to comprehensive safety analysis; clear recognition and protection of safety-critical elements; low-risk operating procedures robust enough to withstand all foreseeable conditions; well-integrated computer hardware and software with inter-operable diagnostic capabilities; clear and effective human-

machine interface ergonomics; and isolation of small imperfections to prevent them from causing cumulative failure. High-quality project management should also be evidenced by resistance on the part of all concerned not to give way to pressures to introduce ADAS prematurely and a well-balanced and thorough dialogue between engineers and management as to what is practicable. By recognition of such measures a clear alignment of interest with insurers can develop, to form a platform for long-term risk transfer.

The second question depends on how far the parties who introduce, finance and regulate ADAS will require it to be made to work efficiently despite any early setbacks. Insurers of the owners, keepers and drivers of vehicles will seek subrogated recovery for claims payments from the insurers of vehicle manufacturers, suppliers, integrators and operators of the systems. Professional negligence insurances of consultants will not alone sustain such exposure. A strategy to establish from inception ring-fenced risk-sharing pools and/or special claims settlement funds could emerge as a good way to protect the brands and reputations and funds/resources of parties associated with ADAS while building up public confidence and responding to political and public-sector expectations. Objective, though confidential, resolution / adjudication of responsibilities between potential co-defendants could save substantial legal and technical costs and enable money set aside for insurance purchase to be utilised for procuring higher-level and aggregate liability and economic loss insurance and setting up funding mechanisms, including alternative risk transfer (ART).

The insurance markets have been very hard hit in the last three years. They cannot at present be expected to have much appetite for complex telematic and electro-mechanical engineering risks. However, a strong capital base will surely have been re-established by the global insurance industry well before 2010. If the approach to good risk management outlined above is presented in a carefully-integrated way meanwhile, there is every likelihood of achieving effective and sustainable risk transfer to support ADAS. One indicator of such a realisation would be possible reductions of insurance premiums for individual owners, keepers and drivers of vehicles equipped with Advanced Driver Assistance Systems. Dialogue should be initiated as soon as possible with leading insurers and brokers with a view to thereby possibly consolidating marketing advantage even ahead of such time as ADAS can be shown to make a substantial contribution to reduction of traffic accidents on Europe's roads.

#### **2.2.3.2.5 System Aspects**

##### *Cost per ADAS Unit (no. 3)*

Since at the end the consumer has to pay, we can state that cost plays, and will continue to play, a major role in the dissemination of ADAS. This assumed, we must find clues to apprehend this item. From a technical point of view, ADAS terminology synthesises an aggregate of various systems. A first classification will split ADAS into two parts: autonomous devices (ACC, Lane Warning Support,...) and co-operative ones (Speed Alert, ...). Then these two categories can be distinguished as between the "steady" ones,

which do not need to be updated (ACC, ...) and the "upgradeable" ones, which need to be updated to offer maximum efficiency. We must then consider the various actors who will interfere with the dissemination of ADAS. We can relate these actors to an economical point of view, which will extend from a micro-economic to a macro-economic approach.

### **Micro- economic point of view**

This will typically represent the point of view of the final customer, the buyer and the common user of ADAS. The customers' opinion or perception of the cost will depend on what they are ready to pay for and what they are used to paying for. To illustrate this sentence we shall take some examples.

First have a look at for example airbags or systems like ABS. People state as a rule that front airbags or ABS are a standard device in cars nowadays and nobody will agree to pay additionally for them. This ensures a fast dissemination of the product.

Consider now Telematics. These are the kind of services which people enjoy but which they are not prepared to pay for. Maybe because they are used to accessing Internet websites for free, all the trials have been unfruitful as soon as they ask for charges. In this case, price is inadequate and dissemination is low.

Consider now product stories such as that of On Board Navigation. At this stage we should point to the "cultural aspect" of a system's price. This is well illustrated by the fact that, despite similar prices, on board navigation is much more successful in Japan than in Europe.

All these examples show that, at a micro-economic level, cost is not related to what customers are paying for but to what customers think they are paying for.

### **Mid-range economic point of view**

We shall describe under this term the point of view of ADAS providers (car manufacturer, OEM, supplier). The main purpose of ADAS providers is to do business by selling ADAS directly (suppliers) or indirectly, as part of a vehicle, (car manufacturers). In this sphere, prices will depend on business models. These business models will define where the provider expects to get money (whether directly by selling ADAS or indirectly by selling services). A good example is provided by Telecom operators who have "given away" cell phones when selling subscriptions. Their business models have shown that this is efficient in disseminating GSM technology. Unfortunately, most of these operators are on the verge of bankruptcy. This example shows also that once a model has been launched it is very difficult to change it.

To summarise, on a mid-range economic focus, the price structure of ADAS will depend on business models, which will themselves, depend on the type of ADAS (autonomous, co-operative and "steady" or "upgradeable").

### **Macro- economic point of view**

The Macro- economic point of view will reflect the thinking of public authorities or private sector institutions such as insurers. ADAS equipment should save tremendous financial costs for global

society by reducing the costs associated with fatalities and injured persons in traffic accidents. Public authorities must balance the economy provided by the use of ADAS with the possible incentives allowed to buy them.

We have seen in the previous chapter that the price of ADAS will depend on numerous factors and that the way each contributor will play his role will determine price and therefore dissemination of ADAS. However, we can expect, as we have already seen in most of the electronic- based products (computers, cameras, DVD players, computer entertainment systems...), that prices can only decrease or stay at their introduction level if accompanied by an increase in performance.

#### *Usability of ADAS (no.6)*

Drivers require ease of use and high functionality of ADAS and do not expect this to lead to unsafe driving. ADAS should support the driver by informing, warning, assisting and intervening in time and at the right situation. This challenge can only be met if ADAS are suitable and comprehensible. Therefore, usability concepts have to be integrated in the engineering process.

Essential prerequisites in such a product engineering process are the implementation and realisation of design and performance requirements of usability.

Design requirements specify the kind of information that is needed and how it should be presented. For example, the driver should be informed about the system status of ADAS at any given time of interaction between ADAS and the driver.

Performance requirements identify the methods and criteria for analysing and assessing the human machine interaction process of ADAS. For example, after a warning by the system the driver is able to interpret and react on this warning within a defined time.

As to usability, the following examples of design and performance requirements should be noted:

- Design requirements

*Road Vehicles – Transport Information and Control Systems.  
Man Machine Interface. Auditory Information Presentation. Part  
1: Requirements DIN/ISO 3958*

- Performance requirements

*Road Vehicles – Transport Information and Control Systems.  
Man Machine Interface. A Framework for assessing  
SUITABILITY for use while driving. Working Document*

The following Figure 13 summarises the main usability concepts and their relationship to acceptance of ADAS.

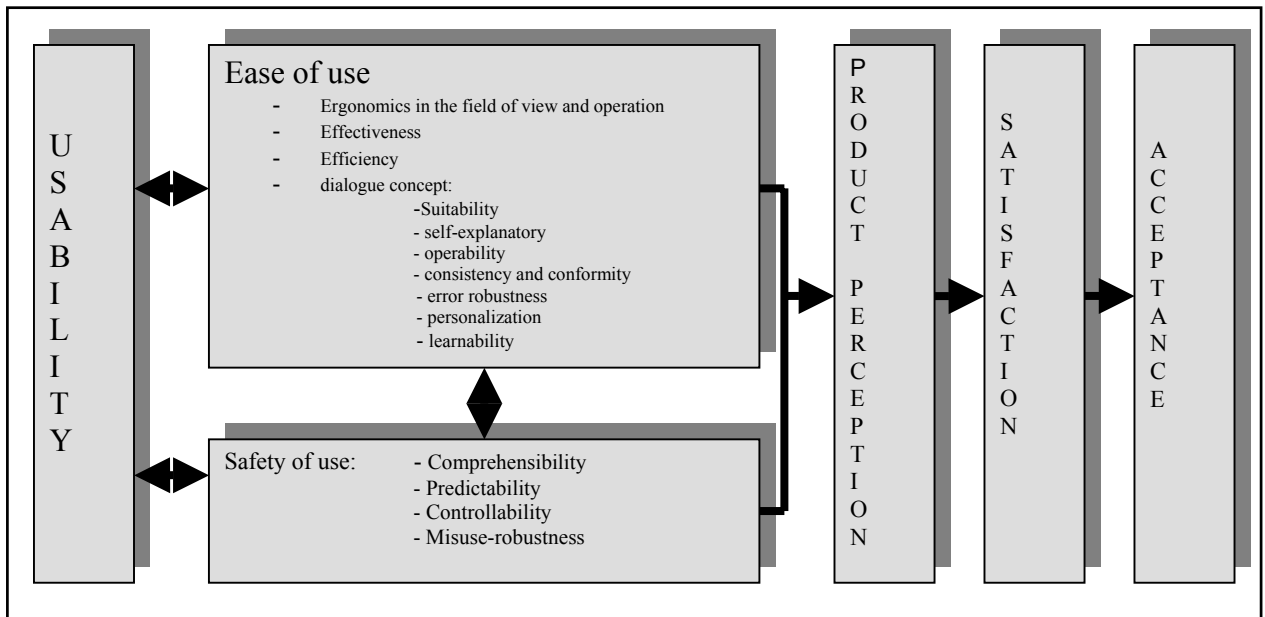


Figure 13: Conceptual relationship between usability and product acceptance (Becker, 2002)

For ADAS the main focus must be on safety of use and its four fundamental concepts Comprehensibility, Predictability, Controllability and Misuse robustness. These four concepts have been defined in the RESPONSE1 project.

#### *Compatibility of ADAS in integrated Systems (no. 13)*

Many independent uncoordinated ADAS versus one integrated system:

One example for an integrated system is Haptic Lane Departure Warning combined with Adaptive Cruise Control, Stop & Go Extension and Emergency Brake with HMI Resource Management.

Integrated assistance can co-ordinate tasks and information/warning that overlap in time and is therefore able to set priorities for the driver, depending on the situation. It may also select the appropriate kind of feedback to the driver. The goal is to not to overload the driver but to provide support and to increase safety by co-ordinating the vehicle's functions (e.g. lateral/longitudinal control).

Many independent and uncoordinated ADAS will result in low usability. Acceptance, especially as to overall perceptibility and controllability, deteriorates. The driver will not be able to cope with many different warnings or contradicting messages. The driver possibly might become disenchanted and turn fully away from using the system.

From a user's point of view a high degree of cross-linking of a few integrated ADAS may further comprehensibility, predictability, controllability and acceptance.

From the point of view of system development it seems that safety assessment of independent and uncoordinated systems can be performed much more easily than safety assessment of an integrated system with comparable performance. This is especially

a topic for a network of systems, in which there are different suppliers involved. Safety Standards focussing on such problems are known from other industries and it might become necessary to discuss the corresponding safety issues in a way, that they are suitable for automotive industry.

*Development into 2010:*

The uncertainty of the descriptor "Compatibility of ADAS in integrated systems" was considered high. Therefore, it will be necessary that integrated solutions with high usability and with high safety benefits will succeed.

## **2.2.3.2.6 Legal Aspects**

### *Regulatory Environment (Tread Act)*

In 2002 the NHTSA (National Highway Traffic Safety Administration) established in the US the Transportation Recall Enhancement Accountability and Documentation Act (Tread Act) (Department of Transportation, NHTSA 2001-8677; notice 3).

Under this rule motor vehicle and motor vehicle equipment manufacturers will be required to report information and to submit documents about customer satisfaction campaigns and other activities and events that may assist NHTSA to identify promptly defects related to motor vehicle safety. The purpose of the Tread Act is to create a global early warning system for motor vehicles in order to enhance safety for US consumers by imposing absolute transparency and rapid response to safety defects. Under the Act, the NHTSA has to be informed within five days of any decision by a manufacturer or supplier to recall a product or to take any other action for safety reasons in any country outside the USA, if such measures refer to a product that is "identical or substantially similar" to a product marketed in the US.

The minimum requirements for reports are:

For claims and notice of death and injury (USA and worldwide):

- Allegation of unspecified defect – for notice only
- Make, model, and model year, must be known before a report can be made. Report in later quarter if information is not available when claim is made.

For property damage claims, consumer complaints, warranty claims, field reports (only USA):

- for a vehicle, the make, model and model year
- for a child seat, the model
- for a tire, the model and the size
- for other motor vehicle equipment, the model name or model number

The TREAD Act is only of slight relevance to the market introduction of ADAS and the subject-matter of this research.

The TREAD Act serves the purpose of generating a stronger market transparency of the automobile industry for the NHTSA and the consumers in the United States. However, these data are not

limited to the American market, but are available all over the world. The general safety of products in the automobile industry and the attitude of companies on the American market are not put in doubt by this legislative development. The development of ADAS is performed under the headings “reasonable safety” and “duty of care”, even if a uniform understanding of those two terms has not yet been determined. These paramount development elements are not influenced by the TREAD Act. The foremost intention of vehicle and accessory manufacturers is still the production of high-quality products with a high safety standard. Therefore, the TREAD Act, with its duty to provide information, and the extended transparency concerning the market situation of ADAS may be considered as balancing each other.

#### *Amount of Legislation (no. 17)*

An evaluation of the descriptor by the Core Team has led to the conclusion that the amount of legislation is important in that regard but not highly important. Future developments in this respect, i. e. as to whether the amount of legislation will be more or less, have been assessed as rather uncertain.

#### The Amount of Legislation Today

Today, laws which explicitly address ADAS are not in force in Europe, nor in the US or Japan. However, many laws, such as national traffic laws, laws regarding admission to public road traffic and rules on behaviour in public road traffic also apply to vehicles equipped with ADAS.

As an example, an overview of existing laws in Germany, which can be relevant for a market introduction of ADAS, will be given below. This overview does not include product liability laws, which will be outlined separately.

##### a) Rules on Admission of Vehicles to Public Road Traffic

According to Sec. 18 §. 1 of the German Regulation on the Admission of Vehicles (Straßenverkehrs – Zulassungs - Ordnung - StVZO) all vehicles running at more than 6 km/h can only be admitted to public road traffic in Germany, if they have received an operating licence (“Betriebserlaubnis”) pursuant to Sec. 19 ss StVZO or EEC type approval (“EG Typengenehmigung”) according to Sec. 3 EEC Type Approval Regulation and an official number plate.

Vehicles equipped with ADAS, of course, also need to receive formal approval by the German authorities. Approval will only be granted if

- the design of the ISA-systems does not contradict technical provisions (ECE rules and/or EU Directives) and
- the use of ADAS is safe.

With regard to the second prerequisite, the competent German authority (“Kraftfahrt – Bundesamt” - KBA) will assess a so-called “abstract danger” (“abstrakte Gefahr”). Both the likelihood of a certain damaging event as well as the extent of a potential damage will be assessed. Between these factors, an interdependency exists.

As yet, the German legislator has not introduced a risk-benefit-analysis for the admission of new technologies in vehicles as has been the case in relatively unexplored new technologies such as genetic engineering etc.

#### b) Rules on Driving Licences

The operation of a motor vehicle on public roads requires a driving licence. This is granted by the competent public authority. The licence refers to certain classes of vehicles such as passenger cars, lorries, motorcycles etc. Beyond this classification, a specific driving licence for certain vehicles is only needed if the law specifically stipulates it. The legal system does not, as yet, provide for a special driving licence for vehicles equipped with ADAS.

#### c) Rules on Behaviour in Public Road Traffic

The rules on behaviour in public road traffic are set out in the German Road Traffic Regulation ("Straßenverkehrsordnung" - StVO). The StVO contains provisions regarding, for example, speed, distance, overtaking manoeuvres etc. Depending on the type of ADAS, the compliance of such systems with certain provisions can be critical.

For example, a distance-keeping system for lorries, which keeps the distance below the legally required minimum distance of 50 metres, could be regarded as contravening Sec. 4 para. 3 StVO. If such a contravention is inherent in the system, this could influence the view of the public authorities when deciding on the admissibility of the system.

In addition, it is a key principle of the StVO that the driver keeps control over his vehicle at all times according to Section 1, 23 para. 1 and para. 1a StVO. Firstly, this requires that upon the driver's command the vehicle accelerates, slows down and moves in the direction intended at any time. This aspect is defined under the driver aspect of "controllability". This can be critical especially for non-overridable systems or such systems as those under which the driver, in theory, can react but in practice the reaction time that the system leaves to him is too short.

Secondly, it requires that the driver must be ready to react adequately to the actual traffic situation, e.g. he is not distracted or inattentive. This aspect must be especially assessed in close relation to the human-machine-interface. For example, if the workload of the driver is reduced by the system to an extent where he loses his alertness, measures must be taken to keep the driver attentive.

### The Development of the Amount of Legislation into the Year 2010

With regard to the admission of vehicles equipped with certain systems, steps have already been taken to create certain standards. Future standardisation in the field of ADAS can be expected to influence positively the admissibility of such systems.

A starting point for new legislation could be to demand that drivers have to pass a specific test to obtain a special driving licence. Whereas such special driving licence can be appropriate for



professionals using highly complex systems, a special driving licence for ADAS in vehicles used for private purposes would create a strong market barrier. In the past, many technologies have been introduced in vehicles without the requirement of a special driving licence, for example, navigation systems, although the driver must learn how to use these systems. To enable the driver to educate himself, it could be appropriate to introduce ADAS step by step and to accompany the market introduction by providing the driver with information, educational training etc.

Alterations of the existing laws could be likely with regard to the above-mentioned rules of the StVO on behaviour in public road traffic. If, for example, the legislator is convinced by testing of the systems that the minimum distance between vehicles equipped with distance-keeping systems can be less than 50 metres without creating dangerous situations, an alteration of this provision could be considered.

It has been experienced in the past that the legislator reacts to certain developments by altering and amending the law. For example, with regard to the use of mobile phones in a vehicle, Sec. 23 para. 1 a StVO has been enacted on 1 April 2001. It can therefore not be excluded that the amount of legislation will increase with regard to ADAS although an uncertainty remains.

#### *Risk of Product Liability (no. 14)*

According to the assessment of the Core Team, the impact of product liability risks on the market introduction of ADAS is very high. In addition, whether product liability issues will increase with regard to ADAS has been defined as being very uncertain.

#### **Product Liability Risks Today**

For every product that is introduced in the market, product liability issues may arise. On a European level, the EC Directive 374/85/EEC on defective products of 25 July 1985 has led to a more or less harmonised European product liability law. The Directive has been implemented in all European Member States into national laws and establishes a strict liability, i. e. a liability irrespective of fault.

Besides strict liability, most Member States of the EU provide for a product liability law on the grounds of contractual relationships and/or tort law. The latter is especially based upon fault; i. e. to be liable, the manufacturer and/or supplier must at least have acted negligently.

In Germany for example, the Product Liability Act ("Produkthaftungsgesetz" - ProdHaftG) came into force on 1 January 1990, implementing the EC Directive. In addition, the courts have developed broad case law on product liability based on Sec. 823 ss of the German Civil Code ("Bürgerliches Gesetzbuch" - BGB), the German law of torts. Both sets of rules apply in parallel.

In general, product liability arises if a product is defective. German courts have distinguished between different categories of defects: (1) design defects; (2) production defects; and (3) instruction failures. For new technological developments, the main focus lies within design defects and instruction defects.

The assessment of a defective product according to the ProdHaftG depends on the standard applied with respect to the expectation of a reasonable degree of safety. Under the law of tort it is decisive whether the manufacturer and/or supplier has applied the necessary duty of care.

In some European countries, especially in Germany, for products, which can endanger the life and health of persons, when assessing the expected safety of a product the expectation of the "most endangered and least informed consumer" is decisive. Therefore, tests for risk analysis must cover all kinds of drivers. For these drivers it must be assessed by testing which dangers can arise from ADAS considering not only the intended use by the manufacturer but also foreseeable misuses. If, after such testing, certain risks resulting from the design of the system remain, drivers must be warned and instructed in order to avoid such risks. Such warnings and instructions must be effective, i. e. they must enable the driver actually to avoid the risk. This must also be proven by testing.

So far, no court decisions dealing with ADAS product liability claims have been published in Germany. However, as can be seen from the examples of airbags and navigation systems, new technologies often lead to numerous product liability claims by consumers. At present, an established procedure to define the overall safety of ADAS as required by the law does not exist, i.e. the concepts of "reasonable safety" and "duty of care" are not yet defined with regard to ADAS. This might bear increased product liability risks. Manufacturers and suppliers cannot rely on accepted tests and development standards in order to limit product liability. It is thus important to monitor ADAS after market introduction very carefully. If risks are detected by monitoring, the appropriate measures must be taken, i.e. either the design must be modified or instructions must be supplied .

### The Development of Product Liability Risks into the Year 2010

A market introduction of ADAS implies that the systems are reasonably safe in legal terms. As mentioned before, this means that all relevant risk scenarios, both resulting from the intended use and any foreseeable misuse, must be considered . ADAS may only be introduced if after such testing the system can be regarded as safe. Especially for innovative technological products it is rather difficult to detect design defects, because the state of science and art is not quite developed in the field of the respective new technology. For example, the first generation of airbags had some design disadvantages, which were only eliminated in the second and third generation.

According to German law, product liability for so-called "development defects", i. e. defects which could not have been detected even by applying the utmost care, is excluded. This easement of liability is mirrored by the obligation to monitor these products extensively after market introduction. If certain risks appear "in the field," the manufacturer must react, i.e. he must modify the design or give appropriate instructions.

It follows from the above that product liability is controllable to a certain extent. Firstly, a translation of the concepts of "reasonable

safety" and "duty of care" into a Code of Practice for the development and validation of ADAS can be used to prove that the product was safe according to the state of art at the time of market introduction and distribution . For development defects, which could not have been detected, liability is excluded. Through product monitoring, product liability risks can be further limited by improving future generations of ADAS.

Thus, future improvements are likely to reduce the risk of product liability the more time has elapsed since the first market introduction. Last but not least, it should be mentioned that although ADAS might reduce the number of accidents overall, this fact alone will not lead to a decrease of product liability risks. This is due to the fact that product liability law does not analyse the question of overall benefits of a product but rather addresses the question as to whether a product is defective.

### 2.2.3.3 Evaluating the descriptors

The phase "finding descriptors" provides a relatively high number of influencing factors, which in their totality are difficult to handle in the subsequent phases of scenario management. Therefore, the descriptors, which influence the scenario field, the most need to be filtered out.

The evaluation of the 17 descriptors found was effected by means of a value allocation from 0 to 2 points in the following two areas and descriptions of distinctiveness:

- **Uncertainty**  
Evaluation of uncertainty to predict the future development of a descriptor. Value allocation:

from "0 = highly uncertain" to "2 = highly certain"

- **Impact**  
Influence extent of scenario field.  
Value allocation:

from "0 = less important" to "2 = very important"

Every group participant had to allot a total of 17 points to "uncertainty" as well as to "impact" of all 17 descriptors:

Descriptor	Total of all participants	
	Uncertainty	Impact
1. Marketing activities	8	18
2. Financial risk (Recall, Image Problems)	21	31
3. Cost / ADAS unit	13	23
4. Economic volatility	21	12
5. Average economic growth in the EU	27	15
6. Usability of ADAS systems	19	30
7. Consumer demand for safety	14	21

8.	Safety consciousness in public	13	19
9.	Ageing drivers	0	6
10.	Customer acceptance threshold	21	19
11.	Customer understanding of the system limits	24	20
12.	Number of accidents with major injuries	22	21
13.	Compatibility of ADAS in integrated systems	24	15
14.	Risk of product liability	23	30
15.	Ownership of infrastructure	16	8
16.	Regulatory environment	23	15
17.	Amount of legislation	18	13

Figure 14: Evaluation of Descriptors

### 2.2.4 Extracting the major Descriptors of the Future and their Development

The evaluation described above may be demonstrated in a two-dimensional diagram.

Figure 15 shows the resulting allocation as a two-dimensional value pair:

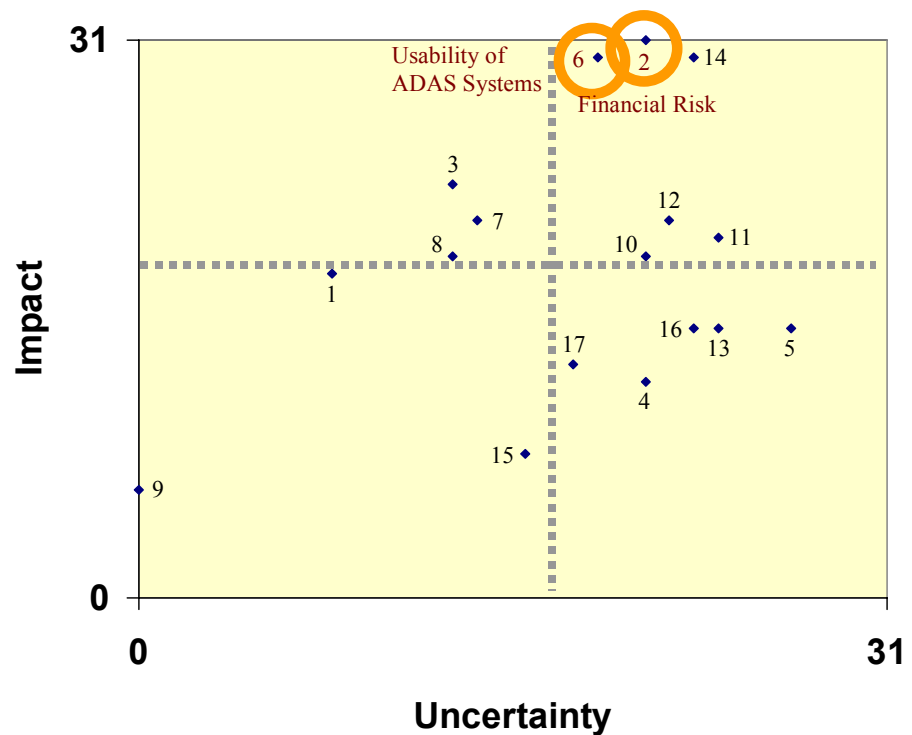


Figure 15: Evaluation of descriptors matrix

In relation to the topic being investigated and the nature of the factor evaluation, the importance of the influencing factors increases the closer their position in the diagram is towards the top right side. Here the value pairs of the evaluation numbers are higher. Descriptors located at the very top of the right side of Figure 16 are considered the most important ones.

As already mentioned in detail, for a scenario development it is necessary to concentrate on the most important influencing factors from the collection of influencing factors. This is the only way to derive a manageable number of scenarios. Factors extracted this way are called key factors for the scenario development.

In the evaluation of the Esslingen Workshop all participants evaluated the following three descriptors as key factors:

Key Descriptor	(Sums)	
	Uncertainty	Impact
2. Financial Risk (Recall, Image Problems)	21	31
6. Usability of ADAS	19	30
14. Risk of product liability	23	30

Figure 16: Key Descriptors

Future prognostics enable an actual "glimpse" into the future. The future development of key factors may be demonstrated by means of two possibilities (Gausemeier, 1996, P223 ff):

- Extreme projection shows extreme but more unlikely development possibilities. Such future scenarios are supposed to distinguish between potential development possibilities in an exaggerated form in order to prevent "surprises".
- In trend projection plausible likely future scenarios are shown. Therefore, these scenarios represent a stronger reference to the present and are more plausible hints towards future development.

To meet research requirements, the development of two key factors, "financial risk" and "usability of ADAS systems" were accomplished by means of extreme projection. The third influencing factor "risk of product liability" has been ignored, since the parties concerned have considered the extent of the possible interference in its future development as being insignificant.

Scenario prognostics had been determined as follows:

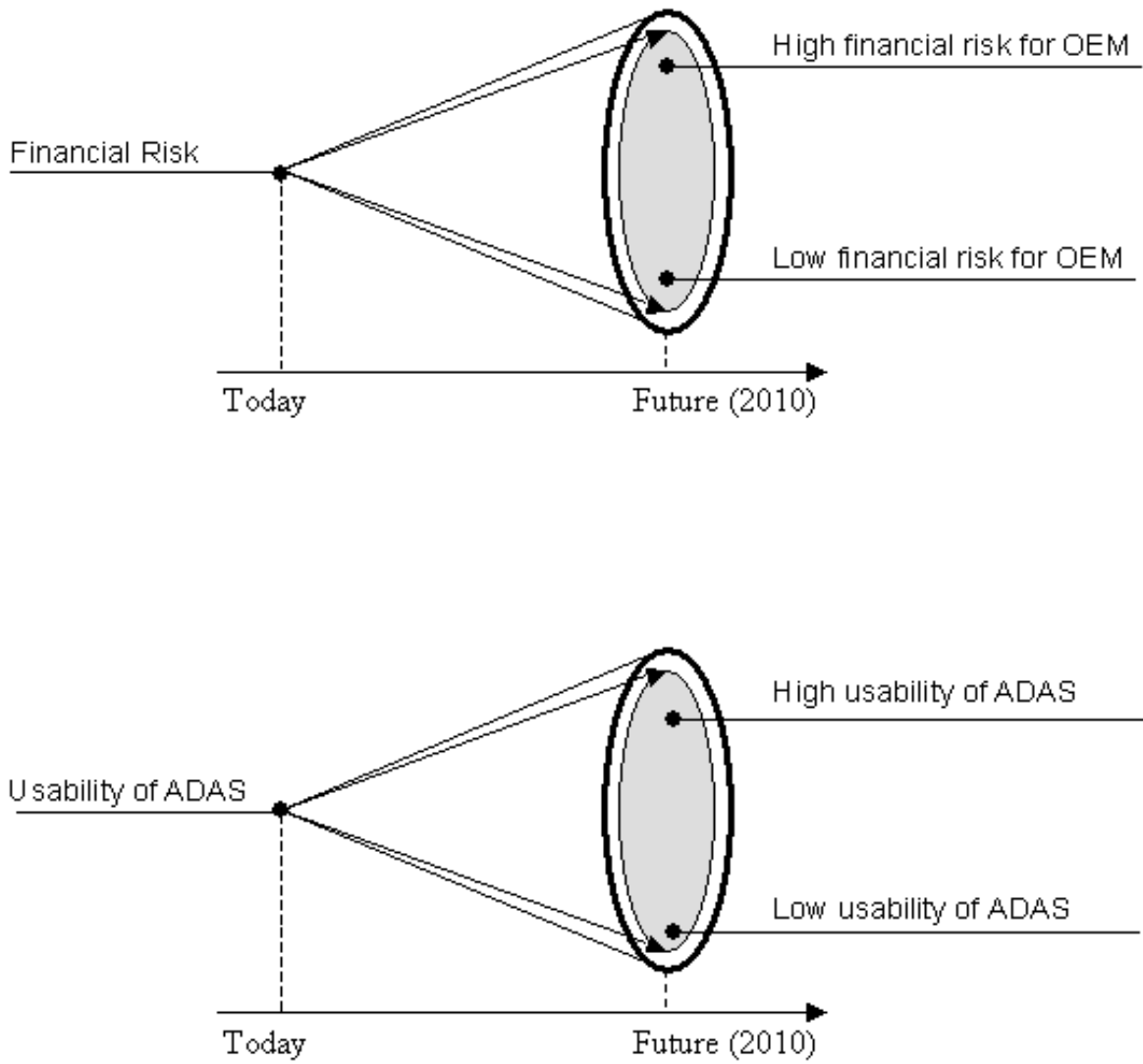


Figure 17: Future descriptors

### 2.2.5 Four Alternatives of Market Introduction Scenarios

For the selected key factors the alternative future projections are now available. Four scenarios result from the combination of these future projections, and are described as follows:

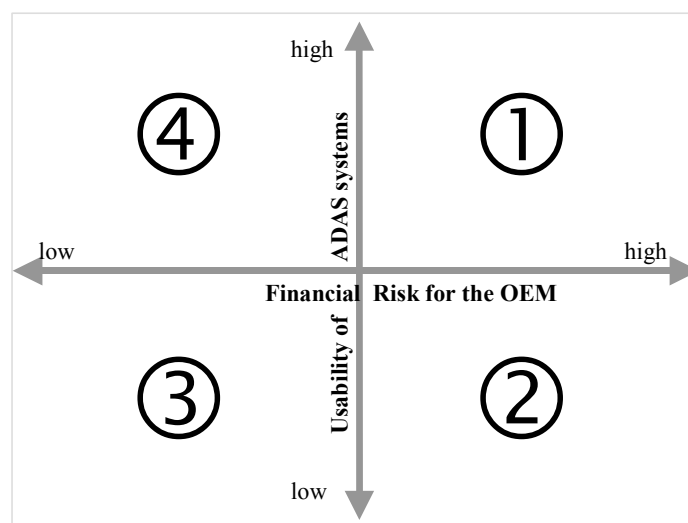


Figure 18: Scenario Landscape

### 2.2.5.1 Scenario 1: High Financial Risk for OEM, High Usability of ADAS

At first, the conditions of this scenario allow a relatively “undisturbed” development and market introduction of ADAS into the year 2010. The ADAS development trends in the year 2003 have since advanced significantly concerning their usability now in the year 2010.

The complex difficulties of sensor based environment recognition in the automobile, which were prevalent at that time, have mostly been overcome. Now in the year 2010 sensor systems like radar, lidar or video technology still show system inherent functional limits based on the respective physical measuring principle. For instance, it is still not feasible to determine the contour of an object by means of radar to provide object recognition. Thus, it is possible to identify that an object is located in the recognition scope; however, a direct object classification is not possible.

However, the evaluation of the sensor data was substantially improved on the whole. In the year 2010, the idea of a sensor data fusion for improved environment model formation that had already emerged in the year 2003, is now reality. All data collected with the sensors in a vehicle form the basis for a uniform evaluation up to a model environment in which the vehicle is operated. Compared to the year 2003, not only the degree of differentiation of environment recognition has been improved by the year 2010, but also the recognition assurance via redundancies.

As a rule, technical solutions that can be developed up to readiness to go into production, will determine product and performance scope offered on the market. Along with the improved performance of sensor based environment recognition in the automobile, the year 2010 also presents high-performance ADAS offering the customer a high benefit. Systems like adaptive cruise control (ACC), an automatic emergency braking device or a lane change support and lane keeping support are already established. In the telematics field navigation systems have been developed which provide to the driver information about traffic flow and warnings of map based dangerous spots. Systems, which are entirely vehicle-vehicle communication based, have not been able to gain acceptance. The difficulty remains that such systems can only be introduced on the market step by step, however, they are not independent systems. Furthermore, the respective „old“ vehicles without these systems still participate in traffic.

The high level of Usability is a consequence of

- the high functionality and performance of ADAS,
- a sophisticated system- and Human Machine Interaction (HMI) design as well as
- extensive user-centred testing.

Crucial for this is the specified Human Factors based development and design processes, taking into account ease of use and safety of use requirements. Hardware and Software of the systems will be well developed and tested through several validation and verification steps.

This lead to ADAS systems, which are suitable, comprehensible and easy to learn due to their self-explaining character. Even very complex ADAS systems can be used safely after a short introduction. The ADAS system is always appropriately informing the driver about the system status. The system is designed to be robust against slips and mistakes of the driver.

Nevertheless, there are still situations, which can't be coped by the system. A 100% guarantee for safe ADAS operation in all environmental conditions is not possible. (e.g.: lane mark detection in a road works section with different parallel road markings). So the driver is always part of the safety concept of an ADAS application and has always to remain attentive to take over the driving task. The share of responsibility for the driving task between driver and system will be realised in safe Hand-over and Take-over operations.

According to the top-down principle, in the year 2010 it will be mainly premium class vehicles that are equipped with ADAS. The entire market portion of vehicles with ADAS therefore is significantly higher in the premium class than in medium and small sized vehicle classes. It is a fact, however, that the market portion of vehicles with ADAS is continually growing.

This is due to the relatively high cost per unit for ADAS, which will have to be paid by the customer in the year 2010. Environment recognition via sensor data fusion requires a number of sensors in the vehicle depending on the respective ADAS functions. An automatic emergency braking device for example requires more than the signal of a radar system. The evaluation of the respective video signals is also necessary. Due to high technical requirements, ADAS still are rather costly for the customer.

Despite the fact that, along with increasing development maturity of technical systems, the individual single unit costs are expected to decrease over the years, the costs for ADAS are actually likely to remain constant. The increasing development expense, which results from the increasing usability of the systems offsets the decreasing prices of standard electronic components. This market situation showed up as early as in 2003 for various market examples with other products. In spite of the fact that the prices for electronic computer components continually decreased, computers did not decrease in price. Along with the increasing functionality, the purchase price of these systems evened out at a certain level, and did not fall any further.

Along with the low percentage penetration rate of ADAS, the positive effect on the entire accident scenario in Europe in the year 2010 is also not significant. National accident statistics are based on the traffic scenarios involving all vehicles on the market. Since the portion of vehicles without ADAS still significantly prevails in the year 2010, the influence of ADAS on the total accident scenario is still low.

As long as ADAS penetration is primarily restricted to premium vehicles it will still depend on the purchase costs of ADAS and will run in opposite direction to the general development of the overall economic situation. In the year 2010 the EU countries will all be in



a growth phase. Consumers will be showing increasing demand in all commodity areas

Due to the high usability of ADAS in the year 2010, a high level of consumer satisfaction for vehicles with these systems can be expected. This is supported by the fact that hardly any accident-prone situations will occur which the public perceives as being linked to a negative influence of ADAS.

This "undisturbed" and seemingly smooth market development for ADAS into the year 2010 has an aura of false certainty about it.

The optimised evaluation of sensor data will lead to improved environment recognition, however, sensor data evaluation performance cannot compete with human performance. Here the obvious difference between „machine recognition“ and „human recognition“ is striking, as well as the difference between control based on „measuring“ and control based on „experience“. Despite a high reliability of ADAS, there are situations in which ADAS will function as designed, however, the traffic situation is too complex for ADAS to react „adequate“ from the driver's view. Therefore, system reactions may occur which do not correspond with consumer expectation. If an accident occurs in this condition, this will lead to the impression that the accident was caused by the respective ADAS.

It will only need a few accidents thought to be connected with ADAS for there to be a powerful change away from the positive attitude of the respective customers and public opinion. The tabloid press and specialist print media, as well as TV broadcasts on private radio and TV stations, may well use these few accidents to question ADAS products by means of exaggerated and distorted reporting. Internet discussions in the so-called chat rooms may create a negative attitude towards ADAS. The influence of the Internet has already shown its impact at the turn of the century. The strongly growing number of the so-called „chat-rooms“ in the year 2010 unites interested customers in an intensive dialogue. Participants in these discussions more than exceeds the number of readers of technical magazines. Despite poor expert knowledge of this audience technical topics are being discussed, considered as true, and therefore a negative opinion is formed, although a real basis is lacking.

Within a very short time, the confidence of consumers in their vehicle systems will be substantially disturbed. Mistrust/suspicion towards ADAS systems will grow. Not only will ADAS be considered with suspicion; so also will the entire safety of the vehicles equipped with these systems. This will result in a loss of trust of consumers in the vehicle brands involved. Further developments will be falling sales of new vehicles, increase in consumer complaints and increase in the number of actions against the vehicle manufacturers.

This clearly reveals the financial risk of the manufacturers.

The expense in time and cost for the development of ready-to-market ADAS in the year 2010 was extremely high. The automobile as well as the supplier and after-market industry has made high investment in the hope of a high ADAS market demand.

This hope of market success has been demolished due to the rapid reduction in demand. Investments made were in vain.

But not only the declining demand in ADAS products weighs heavily on industry. Also vehicles with ADAS, which are already on the market lead to financial damage. Customers who have already equipped their vehicles with ADAS want their systems „repaired“. They want the systems to function as expected when they bought them. Or, the customers might not want to drive their vehicles with the allegedly defective ADAS any more at all. If the customer requests for repair cannot be satisfied adequately, then the dangerous situation is imminent that all customers will claim cancellation of the sale contract. But even if a repair of the ADAS product in question will lead to the desired satisfaction of the customer, the financial burden of the companies due to the recall actions will remain.

Recall actions may place a heavy financial burden on industry. Many examples from the past show this. According to BBC News dated 30 October 2003, Nissan triggered a recall action for the engine of various Nissan models. This action involved a sum of approximately US \$ 140 millions. The defect on the Nissan vehicles was described as: „reports of engines stalling and then failing to re-start. The fault has been traced to defective sensors in the engine management system which will be replaced free of charge.“

At the same time the risk of claims against the manufacturer shows up at an alleged defect of the ADAS. However, compensation claims, which the manufacturer might have to face in Europe, differentiate substantially from the ones originating on the American market. In Europe as well as in the United States of America the claimed damages comprises in general the payment in return for the actual personal and property damage. As for the USA, a possible amount of the so-called punitive damages is added. Punitive damages may sky-rocket the sums claimed by the defendant to amounts, which are no longer calculable. For instance General Motors (GM) lost a product liability case referring to door latches, which would open during an accident, the so-called “The Hardy vs. GM defective door latch case”. Door latches are parts of a vehicle with a long history of development. But nevertheless this accident happened and the lawsuit followed. The jury awarded Mr. Hardy and his wife US \$ 50 Million for past and future health care costs, lost income and to compensate Mr. Hardy because he will never be able to walk again. The jury also assessed US \$ 100 million in punitive damages against GM for callously putting millions of Americans at risk of death or serious injury.

The resulting financial strain will not only be a burden for the vehicle manufacturers whose vehicles are involved in the above mentioned accidents, but also for all vehicle brands which market similar ADAS. Imminent recalls and image losses for all vehicle manufacturers will be the result.

Furthermore, not only will the resulting financial strain on the vehicle manufacturers damage the market situation of ADAS; legislators will be forced to react due to the change in public

opinion. In order to compensate for the shortcomings/inadequacy of ADAS, a reactive and prescriptive body of legislation will result.

### 2.2.5.2 Scenario 2: High Financial Risk for OEM, Low Usability of ADAS

Compared to scenario 1, in the year 2010 the penetration rate of vehicles with ADAS is substantially lower.

ADAS of the year 2010 have a clearly lower performance compared to their benefits than had been hoped for at the time of their initial development at the turn of the millennium. Usability of these systems is lower than expected.

Compared to the expectations at that time, the environment recognition by sensors such as radar or video will not have been further developed in such a way as to enable ADAS to provide a substantial and reliable element of support in the driving task. Networking of the findings from sensor data did not lead to a satisfactory result. For instance, various ADAS refer to several sensors, however the sensor data of a vehicle are not the desired common data bank, which ADAS get their information from. In particular, the all-weather suitability and the application of ADAS in a wide variety of traffic situations such as city traffic or on the highway will not have been entirely covered.

The more system limitations have to be taken into account by the user, the more complex is the interaction between him and the ADAS system. Comprehensibility problems will occur more often and the reduced areas of application will finally lead to a limited acceptance.

The ADAS therefore showing up on the market are basically from the field of information systems. There are no systems, which take over parts of the driving task that cannot be overruled. Even in 2010, ADAS are still designed in a way that the driver is still responsible for the entire driving task. This means that ACC (adaptive cruise control) still functions only within certain speed borders. Automatic stopping and starting of the vehicle is not provided. At the same time, systems for lane keeping and lane change support are only equipped with visual and acoustic information elements. These systems will not automatically interfere in critical traffic situations, but merely inform/warn the driver and request activity. The desirable level of support for the driver will not be reached.

This is the reason why the influence of ADAS on accident statistics for the year 2010 cannot be evaluated. Functions developed up to SOP by the manufacturers have only an insignificant influence on traffic as a whole. Drivers whose vehicles are equipped with ADAS will use this source of information, however, the driver must still handle critical situations himself. Therefore, the effect of ADAS remains minimal due to its low usability.

Furthermore, in the system design of ADAS it will not have been taken into consideration to create a transparent system function for the driver. Due to the reduced situation coverage, the systems will always fall into a failure state, if the situation can't be covered. This makes the system difficult to control. Some drivers will have problems to create a mental model of the system functionality in order to predict system operation in future traffic situations.

All in all the benefit of driving with ADAS is hardly overbalancing the disadvantages.

The task field known as HMI (human machine interface) will have been underestimated in the ADAS development on the part of vehicle- and part system- manufacturers. ADAS will not have been evolved merely for "technology lovers", but also for a wide application group with varying individual relationships to technology. This situation will not have been sufficiently considered in respect of the operation and functionality concept in 2010. The ADAS user will hardly be able to operate ADAS while driving at the same time. The operation units will be showing unclear system feedback and will be too complex.

This situation became obvious as early as in the year 2003 in many other electronic products. In particular, in consumer electronics, at the turn of the century in appliances like video recorders or TV sets, there was a trend to increase technical functions continually, in order to distinguish products from those of competitors. However, this evolution of the resulting product and market advantage did not come about. It was not recognised that the majority of customers did not require nor use the functions offered.

Compared to this restricted technical situation, the expectations of the customer towards ADAS will be proving to be relatively high. The demonstration of the products on the market as well as the general understanding of the customer for the realised ADAS technology will be inducing drivers to expect more from ADAS than these systems are actually able to provide.

The customers' lack of understanding of the existing technical ADAS solutions will result in customer dissatisfaction. In spite of the fact that the systems operate as designed, the user come to think that this is not the case.

In spite of high financial investments, the OEMs have not developed ADAS providing high usability and at the same time they have no significant influence on traffic at large in respect to traffic safety. The customer acceptance of spending money for systems is low, in spite of high customer expectations of the systems. At the same time, purchase costs of ADAS are relatively high compared to other vehicle equipment like for instance Internet or other communication systems. Compared to ADAS, these systems provide a high and obvious customer benefit.

In the year 2010 the obvious financial risk for the OEMs may also be derived from this situation. The money spent over many years on ADAS development has not resulted in products, which have achieved the respective acceptance on the market. The demand for ADAS remains below the manufacturers' expectations. This development leads to the fact that the OEMs will substantially reduce their investments into further development of ADAS.

Based on the imbalance between ADAS in use and the respective system limits and customer expectation of the system relatively high customer dissatisfaction will result. The systems do not operate in a way the customer initially expected them to. As a consequence, this will frequently lead to the situation that ADAS will be blamed for accidents due to alleged malfunction. This

situation will occur, although there are actually only informing and no intervening systems on the market. The manufacturers will have to prove that the system functioned as designed; however, it did not operate the way the driver expected or desired it to operate.

These claims will not lead to compensations, however, the ADAS image will clearly suffer from this situation. Therefore, the market share of ADAS will remain on a low level, and will more likely impair than improve the OEMs' success.

### **2.2.5.3 Scenario 3: Low Financial Risk for OEM, Low Usability of ADAS**

Compared to all vehicle systems related to traffic safety, ADAS will be taking a subordinate role in the year 2010.

Technical progress will have been much slower than had been expected in 2003. The obstacles of technical limits of sensor systems that have not been overcome even in the year 2010 will prevent extensive environment recognition for a vehicle. Compared to human perception the recognition of the vehicle environment is still too low in order to recognise and evaluate the entire scope of all traffic situations. Therefore, intervening ADAS have not been developed up to their readiness to go into production. There are mainly informing ADAS available on the market, which request activity from the driver depending on the traffic situation. In addition, systems taking over partial tasks like longitudinal guidance in the ACC (adaptive cruise control) under the control of the driver.

The driver will still be responsible for the actual driving task. ADAS will provide support for navigational jobs and only take over small, driver-controlled parts of the actual driving task, for instance cruise control. The driver will be able to decide whether or not he would like to use these systems; if in doubt he may switch them off or override them.

In spite of the limited use, customers will tend to buy ADAS. However, the entire market penetration will appear to be limited to a certain volume. Purchase motivation for ADAS will not be the idea of enhanced traffic safety as it is for airbag systems, but more the idea of getting a new "gadget" for the car. It will be "in vogue" to belong to the circle of ADAS owners. In this context it will of course be indispensable to make it obvious to everybody from the outside what kind of ADAS the vehicle is equipped with, in order to stand out from other traffic participants.

This situation is comparable to the after sales field in automobile equipment. Quite a high percentage of customers purchase equipment in the market, without putting too much emphasis on the sense and purpose of the products they are buying. Examples are products such as additional spoilers or additional navigation units.

Since ADAS are actually information- providing systems, and do not take over partial driving tasks, the function and likewise the supposed malfunction will not lead to increased customer annoyance. The expectation attitude of the driver towards the function and the use of ADAS may be considered low.

Therefore, the financial risk which the manufacturer ran in the development of ADAS and also marketing it may be considered small. The investments made for ADAS development have been reduced to a medium range since the year 2000. At that time the development potential of ADAS had been evaluated as very positive, however, the technical obstacles to overcome for a development up to SOP had been evaluated as very high. The proportion of development expense to a possible market success had been considered moderate. Over the years this development proved right. Due to the very low benefit ADAS provides, there is a certain demand for the systems. However, this demand does not vary much from the demand for other optional equipment in a vehicle.

Essentially, in the year 2010 information ADAS have been established on the market, which only slightly influence general traffic safety. In traffic situations in which ADAS did not operate as expected by the customer, this will lead to dissatisfied customers. Since however the expectation attitude of the customers is on a very low level, the cases of customer annoyance may be considered minimal. Critical traffic situations in connection with ADAS are also very unlikely to occur. ADAS provide information and indicate critical traffic situations. Actual interference into the driving task itself does not occur. The driver is and remains the responsible for the entire driving task. Therefore, the driver will never be able to blame ADAS for a conflict in road traffic situations.

#### **2.2.5.4 Scenario 4: Low Financial Risk for OEM, High Usability of ADAS**

As shown in scenario 1, usability of ADAS in this scenario is high. The desired further development of environment recognition, which started at the turn of the century, has reached a high and reliable level. In former times the operation of a system, e.g. airbag on system specific sensors which provide exclusively data for the inherent application. Today, in the year 2010 this single-use situation has been further developed to a sensor data fusion. A multitude of sensors are applied in a vehicle, which collect data about driving behaviour and which record data from the vehicle environment. All values are channelled in a joint information platform and therefore serve as an information basis for a variety of applications. This not only allowed an increase in functional ADAS scopes, but also the back-up of functional safety via redundancies.

In the year 2010, the function of the ACC (adaptive cruise control) on the market with stop-and-go function in stop-and-go traffic is on one hand based on the evaluation of the vehicle's driving behaviour, speed or steering angle. On the other hand, environment recognition with the preceding vehicle is affected by means of data from radar and video sensors.

By the year 2010 systems such as lane departure warning, adaptive cruise control and emergency braking will have been established. Market penetration of these systems will be higher in goods vehicles than in passenger transport. This market development depends on 2 factors:

On one hand the development of ADAS in goods transport has started earlier than in private passenger transport. Optimisation of goods transport, in particular under consideration of the total increase in road traffic has a long tradition. Many research projects have discussed this topic. For instance in the project CHAUFFEUR I and CHAUFFEUR II, „co-operative“ driving of various trucks in a line of traffic was inspected. To be more precise, this project dealt with communication and speed control systems (remote sensors and brake and acceleration actuators), which allows automatic safety distance keeping between these vehicles.

On the other hand, the driving profile of trucks significantly differs from passenger traffic. This is due to the level of education of the drivers and the speeds that can be achieved. Trucks are steered by professional drivers, which ensures that they are trained drivers with driving experience and practice. The drivers of passenger vehicles in comparison reflect the total spectrum of human behaviour in society. This spectrum encompasses the insecure learner or older driver up to the sportive and ambitious driver who wants to get the full potential out of his vehicle. Depending on the type of truck, they have to observe a speed limit of max. 80 km/h. Passenger vehicles, however, have a performance potential of up to 250 km/h.

These different situations also result in different requirements to the system performance of ADAS and the HMI interface. In the field of trucks the functionality of ADAS may be limited to certain partial tasks. These may be applied and safely mastered by the experienced driver. In the passenger transport field the manufacturer must adjust the system design to the so-called „least knowledgeable user“. Therefore, behind the steering wheel a far wider scope of human behaviour and control elements must be taken into consideration.

In 2010 ADAS penetration rates for goods transport will be higher than in passenger transport. This situation is based on the fact that ADAS will first be used in goods transport; passenger transport will follow later, due to higher individuality in traffic and the resulting higher demands.

Due to the high usability level of ADAS, consumer expectation of the systems will also be very high. These expectations are satisfied by ADAS by the year 2010.

The striving for more safety in road traffic was also one of the top topics not only for authorities and commissions. Also the vehicle customer wanted to drive a vehicle as safe as possible. Elements of passive vehicle safety like belt restraint systems or airbags had been long established as standard equipment in new vehicles. The same applies for active systems like ABV (anti blocking preventer). Considering the severe accident scenarios the need for more safety in the vehicle has not been satisfied. Vehicle stabilising systems like ESP have also developed to a standard equipment by the year 2010. New systems like departure warning, adaptive cruise control and emergency braking have rounded off the scope of active vehicle safety. Therefore, a high level of customer satisfaction with the systems can be expected.

This development in the field of active vehicle safety will also have an influence on the effects of accident statistics. The number of accident events will significantly decrease. This does not only apply to severe, partially fatal accidents. Also in the field of small accident scenarios with only slight personal damage the number decreased despite increasing traffic.

Due to high usability of ADAS the extensive function for the respective partial driving task and a functional safety will result. On one hand this is due to a significantly improved mechanical environment recognition and data analysis, on the other hand the optimised HMI interface serves as a basis for safe operation by the driver. Situations in which the driver will come to a false conclusion of the ADAS system reaction will be negligible or can be coped by intuitive operation of the system.

This will affect in particular the financial OEM risk. The confidence of the user in ADAS is large, and will be enhanced by the favourable performance of the systems. Along with high customer satisfaction, the number of complaints about alleged system malfunctions will be low. Legal disputes about compensation are rare. Customer complaints, as well as product liability claims against the system and vehicle manufacturers, will be at a low level.

This market situation in 2010 may be referred to as a “safe market”. The manufacturers will have achieved the aim of introducing into the market safe ADAS systems, which provide a high functional level. Consumer reaction will accordingly have been positive. The market will have accepted ADAS with an increasing penetration rate due to satisfied customers. ADAS will become standard equipment in new vehicles along with the increasing market penetration rate.

## 2.2.6 Market Introduction Scenarios: Strategic Options and Recommendations

On the basis of an extreme projection, the two selected key factors were projected from the year 2003 into the year 2010. The combination of both extreme projections for each key factor resulted in 4 scenarios, which reflect a possible ADAS market situation in the year 2010.

The description of these four scenarios shows that actual development of the future ADAS market situation should lead into the direction of scenario 4, the “safe market”. This reflects a satisfactory future picture for all participating groups such as consumers and manufacturers as well as the regulatory environment. The penetration rate of ADAS will continually increase into the year 2010 with a high benefit from the component systems. Due to market acceptance and customer satisfaction the financial risk for vehicle manufacturers and suppliers will be low.

This leads to the question: “What should we do today in order to approach the goal of developing into the direction of the Scenario 4 “safe market?”. Which recommendations for action could we give to the participating groups of the regulatory environment, the manufacturers and the suppliers?”



### 2.2.6.1 Regulators

European Traffic Policy until 2010 has stated the aim of future traffic policy for there to be a 50 % reduction of fatalities arising from traffic accidents.

The ADAS market introduction is one way to approach this goal. The European Commission accompanies and promotes the various research activities, the investigation of technical feasibility of ADAS as well as their potential effect in traffic and for traffic safety. In spite of all these intensive activities, market introduction of ADAS is proceeding slower and in smaller steps due to various reasons, which the European Commission did not expect.

In order to support further the aim of traffic safety mentioned in the "White Paper" by promoting the market introduction process of ADAS, it seems to be essential to concentrate on those ADAS which promise the best positive influence on the existing accident situation in Europe. But there should be a compromise between expected benefits, the time schedule for market introduction, investment and success probability.

To filter out the appropriate ADAS from the wide variety of all technical possibilities, it is necessary to perform a corresponding benefit analysis for ADAS. For this purpose a macroscopic start must be made in order to consider the overall influence of ADAS on European society. The evaluation of accident data banks could serve as a basis for such a benefit analysis.

Current national accident data banks only supply a limited support for this investigation purpose. They have mostly been established for reasons related to passive vehicle safety. By means of these data banks, elements of passive safety such as chassis improvements, introduction of the seat belt or introduction of air-bags may be analysed. It is, however, advisable to establish a European Accident Data bank concerning vehicle safety as a whole. The time period prior to the actual accident is important in this context.

In the Final Report of the eSafety Working group dated November 2002 a corresponding wording has been formulated:

"One of the most important building blocks in setting up a strategy for the deployment of intelligent integrated road safety into the vehicles is the availability of a European wide database of accident causation data. Only on the basis of clear statistics on the cause of accidents can an impact of new safety systems be evaluated and the real potential of these systems highlighted." (Final Report of the eSafety Working group, P. 17, 2002)

In order to provide further support for ADAS market introduction, it is not enough merely to consider the technical level of ADAS developments and user considerations. Active information and training of the consumer is a necessary supplement. The consumer may only understand the sense and necessity of ADAS through carefully designed communication methods. Parallel to national activities such as stabilising and increasing the use of the safety belt, a similar approach could be pursued for ADAS. With a proactive information campaign about the use of ADAS the purchasing and demand attitudes of the consumer will change.

Additional vehicle systems will at first lead to cost increases when purchasing a vehicle equipped with ADAS. It is necessary, therefore, to enable the consumer to understand this cost increase. In this situation it could be helpful to introduce fiscal incentives for ADAS, as is done in relation to pollution standards today.

### **2.2.6.2 Vehicle Manufacturer and Suppliers**

Procedures must also be found for the vehicle manufacturers and supplier industry procedures to develop the market introduction of ADAS in the direction of Scenario 4, the “Safe Market”.

A significant factor for market acceptance of ADAS is usability. It is continually necessary to support further all proactive efforts for the development of ADAS in all relevant branches of industry. A consistent further development of usability is a significant prerequisite for market introduction and for increased penetration rates of ADAS. Without transparent customer benefit, ADAS will not prove successful in the market.

In the development of ADAS, factors such as individual items of cost, which the consumer has to invest, and user- friendly operation must be taken into consideration. Customers will only be ready to invest these additional costs for their own safety and the safety of their fellow men if these costs for ADAS systems are kept at an acceptable level. The same applies to the functional realisation of the systems. The user must be able to operate ADAS. Transparent functional presentation and ease of operation are significant factors.

By taking these thoughts into consideration, manufacturers should be able to find a way of developing products, which will meet the demand of “reasonable safety”. Here the question comes up: What does the term “reasonable safety” imply? The automobile industry should provide a common understanding in order to reach a common evaluation, as to the point at which a product complies with these requirements. The expectations of the consumers with regard to ADAS play an important role here. Consumer expectation can be derived from vehicle systems, which are already on the market. The customers’ confidence in today’s vehicle developments must under all circumstances be maintained and cultivated.

What applies to the term “reasonable safety” also applies to the term “duty of care”. Manufacturers must come to a common understanding about the demand of “duty of care”. Stable processes need to be established in the field of ADAS development as well as in the field of system validation, in order to provide safe products. These processes could be derived from standard recommendations, which should be determined through inter-disciplinary agreement.

A helpful instrument for supporting this inter-disciplinary work lies in a risk-benefit consideration on a microscopic level. Other industries such as the railroad or aircraft industries have already evolved practices, which could possibly be adapted by the automobile industry. Compared to other branches of industry, the aspect of HMI (human machine interface) integration must be

included in the overall consideration to a substantially higher degree. This is due to the fact that automobiles are operated by many consumers with far more widely differing abilities and skills than is the case with operators of aircraft or trains.

## 2.3 Summary and Prospect

By means of the tool “scenario management”, a systematic analysis of possible developments in the ADAS marketing situation from the year 2003 into the year 2010 has been performed in the preceding chapters. Expert forums revealed that both influencing factors “usability of ADAS” and “financial risk for OEM” are the influencing factors, which will play a domineering role in the future, market introduction of ADAS into the year 2010. The discussion of possible future developments for these influencing factors indicated that a speedy ADAS market introduction might be evaluated marketable if the factors “high usability of ADAS” and “low financial risk for OEM” is achieved.

### 2.3.1 Usability of ADAS

The term “Usability of ADAS” describes the perceptible, and also the actual ADAS benefit for the driver. Usability from a technical point of view and the resulting functional safety represent a significant condition in this context. Furthermore, the technical interactions put into practice with the driver provide further conditions which influence and limit perceptible and practical benefit of the systems (usability from an HMI point of view).

#### Usability from the technical point of view

The automotive industry introduced yet active safety systems with a high level of system safety and system quality. This has been shown for example with systems like ESP (Electronic stability program), brake assistant or active front steering.

Future ADAS are supposed to increasingly support the driver in the driving task, in particular in critical driving situations. This support should also include complete partial tasks, which the driver cannot overrule. Practical possibilities for these aims depend for instance on technical limits of environment recognition. Modern sensors may recognise the vehicle environment only to a limited degree compared with a human. Automatic perception is still far behind the human capability. In spite of that, ADAS is expected to function properly and in a transparent way.

Quality is assured by the intensive development and test processes that are installed at the OEM. Based on the increasing system complexity for the new tasks of ADAS the development of a reasonable safe system, concerning a least informed consumer, becomes more and more difficult. Regarding the acceleration of the market introduction of ADAS this situation seems to become more and more a disabling factor.

Concerning system safety there are several issues that are linked to the complexity of electronics with safety functions.

In the automotive industry the existing guidelines for safety issues aren't sufficient enough to react on the increasing functionality with a permanent growing system complexity. There are permanent

discussions between manufacturer and supplier how to specify and how to verify certain functions. That means that there are always new, even different negotiations between different parties on the same subject for the hardware design as well as for the software quality and safety level.

Other industries dealing with safety electronics like aircraft or railway have yet certified processes and qualified tools like certified compilers for years. Additionally the users of these systems and products have a certain or a minimum level of education. Compared to the long history of vehicle development today the automotive industry is faced with an excessive increasing level of system complexity. On the other hand the automotive industry has still to deal with user groups of their products that contains also the least informed consumer. In order to introduce reasonable safe products for the whole user group the automotive industry starts to establish safety issues like the other industries.

Today in the automotive industry there are no standard electronic components available for safety functions that would fit to the automotive requirements and would serve as qualified components for the usage of redundant information processing, so that they could be used for different functionalities. As safety is always linked to the certification of all components and processes, a change of one component means often the re-certification of the whole system and process again. The use of certified standard safety components could give a huge benefit to accelerate the development processes that are necessary to develop safety functions.

Compared to other industries a further major issue is the risk consideration of safety functions itself. Up to now in the automotive industry hazard analyses is widely used to determine the potential severity of damages due to a certain malfunction of the system. The aim of this evaluation is to cover potential hazards by the use of correspondent safety concepts. For example this basic idea has been included in the new ECE regulations "R13" and "R13-H" for brake systems.

Other transport industries like railway or aircraft act in another way. Although not explicitly written the evaluation of the electronic safety includes the description of risk levels for hazards. These levels are the result of the combination of the potential severity of a hazard and the probability for the system malfunction causing this hazard. This is new for automotive industry and there is yet no common agreement whether this is the right way. Nevertheless the discussion about it has started.

Especially for the layout of ADAS hardware and software this evaluation could be a way to determine the reasonable safety of different functions. The use of such a standardised procedure could help to find decisions for the design of the necessary safety concept, which is the central part to be certified. Within that issue there is the need of a common agreement, how to consider risk levels for safety functions, so that the engineers in the automotive industry have a starting point for their product development.

Usability from an HMI point of view

ADAS usability does not only stand for the ease of system use (e.g.: ergonomic design, operability and error robustness) but also implies the safety of use and its four fundamental concepts:

- Comprehensibility (ensuring a limited operation complexity as well as a transparent and consistent system design in order to make the system understandable also for drivers with lower cognitive capabilities)
- Predictability (designing the system comprehensible and consistent to provide system behaviour that can be predicted by the driver)
- Controllability (ensuring e.g. permanent overriding possibilities and sufficient time frames for driver reaction to guarantee safe take-over manoeuvres from system to driver control)
- Misuse robustness (firstly minimising the possibilities of using the system in non intended situations, e.g. driving with radar through foggy weather and secondly designing the system to be robust against operating slips and mistakes of the driver.

These usability concepts have to be addressed already in the earliest phases of the engineering process. But Human Factors aspects are traditionally not well integrated within system design and development processes. Nevertheless in the field of ADAS it is essential to implement and realise design and performance requirements of usability.

- Human Factors aspects have to be consequently addressed beginning in the ADAS architecture and system design phase as well as in the hardware and software design phase of ADAS systems and subsystems. Accurate evaluations earlier in the design phase can save money and time.
- Furthermore it is crucial to avoid incomplete specifications or design failures by implementing methods of a user centred validation before system and vehicle integration. Due to the fact that there is still a lack of appropriate methods, further development of such tools is needed, e.g. an enlarged Hazard and Operability Study (HAZOP) and a Failure Mode and Effect Analysis (FMEA) including human behaviour aspects.
- Human reliability has to be assured in the product engineering process. Human failures, which are causing implementation errors such as software bugs and manufacturing failures, have to be avoided by using Human Factors analysing tools integrated in quality measurements.
- After vehicle integration of an ADAS system, a validation procedure has to be carried out according to Human Factors methods measuring Usability aspects.

It can be stated that today there are no structured methods for user interface design. There are several guidelines and qualities that are desirable for a usable, safe Human Machine Interface, but the method of achieving these qualities is not well described. Currently, the best method available is iterative design, evaluation, and redesign. This is why user centred evaluation methods are

important. If it is possible to perform efficient evaluations and to correctly identify as many failures as possible, system architecture and interface design will be greatly improved.

Unfortunately, Human Machine Interaction (HMI) and ADAS Usability as a subject is still "immature" and not fully understood. This situation reveals the strong need for further method development to come to the definition of uniform 'metrics' for ADAS systems in the future.

### 2.3.2 Financial risk for OEM

The influencing factor "financial risk for OEM" comprises the variety of company risks, which result from the development of products with the aim of marketing them, and the distribution of ADAS products in particular.

The first financial risk consists prior and at the market introduction of ADAS. A basic corporate objective is a profitable sale of products to the customer. For the implementation of this aim acceptance of the products in the market is an indispensable precondition. If products are developed and produced with high expenses, investments made with high hopes will turn into high losses. The development of ADAS on a high functional level tells only one side of the story. Positive market acceptance and resonance, which these systems are supposed to achieve, is the other part of the story.

Future ADAS market acceptance will mainly depend on the achievable and represented customer benefit (usability of ADAS). As described above, these technical conditions and limitations must be taken into consideration concerning the development of these systems, as well as the future interaction with the user. Only when an adequate system performance on a high level can be developed, future ADAS will get a chance to establish themselves on the future market.

Further financial corporate risks will arise as soon as the products are on the market.

The developed and distributed systems must satisfy the customer expectations. If this is not the case, claims for cancellation of the sale contract are imminent. These claims may result in a product repurchase obligation, if significant product characteristics the customer may expect, are not complied with. If the majority of the market reacts, high losses due to product repurchase and subsequent slump in sales are imminent.

At the same time, the products must function correctly. A customer is always entitled to receive a product without shortcomings. If this is not the case, besides cancellation of the sale contract also repair or purchase price reduction may be a possible consequence. If the product failure is not an individual failure but a series failure, then a product recall may result. This recall is obligatory if the failure lead to dangerous situations.

An analysis of the Federal Traffic Authority (Kraftfahrtbundesamt KBA) for the year 2003 reveals for Germany that the KBA registered 144 recall actions including a total of 939884 vehicles. The involved vehicles had been recalled to workshops for repair on

the manufacturers' expense. This shows the enormous financial risk the manufacturers can be confronted with. The manufacturers are confronted with these financial risks without prior warning, since the manufacturer expected the products to be fit for use due to high development and production standards.

### 2.3.3 Prospect

The analysis of the possible future development of ADAS into the year 2010 showed that customer acceptance and confidence in the product play a significant role in market success. The customer desires a benefit by purchasing the product. This customer reaction is highly dependent on the "usability" achieved by the manufacturer. The financial risk for the manufacturer is a decisive criterion whether the customer should be offered or not the product for purchase at all.

Both of the influencing factors "usability of ADAS" and "financial risk for OEM" dominate the development if and how ADAS will be introduced and establish on the market. Success will only be achieved if both influencing factors are accompanied by the "appropriate development": "high usability" and "low financial risk".

Based on these development aims for the major influencing factors, the subsequent chapter "Risk-Benefit-Analysis" will perform an analysis of the ratio between risk and benefit of ADAS. The consideration will be performed on two different levels. On one hand, the microscopic level seeks to answer the question what ADAS means for every individual user. On the other hand, the macroscopic level focuses on the influence of ADAS on the entire society. The results from the chapters "Market Introduction Scenarios" and "Risk-Benefit-Analysis" serve as a basis for the description of the first steps in the direction of a Code of Practice in the chapter "Steps Towards a Code of Practice".

## 3 Methods for Risk-Benefit-Analysis of ADAS

### 3.1 Risk Benefit Considerations in Non-Automotive Areas

In contrast to the automotive industry, other industry have already a long history on the performance of risk-benefit and cost-benefit analyses.

Depending on the involvement of people at risk, there are often cost-benefit analyses that are performed, like in the shipping industry. Basically decisions have to be made as a fast response to accidents, and the decision on the risk benefit issue is mainly built upon the prior knowledge of an individual or a small group. A formalistic risk benefit approach that is based on mathematical formulae has only recently been introduced into shipping industry.

A formalistic approach is widely used in many different industries. There are standards for all technology risk issues available, where a comprehensive consideration of all risks is feasible, e.g. aviation, railway, process and chemical industry and even nuclear industry. Not all can be mentioned here. But it is not a question how catastrophic a major failure could be, it is still possible to establish a correspondent safety standard.

But what to do if there are side effects that cannot all be clearly assessed? A typical situation can be found in the pharmaceutical industry. There we can find a Code of Practice approach. Because there is no fully comprehensive risk assessment feasible, there is a need for an agreement of best practice to go forward. Regarding the human factors discussion, this approach is in a way comparable to the situation of ADAS, but should be easier in that field, as the severity of possible side effects seem to be limited. Additionally, traffic can still be better controlled also by other means compared to the effects of drugs.

In a nutshell we could summarise the findings (a more detailed presentation and discussion of the risk-benefit considerations in non-automotive areas can be found in Deliverable D2) as follows:

- If risks can be described and evaluated, make relevant safety standards
- If there is a lack of knowledge due to possible side effects, a Code of Practice approach seems to be adequate.

### 3.2 Risk Benefit Considerations – the Micro Perspective

#### 3.2.1 General Risk Consideration

##### 3.2.1.1 Hazard, Harm, Risk and Co.

Before talking about risk, it is important to give a clear definition of this term as well as the other related terms that will be used in this work. Within the legal issues often the terms risk and hazard are used in a similar way, whereas in the technical literature we can find a clearer distinction between these relevant terms. Therefore a list of relevant terms is given below [taken from IEC 61508-4, 1998]:

**Hazard:** potential source of harm.



**Harm:** physical injury or damage to the health of people either directly or indirectly as a result of damage to property or to the environment.

**Risk:** combination of the probability of occurrence of harm and the severity of that harm.

**Tolerable Risk:** risk, which is accepted in a given context based on the current values of society.

**Residual Risk:** Risk after protective measures have been taken.

**Safety:** freedom from unacceptable risk.

### 3.2.1.2 Risk of life

Risk of life is a topic, where we face many possibilities, how to express risk by using numbers. The reasons for that are also manifold, because it is the choice of basic population, that makes the difference (as we know from all kinds of statistics, that are used around the world) and so it is your own perspective, that will tell you the relevance of the numbers in a statistic for yourself. As we are focussing our work on the reduction of the road traffic fatality rate within Europe, it is the huge number of more than 40.000 lives that Europe is suffering within a year, which tells us to act. But, Europe consists of 15 member states with 375 million inhabitants and there are certainly different aspects for different people, interpreting this number. Not all people are taking part in every day traffic, whereas others are spending most of their time on European Roads. The personal involvement in the considered risk topics plays naturally a major role, if the related risk will be acceptable or not. These few lines show already, that is not easy to describe risk of life for everyone in the same way, and their will always be the individualistic risk perception, that leads to risk acceptance or rejection, which is the content of the next paragraph.

Although the consideration of mortality rates in society are not the numbers that should be used for a risk-benefit analysis of ADAS, which will be shown later on, the corresponding statistics are widely used and are at least a mean to show the relation between different causes of death, natural as well as not natural.

Why do people die?

The following examples are taken from the federal state HESSEN in Germany. The reason for taking these numbers as an example is the available granularity of the data. Comparing the overall mortality rates of HESSEN to the average of Germany, there is no big difference that the assumption should be valid, that also the distribution of more detailed causes of death can be taken as being representative. To have always in mind, what there should be compared, we can easily calculate the traffic mortality rate of Europe, which can be built by dividing the number of people killed in traffic by the European population.

$$\text{EuropeanTrafficMortalityRate} \approx \frac{40.000}{375000000} = 1,07 \cdot 10^{-4} / a$$

which is, roughly speaking, equal to 1 person out of 10.000 will die in European traffic per year.

In comparison to our chosen data source, in Hessen the traffic mortality rate of 2001 was  $0,9 \cdot 10^{-5}$ , which is the same order of magnitude. As we will see in the next chapter, risk principles to define an accepted risk level, are considering the mortality rate that is introduced by a new technology in comparison to the natural mortality rate. Not considering the strong dependence of the natural mortality rate from age we get the following mortality rates in the society. Although the numbers are calculated from the chosen example, the magnitudes can be used as being representative for the industrialised countries

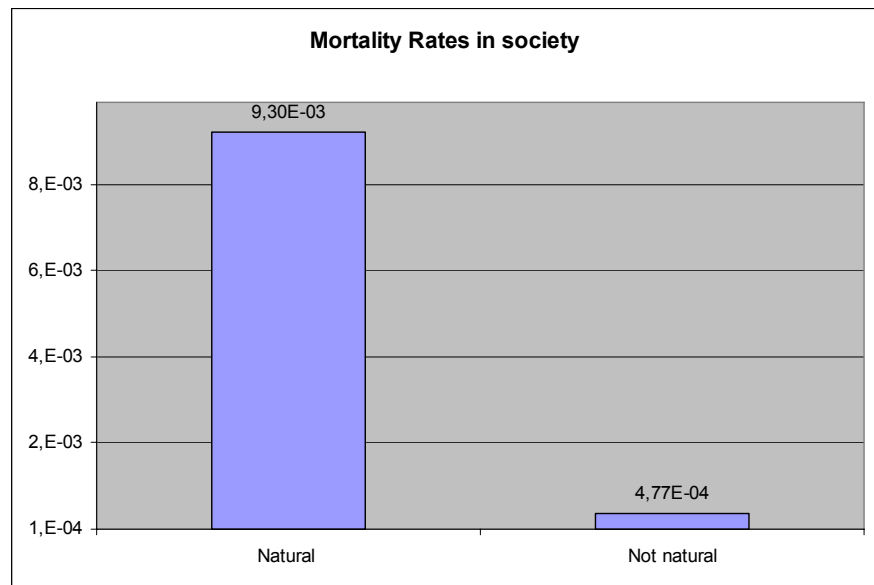


Figure 19: Mortality rates in society (source: Statistisches Landesamt Hessen 2001, Germany)

In another way, the natural mortality rate is about 1%, i.e. one person out of 100 will die per year due to a natural cause. To get a deeper understanding the next diagrams show the mortality rates for the main causes for natural causes as well as for not natural causes. Looking at these diagrams we could get the impression, that the traffic mortality rate is not a big deal compared to the natural mortality rate. But, as already mentioned before, the problem with this kind of consideration lays in the fact, that not all of the entire population have got the same risk. A good example to demonstrate that, could be the consideration of misuse in relation to alcohol and tobacco. Regarding year 2001 in Germany, there have been 111.000 fatalities addressed to misuse of tobacco and 73.000 fatalities due to alcohol by an absolute number of 850.000 fatalities, which would already yield 18% of all fatalities linked to alcohol and tobacco. Calculating corresponding mortality rates (about 17 Million smokers and 10 Million with risky consumption of alcohol), there is a smoker/alcoholic mortality rate of about  $7 \cdot 10^{-3}$  /a. we can conclude, that we will have to take a much closer look to the risks lying behind the statistics not only of mortality rates but also statistics corresponding to traffic accidents.

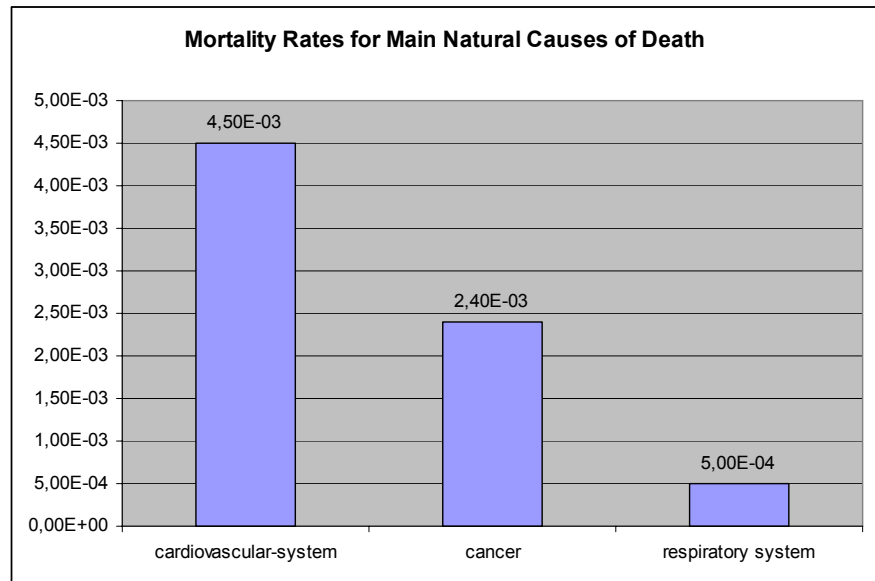


Figure 20: Mortality Rates for Main Natural Causes of Death

It is necessary to remark that although these numbers in the figure above stand for natural causes, these causes can also have their origin in the misuse of tobacco or alcohol, which already shifts the “natural” mortality rates.

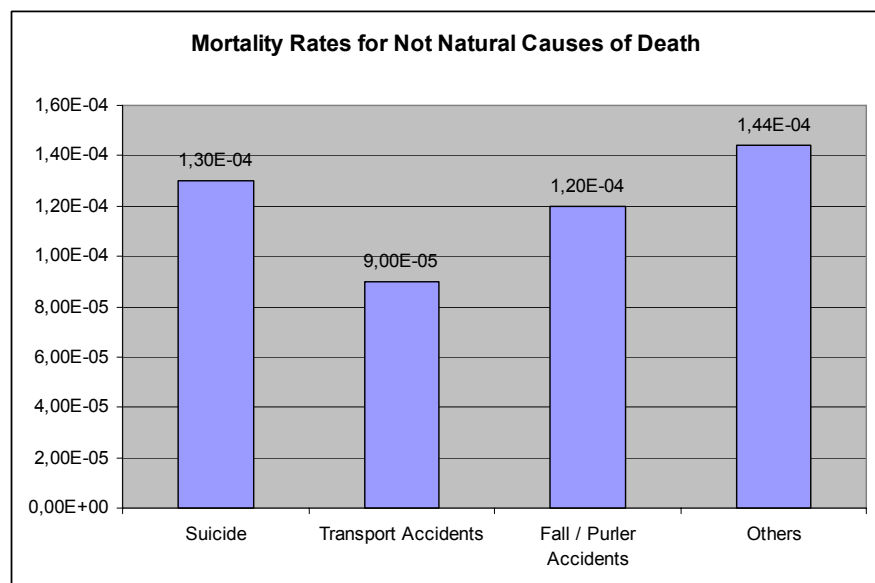


Figure 21: Mortality Rates for Main Topics of Not Natural Causes of Death

### 3.2.1.3 Risk Perception and Acceptance

The considerations of “risk of life” leads to the question, what are objective methods for risk evaluation and are existing methods available.

The work showed, that there are 3 main principles on risk acceptance available, called

MEM - Minimal Endogenous Mortality,

GAMAB - Globalement Au Moins Aussi Bon, and

ALARP – As Low as Reasonably Practicable

The MEM principle considers the mortality rates within a society, and that these mortality rates are dependent on age. A certain percentage of the fatalities is caused by technical systems. The MEM principle claims, that a new technical system must not increase nameable this percentage – and this must be also independent from age. Therefore in Germany MEM takes the lowest mortality rate, which is  $2 \cdot 10^{-4}$  for 13 years old boys as centre of reference. (see above the average mortality rate is about  $10^{-2}$ , which is two orders of magnitude higher!) The EN 50126, RAMS within railway applications is using this MEM principle and claims that a nameable technical contribution to the mortality rate would be  $10^{-5}$  per person and year. Additionally MEM acts on the assumption, that the acceptance will decrease with a higher number of people being killed in an accident under consideration. This leads to the following diagram that shows the limit of accepted technical mortality rate with respect to the severity of considered accidents.

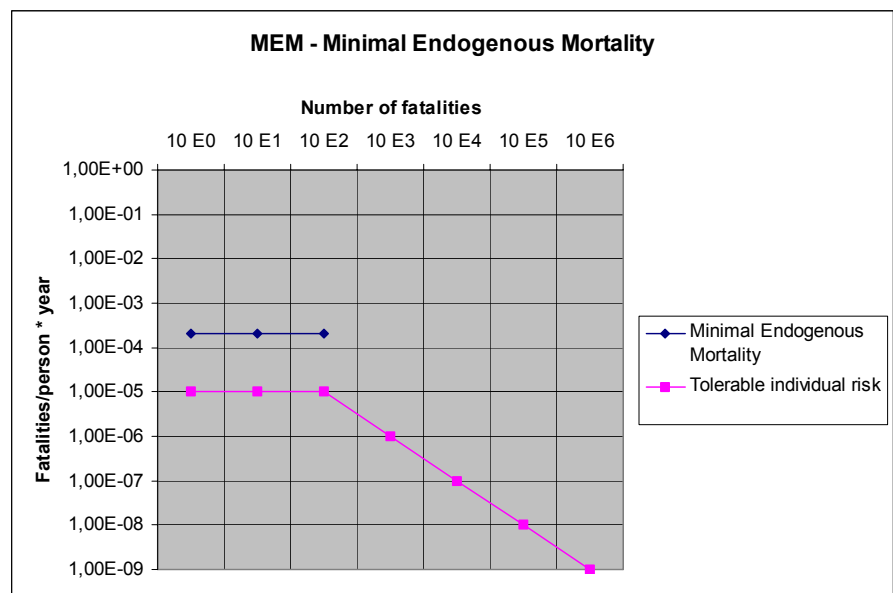


Figure 22: Principle of Minimal Endogenous Mortality

GAMAB – a principle for risk acceptance coming from France, has the following assumption: There is an already accepted technology available as solution for a certain task. The risk that is introduced by switching to a new technology must be at least equal or lower than the existing risk. The word “globalement” is important to consider, as this includes a risk-benefit-consideration within time and location, i.e. an increased risk at a location may be compensated with a decreased risk at another location. There are similar procedures within German railway regulations like “Verification of the same safety level as yielded with adherence to the acknowledged rules of technology.”

ALARP has the assumption: The socially accepted risk is known. The claim is now, that the intended risk introduction must be below that accepted risk level. The term “reasonably practicable” determines, how much lower the risk must be with regard to the accepted risk. Theoretically we could have an endless effort to reduce the risk to a minimum, but also at infinite cost. Therefore a

second limit is introduced that will accept risks, where a further risk reduction cannot be justified. The following picture should give here some insight into the ALARP concept.

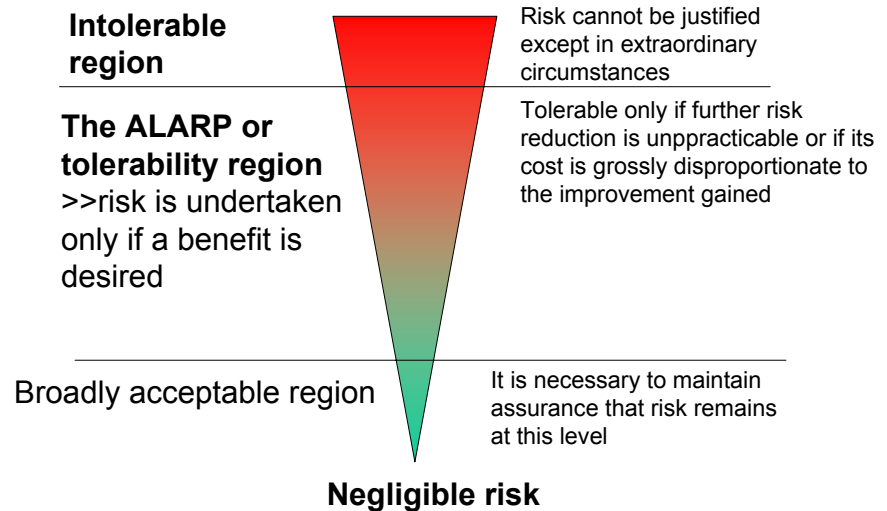


Figure 23: The ALARP - principle

The ALARP principles afford the comparison of different technological solutions with respect to cost, effort and risk reduction, whereas cost and effort are not always solely of monetary nature.

To give an impression of possible values for the tolerability region, the Figure 24 represents some fatality risk values used by Rail track [Engineering Safety Management, Volume 2: Train and Infrastructure Change Management Processes, Issue 2.0, also called Yellow Book 2) in GB.

Group	Upper limit of tolerability	Limit of general accepted risk	Typical used values
Employee, Worker	$10^{-3}$	$10^{-6}$	$10^{-4}$
Passenger	$10^{-4}$	$10^{-6}$	$10^{-5}$
Public	$10^{-4}$	$10^{-6}$	$10^{-5}$

Figure 24: Fatality risk per person and year; risk for different groups (Rail track)

## 3.2.2 Risk Perception from the perspective of science, media and public

### 3.2.2.1 Introduction

A central finding of the risk perception research is: The risks, which are frightening the public most are often not those risks, people are dying from most frequently (statistically). Scientific risk research, mass media and so-called laymen have most different pictures of their "risk reality".

In many cases the public risks perception does not correspond to the scientific risk estimation. But there is not only a discrepancy between public and scientific risk perception, the discussion among the experts is frequently controversial and uncertain. Often, no common scientific evaluation of a risk is possible anymore. This

has consequences both for the risk management of the responsible institutions and authorities as well as for the risk perception of the public.

In the following we outline first "rules" of how the scientific, public media and individual risk concepts are developing. Then we discuss the consequences of the discrepancy of these risk concepts for the social risk management.

### 3.2.2.2 The Scientific-Technological View on Risks: Risk Assessment

The two parameters

- extent and Severity of effects and
- risk or damage probability

have to be assessed and related specifically, which is varying in the different science disciplines (e.g. technical risk analysis<sup>5</sup>, toxicology<sup>6</sup>).

The methodical procedures for the scientific-technologic evaluation of risks are summarized under the term risk assessment. Objective of a risk assessment is the identification and quantitative description of the risk. Depending whether it concerns the estimation from health risks or risks of technical systems, different procedures were applied.

Within the estimation of health risks usually four steps are differentiated<sup>7</sup>:

1. Risk identification, i.e. the qualitative characterisation of the health risks of a certain substance (e.g. if it is a carcinogenic substance).
2. Quantitative description of the dose-effect-relationship, including threshold values and etc.
3. Estimation of exposition, i.e. the strength and temporal duration, with which a population is exposed to the pollutant.
4. Risk characterisation, i.e. a recapitulatory evaluation of the risk, where type and frequency of the health damage, which can be expected, is summarised.

Looking at the determination of the risks of technical plants, main focus is the statistic gathering and modelling the behaviour of the individual components of a technical system. Here procedures are used as Fault Tree or Event Tree Analysis. On this basis the failure behaviour of the overall system with the appropriate probabilities is computed. Finally then the possible exposures (for instance environmental or health damage in the neighbourhood of a technical plant) can be indicated for the specific technical failure or breakdown situation.

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5 Johannes Mertens, Risikoanalyse, in: Holger Schütz/Peter M. Wiedemann (Hrsg.), Schlüsselbegriffe der Technikbewertung, Frankfurt/M. 1993, S. 187

6 'D. Neubert, Möglichkeiten und Methoden der quantitativen Risikoabschätzung, in: Hans Marquardt/Siegfried G. Schäfer (Hrsg.), Lehrbuch der Toxikologie, Mannheim 1994

7 National Research Council, Risk assessment in the federal government: Managing the process, Washington 1983

Common to all procedures of risk assessment is the substantial role of assumptions and decisions of experts. E.g. with the identification of health exposures the risk assessment can refer only to lethal or chronic damages or also to slight indispositions.

Due to limited temporal and economic resources in most cases the emphasis is naturally on the serious exposures first.

A central problem of scientific risk assessment is the handling of uncertainties. Therefore an abundance of assumptions and decisions are necessary as well.

In many cases there is no chance to gather the necessary data directly, but they have to be estimated. So usually it cannot be measured directly, in which way a certain pollutant effect affect humans. Different subgroups could be affected over different exposition paths with different intensities within different periods. The estimations of all these aspects are interrelated to uncertainties, which must be considered during the exposition estimation.

These examples show that scientific risk assessment cannot take place without assumptions and judgment via experts. The American sociologist Allan Mazur proved for a set of risk fields that factors like gender of the expert, visited university, technical discipline and political attitude is substantially influencing the risk judgements.

Risk assessments are not arbitrary but allow however range for interpretations.

### 3.2.2.3 The view of the media on risks: Risk Journalism

Mass media regularly refer to scientific risk analyses and sources of information, but they integrate risk statements of experts in "stories", in which they

- warn and awake the public,
- expose malpractice of industry and state
- advise and inform their readers and or
- explain political procedures<sup>8</sup>.

Accordingly, the reporting of the mass media is not congruent with the risk concepts of the experts. Various Communication scientists compare<sup>9</sup> the extent of media reporting regarding a certain risk with the magnitude of this risk determined by experts. They come to the conclusion that the media attention hardly correlates with the actual degree of risk.

Therefore the presentation of risks by the media is - in the opinion of these researchers - leading to a biased public risk perception.

<sup>8</sup> Sharon Dunwoody, The Media and Public Perceptions of Risk: How journalists frame risk stories, in: Daniel W. Bromley/Kathleen Segerson (Hrsg.), The Social Response to Environmental Risk, Boston 1992

<sup>9</sup> Hans-Mathias Kepplinger, Künstliche Horizonte. Folgen, Darstellung und Akzeptanz von Technik in der Bundesrepublik, Frankfurt/M. 1989; Eleanor Singer/Phyllis Endreny, Reporting on Risk. How the Mass Media Portray Accidents, Diseases, Disasters, and Other Hazards, New York 1993; Barbara Combs/Paul Slovic, Newspaper Coverage of Causes of Death, in: Public Opinion Quarterly, 56 (1979) 4, S. 837-843 und 849

But it can be replied that mass media in our society is covering other tasks than to describe the reality as exact as possible with the eyes of an expert. Trade-off between the different tasks occurs so that each reporting can be in the optimal case only one compromise product<sup>10</sup>.

Also scientific accuracy during the representation of risks is not one of the central quality criteria of journalism. Researchers obtained<sup>11</sup> a neglect of information about risk probabilities during reporting. This means that journalists do not inform about risks itself but report only on occurred and/or expected damage. In addition they determined a high error rate when using risk studies journalistically.

Michael Haller<sup>12</sup> came to similar results in his analysis of the correctness of the reporting over the radiation risks of the Tschernobyl disaster.

Nearly always journalists place risks into a context of practical decisions. Thereby three typical perspectives can be differentiated:

1. Acting in everyday life, which is effecting directly or indirectly our health, security or the condition of our environment: smoking, fastening of seat belts, "Safer Sex" practices, nutrition, energy savings behaviour etc. These everyday life decisions are dealing with the choice between comfort, habit and consumption on the one as well as health, security and the quality of the environment on the other side. Within this media want to inform their public about the risks, in most cases they want them to warn, sometimes also to calm. The journalists let experts explain the risks and make suggestions for a lower-risk behaviour.
2. Decisions of enterprises and authorities about the implementation of new sources of risk: Power stations, chemistry factories, incineration plants, as well as gene foods etc. In these decisions there is a contrast between the advantage from e.g. the use of a technology and on the other hand the endangerment of residents of a plant or the damage of the environment. Here the question about the legitimacy of the new source of risk arises. With which arguments can be debated to justify that the environment or persons concerned may be exposed to the dangers outgoing from the plants or technologies? In this context it comes to forceful public risk controversies, which are then delivered also in the mass media.
3. Political-administrative regulation of existing risks: Permissions of technical plants, flood protection, vaccination campaigns, prohibition of risky technologies and products, protection of the consumers from BSE,

10 Hans Peter Peters, Mass Media as an Information Channel and Public Arena, in: Risk: Health, Safety Environment, 5 (1994) 3, S. 241-250.

11 Eleanor Singer/Phyllis Endreny, Reporting on Risk. How the Mass Media Portray Accidents, Diseases, Disasters, and Other Hazards, New York 1993

12 Michael Haller, Wie wissenschaftlich ist der Wissenschaftsjournalismus?, in: Publizistik, 32 (1987) 3, S. 305-319



implementation from political programs to the reduction of CO<sub>2</sub> emissions etc. Political committees or the responsible authorities reflect on (economically) the costs of the measures in these decisions for minimizing the risk considering the risks themselves. "How safe is safe enough?" is thereby the point of issue, which can also lead to intensive risk controversies like around the creation of new risk sources.

The journalistic focus is on those aspects, which is relevant for the typical media user and his judgements and decisions. In the user's considerations however the statistic height of a risk plays only a subordinated role.

Apart from the service-oriented reporting journalistic reporting is often politicizing and deals rather with the political processes regarding a risk than the risk itself.

### 3.2.2.4 The view of the laymen on risks: Risk perception

In the comparison to the scientific-technologic, quantitative risk assessments the risk perception is at the same time simpler and more comprehensive:

- Simpler because it does not rely on methodically sophisticated procedures;
- more comprehensively, because it includes still numerous "qualitative" aspects, which do not find consideration during the scientific-technologic risk assessment including above all:
  - the controllability of the risk
  - the voluntariness of risks acceptance
  - The potential of disasters
  - the estimation of the scientific level of knowledge towards a specific risk
  - individual risk
  - familiarity with the risk
  - the personal use of the source of risk
  - the distribution of benefits and risks in the society as well as
  - possible effects on future generations.

Apart from these qualitative aspects of risk also the subjective probability of damage events plays a role for the risk evaluation of laymen. However humans in the everyday life do not have usually the necessary statistic data in order to come to accurate probability and/or frequency estimates.

Laymen use heuristics, i.e. simplifying mental strategies. E.g. humans estimate the probability of events the more highly, the more easily these information is cognitive "available"<sup>13</sup>.

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<sup>13</sup> Amos Tversky/Daniel Kahneman, Availability: A heuristic for judging frequency and probability, in: Cognitive Psychology, 4 (1973), S. 207-232

So spectacular causes of death such as murder or natural catastrophes are often overrated due to the frequent reporting in the mass media. But everyday causes of death become underestimated like Asthma or cardiac infarction, which are typically rarely reported in mass media<sup>14</sup>. So the use of sources of information like the mass media, which obtain a selective picture of the world, can lead then to wrong probability estimations.

An emotionalising of risk representation can be obtained and can lead to higher risk evaluations.

### 3.2.2.5 Divergent risk concepts: Consequences for the political risk regulation

Although the media bring both sides of a risk into discussion nevertheless new and additional risks were estimated as threatening. Those are also exactly the risks, which must be treated in the context of the political-institutional risk management.

Enlarged pressure to act is the result especially if the experts come to no consistent risk assessment, because risk controversies can only develop and/or continue, if they are based on a disagreement of the experts<sup>15</sup>.

In such situations strong political decisions must replace missing scientific security. That does not mean that political decision-making would not base on scientific analysis, but a regulation cannot be justified only on a secured scientific risk analysis. Other decision criteria must be consulted.

In the discussion around the regulation of controversially estimated risks at present the application of the precautionary principle is discussed as a substantial decision making aid<sup>16</sup>.

The terror attack of the 11th September 2001 in New York showed a further problem of scientific risk assessment clear: the difficulty to anticipate new risks. Each risk assessment is in a certain way an anticipation, because statements about risks have the logical character of prognoses, since they represent expectations of future possible damage.

Such prognoses work particularly well if the past can be extrapolated easily into the future. This scientific construction rule has - retrospectively - during the estimation of the risk of mega terrorism failed completely. The authors of disaster movies submitted here substantially more realistic descriptions of risk than the scientific risk research.

That shows that experts are more reliable with the analysis of well-known risks than with the anticipation of new risks.

But of course scientific risk research is still the basis for all risk analysis. You cannot expect a statistically founded judgement about a risk neither from the media nor from the layman, but only

14 Sarah Lichtenstein u. a., Judged frequency of lethal events, in: Journal of Experimental Psychology: Human Learning and Memory, 4 (1978), S. 551-578

15 . Hans Peter Peters, Risikokonflikt/Risikokontroverse, in: Holger Schütz/Peter M. Wiedemann (Hrsg.), Technik kontrovers. Aktuelle Schlüsselbegriffe für die öffentliche Diskussion, Frankfurt/M. 1993, S. 203-208

16 Vgl. EU Commission communication on the precautionary principle: COM(2000) 1; Bull. 1/2-2000, point 1.4.60

from the experts. Everywhere, where we depend on a systematic and founded knowledge over risks, it would be fatal to rely only on the reality perception of media and laymen.

Besides the expert analysis, medial and individual risk constructs reflect social and individual values. They have an alarming effect and they produce crises in the political-administrative system and at the industry. They disturb old routines and promote a considering of usual practice. Briefly: They are quite a chance for change and innovation in handling risks.

### 3.2.3 Known Risk Benefit Considerations in Automotive Industry

#### 3.2.3.1 What has been done already

In spring 1967 the Federation of the German Automobile Industry (VDA e.V.) awarded a research project for the improvement of the safety of road vehicles to the Institute for Motor Vehicles of the Technical University of Berlin under the direction of Professor Dr. E. Fiala.

Apart from numerous technical laboratory tests also an economical investigation of the possibilities of an evaluation of safety programs within the range of the traffic were made (Niklas 1970).

The conclusions should serve the legislator as decision-making aid in the measures to be arranged.

Road accidents in the western industrial nations moved at that time already on a high level.

The legislative bodies of some states recognised the political quality of this range in those years and issued laws, which had the goal of reducing the endangerment of road users to the actually unavoidable measure.

The fight against traffic death and its causing factors was introduced, since with the beginning development of the modern traffic constantly rising accident numbers had to be registered. In the course of those decades a great number of the most different safety precautions were examined, publicised and partially carried out. From traffic instruction in schools to the installation of guardrails on the motorways, from the use of emergency surgeon helicopters to the installation of head restraints into each vehicle – there is practically no domain, where it was not tried to prevent dying on our roads.

The character of the accident prevention measures changes itself not only sequentially with the progressive motorising degree and the changing motor vehicle types, but also with the realisations achieved by the developing accident prevention research. Common to these projects was and is: Protection human life from injury and death, avoidance of material damage in the traffic.

The implementation of each of these measures causes costs (in the sense of a resources consumption) and causes benefits (in the sense of an increase of individual prosperity). The means available for an increase of the road safety are however incontestably scarce. Thus almost exemplarily that quantitative relation is given, which is the origin of economic thinking and acting: the scarceness of the means, based on the range of the needs. This limitedness of

resources forces to economise or differently said, the economic principle provides itself validity: with a given use of funds obtain the greatest possible yield and/or achieve a given yield with the lowest possible use of means.

Nine measures for safety precaution have been proposed and investigated concerning cost/benefit:

1) Standard installation of seat belts in motor vehicles.

Which benefit is derived, which costs are caused by the installation of seat belts into each motor vehicle (obligatorily prescribed by legal regulations)?

2) Standard installation of head rests in motor vehicles.

Which benefit is derived, which costs are caused by the installation of headrests into each motor vehicle (obligatorily prescribed by legal regulations)?

3) Standard installation of underrun protection devices on heavy vehicles.

Which benefit is derived, which costs are caused by the installation of underrun protection devices on all heavy vehicles and their trailers (obligatorily prescribed by legal regulations)?

4) Illumination of motorways.

Which benefits are derived, which costs are caused by installation of illumination on all German motorways?

5) Keeping free of ice, snow, and sludge of particularly endangered road sections by a road surface heating.

Which benefit is derived, which costs are caused by the installation of a road surface heating on all motorway bridges in Germany?

6) Hazard warning flashers on the motorways.

On the motorway at distances from 200 to 250 m signal posts are installed. Each of these posts carries on top a yellow signal, which can be brought to flashing in the danger case by the motorway maintenance or by motorists. These signals are brought to flashing in groups of 5 and can in this way warn approaching motorists on a distance of approx. 1 km before an accident; the signal alarm systems can draw attention also on sudden ice formation, nebula banks etc.

Which benefit is derived, which costs cause the installation of hazard warning flashers on the motorways?

7) Rescue of accident-injured by emergency surgeon helicopters.

Which benefit is derived, which costs are caused by the use of helicopters for the rapid medical supply of traffic-injured at the scene of accident as well as for their fast transfer into a hospital?

8) Emergency treatment of accident-injured by the use of emergency ambulances.

Which benefit is derived, which costs are caused by the use of emergency ambulances for the rapid medical supply of traffic-

injured at the scene of accident as well as for their fast transfer into a hospital?

9) Periodically recurring road safety training for driving licence owners.

A suggestion, which frequently returns in the discussion over measures for the lowering of accident numbers, is some periodically repeating road safety training for a specific group of road users (selected according to certain criteria).

Which benefits are derived, which costs are caused by periodically recurring road safety training for driving licence owners?

Project:	B/C <sub>G</sub>	B/C <sub>K</sub> *	B/C <sub>SEI</sub>	B/C <sub>SLI</sub>	B/C <sub>D</sub>
seat belts	1,076	8,4	73,6	205,1	-
head rests	0,041	0,3	3.5.	13.8	-
underrun protection	0,127	0,9	10,6	42,4	-
illumination of motorways	0,227	1,4	7,3	17,9	63,6
road surface heating	0,056	0,3	1,9	4,6	17,4
hazard warning flashers	1,859	9,3	82,9	205,3	729,9
helicopters	3,379	30.5	-	-	-
emergency ambulances	1,301	11.3	-	-	-
driving instruction	0,666	2,6	22,1	50,1	183.2

Figure 25: Overview of the benefit/cost factors of the analysed safety programs (Niklas 1970)<sup>17</sup>

Résumé:

A methodology was developed which makes clear the relative efficiency of realised and/or planned safety precautions. The statements, which could be met, are independent of who is the accounting site, who is the benefit receiver. Three questions were answered:

- Which possibilities exist to determine the relative efficiency of a road safety program?
- Do the results of the efficiency analyses to be accomplished make it possible to provide a ranking of the safety programs?
- Do the efficiency calculations influence the decision-making process of the legislative bodies?

In addition a concept was developed, which allows a statement over the relative efficiency of safety programs. The applied methodology relies on a number of elements of the benefit/cost concept. The practicability of the procedure (particularly regarding the given volume of data) was the centre of the considerations.

For the determination of the relative efficiency degrees of preventing measures two kinds of benefit/cost factors were formed:

<sup>17</sup> Meaning:

B/C<sub>G</sub> general benefit/cost factor,

B/C<sub>K</sub>\* special benefit/cost factor for killed persons,

B/C<sub>SEI</sub> special benefit/cost factor for seriously injured persons,

B/C<sub>SLI</sub> special benefit/cost factor for slightly injured persons,

B/C<sub>D</sub> special benefit/cost factor for damage to property events.

\*) "special" means: use of DM 1.000.000 saves 8,4 human lives.

a) The general benefit/cost factor which expresses the relationship of all monetarily detectable benefit and cost elements discounted on their present value of the analysed project;

b) The special benefit/cost factors which are determined in terms of figures referred to the monetarily expressible total costs of the project of safety yields in the damage classes killed, seriously injured, slightly injured person, and damage to property.

The starting point of the comparison, which is the basis for the determination of the special benefit/cost factors, is aligned to the safety yield of the projects and produces a statement about its structure. The instrument of the general benefit/cost factor tries to let enter all those sizes in their overall economic meaning into an efficiency number, which can be conceived with the help of the amount of money directly or by means of approximation method.

A ranking, under which road safety programs clearly can be classified according to their cost effectiveness, does not exist. The elements, which are crucial for the relative efficiency of preventing measures, can not all be quantified and be transformed problem-adequately into a rating number.

The explained procedure obtains guideline data for the decision-making process in the legislation, which is essential for the desired optimal allocation of resources.

In the analysis it was necessary to gather the facts and represent them in problem-adequate form. These guideline data require then the interpretation and the weighting of the decision maker.

In nine analyses the developed methodology was exemplarily used. The incompleteness of the volume of data available permitted only the determination of efficiency numbers with limited evidence. Nevertheless the results of the analyses for a set of safety programs made it possible to pose good-bad statements regarding their cost effectiveness. The practicability of the developed procedure was made clear. The necessity for a better volume of data is undisputed. The instrument of the benefit/cost analysis proved to be particularly suitable to make the existing information gaps clear. For the desired optimal allocation of the means, which can be made available only first reference, points could be won.

This research report (Niklas 1970) was published 33 years ago. Many of the suggested improvement measures have been introduced in the meantime and/or flowed into the legislation and worked satisfactorily. Many of these measures helped to decrease the number of the persons killed in traffic accidents in Germany from 21.000 (1970) to 7.500 (2001) in spite of the rising number of motor vehicles (1970: 21 Mio, 2001: 54 Mio).

### 3.2.3.2 Risk assessment of hazardous goods transport

#### 3.2.3.2.1 The current status of hazardous goods transport

The process towards a Code of Practice for development can be compared to processes and procedures from Public Authorities required and under development in the hazardous goods section. This section intends to give an indication of the regulation issues and trends in this area.

The movement of hazardous goods by road introduces hazardous goods into the public domain, with marking on the vehicles, clearly announcing they are 'dangerous'. Transport, particularly with large goods vehicles, and also 'Chemicals' put together two items that are negatively sensitive. The natural fear of hazardous goods increases concerns when transport and chemicals come together. This perception is not based on the few number of accidents where a chemical is involved, nor do the motoring public recognise their reliance on transport to move goods essential to their lifestyle.

What is not widely understood is how the risks are managed and that it is one of the most legislated industries covered by many aspects of quite specialised law and has a good safety record, and strong policing to check compliance.

Once the basic transport operation meets the general regulations, where the movement of hazardous goods are involved, the additional regulations place special demands on the transporting company covering the equipment to be used, documentation and markings, and also the competency and training of the people involved, all intended to make the operation safe.

Each transportation mode has its own set of regulations concerning hazardous goods. For road, the regulations are set forth in the ADR. The ADR is the common abbreviation for the United Nations Economic Commission for Europe (UNECE) European Agreement concerning the International Carriage of Dangerous Goods by Road. All EU Member States have adopted the ADR as their national legislation. Its provisions set out how producers/consignors and carriers should classify, package, label and transport dangerous goods. Also included are specific vehicle and tank requirements and various other operational requirements such as driver training.

Regulation on hazardous goods is somewhat complex and confusing and can be subject to interpretation from different control and enforcement agencies. However, efforts have been and are being made to mitigate this. Some general issues include:

- writing is often not legible,
- the documents are written only in the language of the country of origin or written in a mix of different languages,
- it is sometimes time consuming to find documents for particular goods when dealing with mixed-goods vehicles,
- there is currently no standardised and centralised approach to collect data on incidents involving the transportation of hazardous goods between and even within Member States,

- lack of standardisation between different public authority agencies and between different EU Member States creates a series of communication and organisational issues related to transferring documents or incident management

### 3.2.3.2.2 Telematic systems and dangerous goods

A number of Member States are planning to implement data collection systems, on a national level, within the next year. Electronic and language independent information could enhance incident handling considerably. The UNECE wants to add “Chapter 1.4 SECURITY PROVISIONS” to the ADR. Of particular interest is paragraph 7.2.4.2, “When appropriate and already fitted, the use of transport telemetry or other tracking methods or devices shall be used to monitor the movement of high consequence dangerous goods”. However, this paragraph has generated a lot of debate because many parties concerned feel that this will increase the amount of data that needs to be shared to levels that are not practical or feasible.

## 3.2.4 Benefits of Driving with ADAS

The determination of potential ADAS benefits is a difficult task.

One approach is the use of retrospective analysis on the basis of accident database. The problem is that an accident is a very complex event with various influencing factors. Often more than 500 parameters are used to describe an accident.

So it is hard to get precise numbers for the ADAS benefit. The following Figure 26 depicts the different approaches.

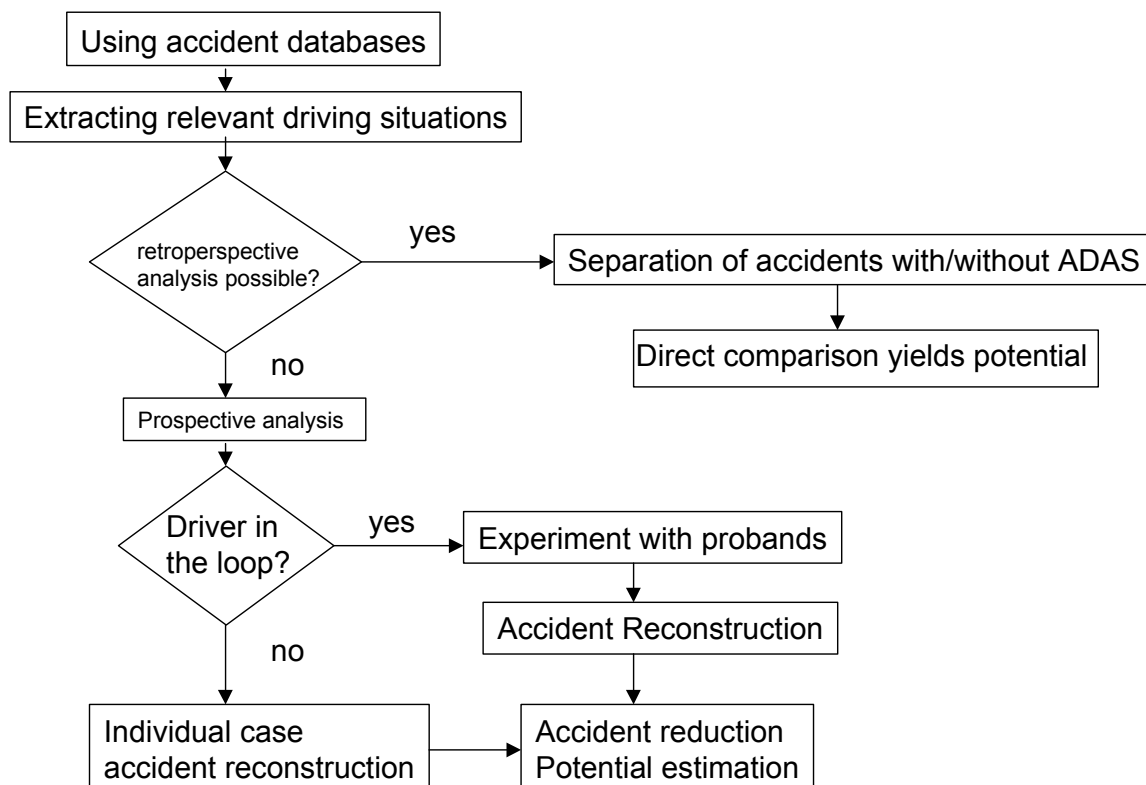


Figure 26: Procedure for assessing ADAS benefit using accident databases



Of course it is possible to wait until the retrospective analysis gets feasible (which requires enough ADAS already in the market and high quality accident data base), but a rough estimation by the use of single cause accident reconstruction and many test trials and driving simulator tests is the best what can be done at the moment.

It should be given more interest to the investigation of driver behaviour in critical situation and not only to the accident reconstruction.

As mentioned previously, Human Factors deficits are the major causal factor for traffic accidents. This does not mean that the majority of the road participants is not able to drive safely. It has to be pointed out that the human being is matchless in his ability and skilfulness to detect and interpret the driving environment and to control a vehicle in road traffic.

But the driving task (with all the corresponding subtasks) in an complex environment is demanding a high and constant human performance and is unavoidably coming along with human "errors" in perception, information processing, attention, psychomotor performance, motivation or emotion.

In which way can Advanced Driver Assistance Systems help to avoid or compensate human errors and deficits?

By means of the well known ESP-system the benefits can be pointed out exemplarily:

- The average driver shows deficits in his psycho-motor-performance regarding the lateral vehicle control.
- Especially the problem of lateral stabilisation of the vehicle while emergency braking and / or while curve driving can lead to skidding.
- Especially in low friction conditions and split friction conditions the driver performance is insufficient and ESP can give the needed support to avoid skidding and unintended lane departure.

The following chapter outlines the potential of the compensation of these driver deficits leading to a significant decrease of accidents, which can be clearly pointed out by separating accidents with and without ESP and comparing both situations in a retrospective analysis.

### **3.2.4.1 Retro Perspective Analysis of Accident Database – Example Benefits of ESP**

Although retro perspective analysis of accident data for an estimation of the potential benefit won't be applicable for most of the ADAS, it is worth to mention, how it works, if the conditions for doing so are given. Regarding the ESP-System built in Mercedes-Benz cars, we have the optimum of framework that can be found. Due to the "Elch-test", Mercedes-Benz decided to install the electronic stability program into all Mercedes-Benz cars, which has been done with the year 2000. That means, we can just compare accident data after 2000 and before with respect to the percentage of Mercedes-Benz cars involved in specific accident types. For the ESP that means primarily the driving accident, which is a

predominant accident type for passenger cars. As there was no other major change in the Mercedes-Benz cars, a possible effect can be clearly addressed to the introduction of ESP.

The following Figure 27 shows the dramatic change of the involvement of Mercedes-Benz cars in driving accidents. As in the years before 2000, there was no significance of a difference between Mercedes-Benz cars and the average of all other brands. Regardless to the brands, the percentage of driving accidents was located between 14 and 15%.

But with the introduction of ESP as a series product into all cars of Mercedes-Benz, the change becomes obvious.

Meanwhile also other brands can verify this effect by selling more products that include also an electronic stability program.

On the one hand getting such a persuading diagram is like a stroke of luck, but on the other hand it will tell us, that it will be very difficult and it will take a long time for other ADAS to reach a comparable significance.

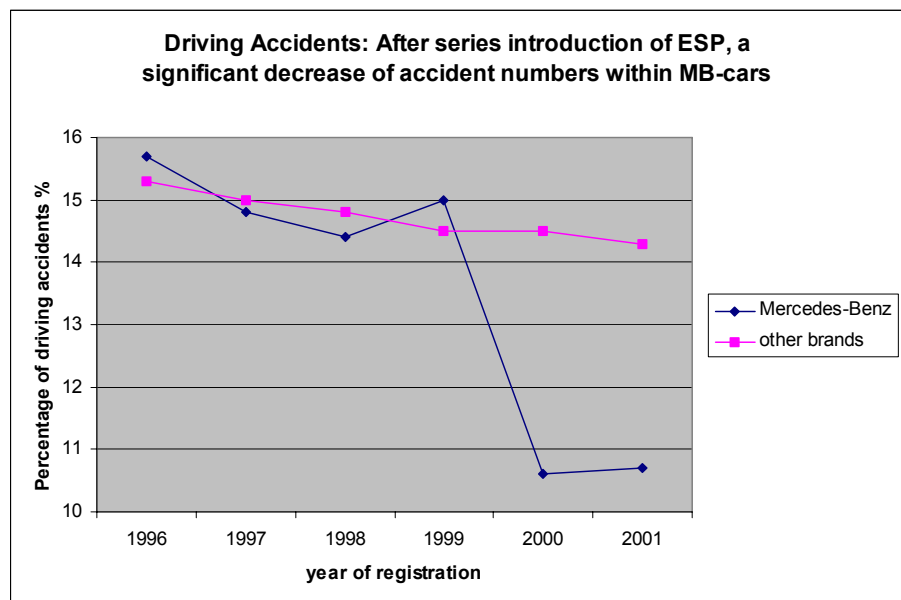


Figure 27: Effect of ESP on accident reduction

Just to summarise the most relevant factors that made it possible to get such a clear benefit representation:

- Penetration rate: There has been a management decision to equip a whole fleet (roughly 1 million cars) from a certain date on with the system
- The system effect will manifest without the driver being in the loop
- There are typical specific accident types, where the system effect can be addressed to.










### 3.2.5 Risks of ADAS – Checklist for ADAS Design

#### 3.2.5.1 System / Sensor Limits

##### 3.2.5.1.1 Long Range Systems on the Market

Current market monitoring of driver assistance systems reveals the following tendency: For the realisation of ADAS as a comfort system with recognition of the surrounding area over far distances shown on the example of adaptive cruise control (ACC), vehicle manufacturers mainly use Lidar and radar systems for this function. Many vehicle manufacturers offer ACC systems with radar sensors. The respective system suppliers offer various sensor models for the 77 GHz range. The recognition range of these sensor systems, also called dihedral angles, are specified from +/- 3° up to +/- 8°. Laser technology based Lidar systems have a similar specification for the emitting angle range.

### ACC - System Comparison

OEM	 Audi	 BMW	 Mercedes	 VW	 LEXUS	 NISSAN	 TOYOTA	 HONDA	 JAGUAR
Model Name	Audi A8 (new)	BMW 7 Series (new)	Mercedes S, CL, SL	VW Phaeton	Lexus LS430	Nissan Cima	Harrier (RX300)	Honda Accord	Jaguar XKR, XK8
Sensor sub-supplier	Bosch	Bosch	ContiTeves (ADC)	TRW	Denso	ContiTeves (ADC)	Denso	Honda elesys	Delphi
Sensor - model	Radar, 77 GHz FMCW-radar 3 - beam	Radar, 77 GHz FMCW-radar 3 - beam	Radar, 77 GHz Pulse - radar 3 - beam	Radar, 77 GHz FSK - radar 3 - beam	Lidar Scanner	Radar, 77 GHz Pulse - Radar 3 - beam	Lidar Scanner	Radar, 77 GHz 5 - beam	Radar, 77 GHz Pulse - Radar 1-beam, scan.

FMCW = Frequency Modulated Continuous Wave FSK = Frequency Shift Keying




	vehicles in the European market
	vehicles in the Japanese market
	vehicles in the US market

Figure 28: ACC system comparison date 2002

##### 3.2.5.1.2 Technical Perception

By means of the currently on the market available sensor technology, a very simplified and incomplete model for functional description of technical perception is supplied.

The following Figure 29 shows the technical “environment world” around the vehicle without sensor. A black area demonstrates this condition. This means that no information at all is available for the environment.

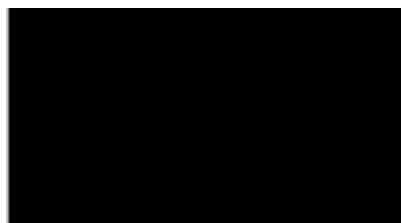


Figure 29: Environment without sensor

In order to receive information about the area surrounding the vehicle it is necessary to use the corresponding sensors.

In general, sensors may be classified according to their physical measuring principle.

Sensor technologies nowadays applied in the automotive sector mainly comprise the following:

- ultrasonic sensors
- radar sensors
- Lidar sensors
- image data processing
- infrared sensors

#### Ultrasonic sensors:

Ultrasonic sensors emit sound waves followed by the evaluation of reflected waves. From the reflection of the sound waves, the object surfaces are formed. Since the range of this sensor technology is limited to short distances up to 10 m, this sensor model is only used for park assist systems.

Compared to ultrasonic measurement, all other above mentioned sensor technologies do not have such limited operating ranges. Therefore, these systems offer a substantially higher application field, even for lateral and longitudinal assist of a vehicle.

#### Radar and Lidar Sensors

Radar as well as Lidar technologies are initially based on the reflection of electromagnetic waves. Only when the emitted electromagnetic waves are reflected on objects, the radar or Lidar sensor may evaluate them as to recognise objects.

Following, radar technology is shown in comparison to Lidar technology, and the limits of those systems are demonstrated.

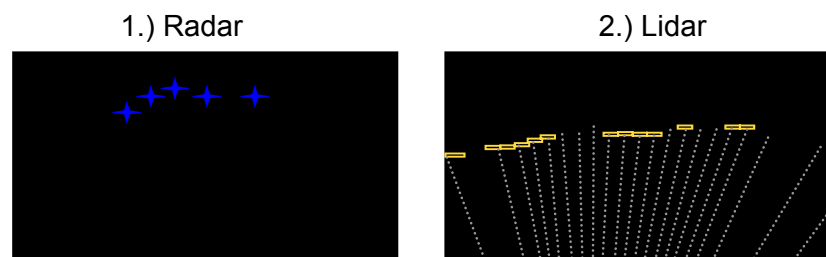


Figure 30: Radar and Lidar sightings

Each one of the coloured markings shown here is the result of an individual measurement of reflected electromagnetic waves.

Radar emits electromagnetic waves in the shape of a cudgel. Lidar emits in the shape of beams.

For both measuring principles the energy of the reflected beams is recorded by a receiver. From the distribution of the received waves the reflected energy is evaluated for the recognition of individual sightings. Based on the collected sightings, subsequently in further information processing object hypothesis are formed. Besides the distribution of the received waves, the reflected energy is evaluated for the determination of individual objects.

In radar technology, the time measuring corresponds to the distance (technical term: Doppler effect). The speed of an object is

derived from the change in position of two subsequent measurements. Always one signal is measured, i. e. a reflection maximum, which is not rigidly connected to the object, but depends strongly on the orientation of the surface of the object. Therefore, fictitious movements may result.

In Lidar however, the time measuring is used for distance information. Characteristically, Lidar measures the “time of flight” to the reflected sighting and therefore the distance. Furthermore, the angle resp. beam is determined in which the reflection is measured. Thus, the theoretical possibility exists to measure a geometry. The angle resolution is superior to the one in radar. A direct speed measurement does not exist in Lidar. Also here sightings are no object related locations. Typical sightings from a vehicle are for instance reflectors in rear lamps or edges of the body.

For angle determination differences exist between radar and Lidar regarding the multi beam systems and scanning systems. In scanning systems a focussing beam scans the angle range. In multi beam systems the angle resp. the expansion of an object is determined by the performance distribution in the various beams. A system disadvantage of Lidar technology is the limited usability at bad weather conditions. In rain or snowfall or at foggy conditions the light emitting system operates only to a limited degree.

In order to demonstrate the system limits, the marked sightings by the sensors are inserted into a real image.



Radar sightings + real image

Lidar sightings + real image

Figure 31: Radar sightings + real image & Lidar sightings + real image

The Data analysis in the radar sensor classifies sightings of same distance and speed in a defined range to a single detected sighting (Figure 83 - left). Via the Doppler effect further information can be retrieved about a change of distance of the sightings.

Recognised sightings are merged into one object if they have a certain proximity to each other and have the same relative speed as the radar sensor. This process is called object hypothesis.

Since the recognised individual sightings are not connected to a position of the real surface, it is not possible to recognise the dimension or contour of the object. This also applies to the extension of the detected individual sightings.

In the right side Figure 31, recognised sightings are shown as blue crosses. By means of overlay of an image of the real environment a comparative allocation of the received sightings is possible. The following description from left to right: The first sighting indicates a

recognised “ghost object”. Possible triggering factors could be e.g. expansion gaps, drain lids or beverage cans on the road surface. A vehicle in the oncoming traffic can be referred to the second sighting. The third sighting shows a distant object. Clearly recognisable is sighting four on the rear of a preceding vehicle. Sighting five shows the reflection of a tree on the right side of the road.

Some beam segments of the Lidar sensor (Figure 31 – right side) also receive sightings. Several sightings may be combined to one object by means of suitable movement algorithms. Via an object hypothesis the evaluated data lead to an object allocation. In the left third of the image five yellow squares are shown. Here the posts of a crash barrier on the left side were recognised as an object. In the center of the exemplar image the reflexes of the individual beams were combined. They correspond to the rear of the preceding vehicle. On the right reflecting signposts lead to an object formation.

#### Image data processing (monochrome)

By means of video technology (mono or stereo video) we receive environment information via image dots (pixels). The evaluation of the distribution of the recognised shades of grey initially leads to the determination of contour lines, which separate the objects.

For further object hypothesis it is required to determine distance and relative speed in relation to the image data sensor. Here the mono video technology shows significant differences to the stereo video technology.

In stereo video the simultaneously taken images of two cameras are compared. The object distance is calculated by means of correspondences and geometric dependencies. The object relative speed is derived from the change of the object distance.

In mono video an unambiguous back tracking is only possible under strict marginal conditions as for instance an even road. Video sensors comprise a very complex method for back tracking of object information from the images, since the required values (distance, speed) may not be taken directly from the images. Therefore, this kind of back tracking may cause errors if the assumptions they are based on are not fulfilled.

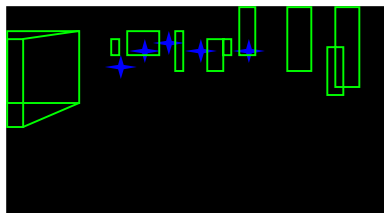


Figure 32: Radar + Video

Besides the identification of objects, a lane recognition may be performed via video technology. In the following figure the recognised radar objects (blue), evaluated video objects (green) and the lane recognition (red) are shown in combination. The image of the real environment has been inserted for comparison purposes.

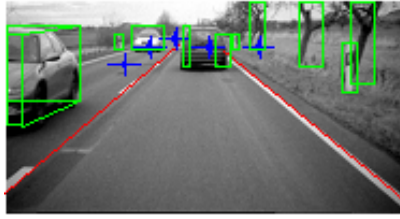


Figure 33: Radar + Video + Lane recognition + Real image

#### Infrared sensors:

The measuring principle used here is based on the evaluation of electromagnetic waves in the infrared range.

The active infrared technology emits waves in the infrared range by the sensor. These waves are reflected from objects and may therefore be evaluated again. The result is an infrared image.

In the passive infrared technology the thermal radiation that objects continually emit depending on their inherent temperature is received and recorded. This also leads to an infrared image. In contrast to proximity infrared objects with higher inherent temperature are lighter in colour than colder objects. In proximity infrared the lightness of the objects depends on the characteristics of the reflecting surface. The evaluation of the image is done by the human.

#### **Future Sensor Systems Perspectives:**

Currently, the individual sensor systems still operate isolated. For the future, developers intend a higher networking. A fusion of various sensors for environment recognition is considered the future perspective. This vision of the future supplies a consistent image of the vehicle environment by means of sensor data fusion. Also, a parallel utilisation of resources and information by several systems may improve the information. This would increase the quality of object recognition, object dimension and classification of the objects. The results would be increase in benefit of the driver assistance systems. Obstacles that have to be overcome here are sensor data evaluation and object hypothesis assumptions, in particular when contradicting evaluation results occur.

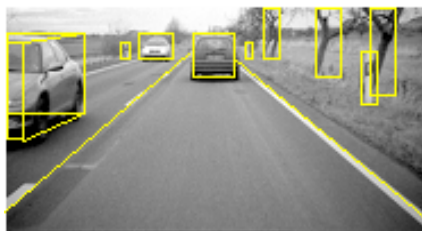


Figure 34: Sensor data fusion

However, it must be taken into consideration that such an increase in data will also result in higher complexity and more influencing parameters. Reliability statements of such systems are difficult to quantify.

A precondition for series application of such ADAS requires robust and reliable operation in the respective traffic conditions.

Unfavourable weather and lighting conditions, which often leave the systems unable to operate, must also be taken into consideration.

In spite of continual further development of computer technology the required computing efficiency is high. The required installation space for the implementation into the vehicle also must be considered.

### 3.2.5.2 Test procedures of NHTSA and ISO

NHTSA (National Highway Traffic Safety Administration) as well as ISO (International Organisation for Standardisation) have been developing first steps for specifying ADAS minimum system functions.

In the following some criteria are demonstrated on the example Collision Warning and Avoidance Systems. The demonstrated contents refer to the documents:

#### 1. DOT HS 8080 964 NHTSA Technical Report, 08/1999

Title: Development and Validation of Functional Definitions and Evaluation Procedures for Collision Warning / Avoidance Systems

In August 1999 the U.S. Department of Transportation published the DOT HS 808 964 NHTSA Technical Report. The document comprised almost 700 pages introducing requirements of Forward Collision Warning Systems. The compilation of this report was based on the number of more than 1.8 million rear-end accidents in the United States in the year 1996. This type of accident apparently involved 2.000 fatalities and 800.000 injured persons.

Amongst others, Human Factor Studies and System Operational Scenarios for checking Forward Collision Systems are shown.

#### 2. ISO 15623 International Standard, October 2002

Title: Transport information and control systems – Forward vehicle collision warning systems – Performance requirements and test procedures

Like in the NHTSA document, the ISO Standard 15623 describes requirements and test scenarios for Driver Assist Systems.

Both documents describe test situations, which mainly specify and test sensor performance. This aims at providing specifications for reproducibility of various interactions of objects and vehicles in traffic scenarios. Concerning the radar technology nowadays on the market, system limits become obvious when regarding the scenarios. Functional limits can be seen in:

Overridable objects

Stationary objects

Interaction of several vehicles

In the NHTSA as well as the ISO paper criteria are described where recognition of the system is not desired, and scenarios with



desired recognition. These scenarios maybe classified into activation scenarios and non-activation scenarios.

#### **Overridable Objects (non-activation scenario):**

In the following figure „overridable“ objects are shown in the lane. These relatively flat objects are no direct collision danger for the approaching vehicle. However, bigger and higher objects represent a relevant collision danger. For sensor systems it is technically a difficult task to differentiate between small and larger objects. The sensor technology will reach its limits in the ability to differentiate. In particular small moving objects like for instance a rolling Coke can, cannot be differentiated from other moving objects.

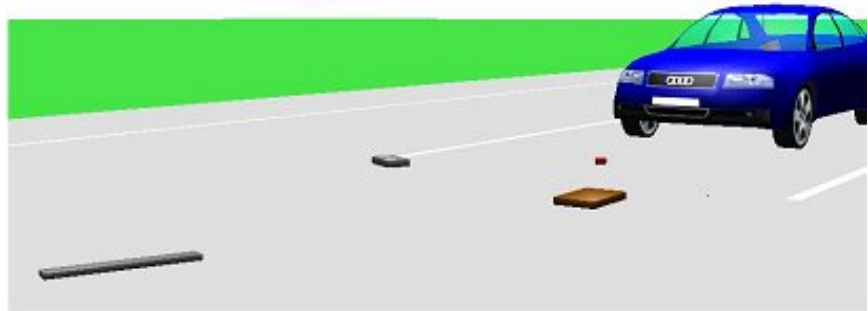


Figure 35: Scenario small objects on road

#### **Stationary objects (non-activation scenario):**

The nowadays on the market available adaptive cruise control (ACC) does not take stationary objects into consideration. However, for ADAS systems reducing accident severity it is desirable to react to stationary collision dangers. When fixed objects are to be included into the functionality, further functional limits of the sensor systems will occur. In addition to the crash relevant fixed objects, the system also detects repeatedly occurring structures at the roadside, like for instance crash barrier posts (shown in the Figure 36).

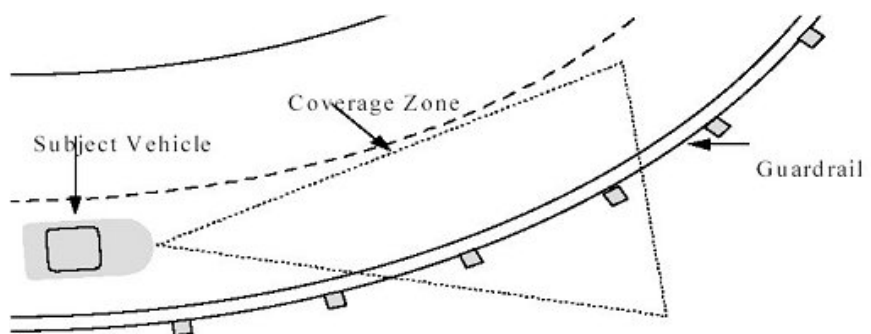


Figure 36: NHTSA roadside objects

At the same time reflection areas on the road are detected. Also here the sensor may not differentiate between regularly repeated structures or reflections and real crash relevant objects. Examples for none relevant objects are level crossings, gaps, gratings or cattle grids in the road.



Figure 37: Road grid

### Interaction of several vehicles (activation scenario)

Various interactions of objects and vehicles also represent sensor system limits. Several vehicles travelling side-by-side may not be detected as such, especially not if the objects are of a different size.

Other in the papers described scenarios cover border areas, which comprise stationary and moving objects at the same time. A further limit shows the example of a small shadow driving in front of a large shadow. This situation is likely to occur if a motorcycle follows a truck (2) (see Figure 38).

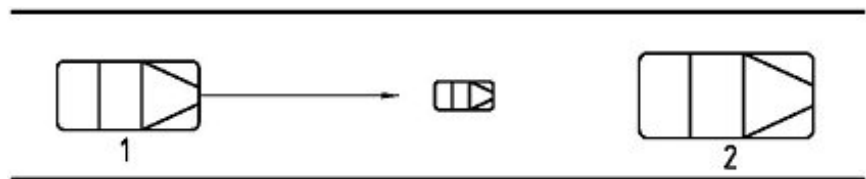


Figure 38: ISO - Small object in the reflection area of a large vehicle

Further sensor system limits are correct lane allocation of several vehicles in bends. Only the crash relevant vehicle in the respective lane should be detected and not the object on the neighbouring lane.

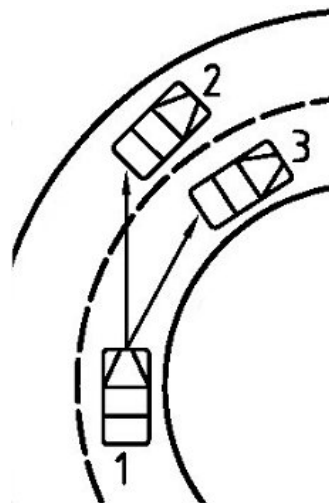


Figure 39: ISO - Course prediction and object allocation

### 3.2.6 Methods and procedures for the identification of risks and their classification

Methods and procedures for the identification of risks and their classification are well known and some are already listed in the final report to RESPONSE 1:

- Safety Checklist,
- MIL-STD-882 „System Safety Program Requirements“,
- EN 1050 “Safety of machinery; risk assessment”,
- Norme française NF F 71-011 “Installations fixes et matériel roulant ferroviaires, Informatique, Sûreté de fonctionnement des logiciels – Généralités”,
- Risk Graph DIN V 19250 „Grundlegende Sicherheitsbetrachtungen für MSR-Schutzeinrichtungen“ [1],
- IEC 61508 „Functional safety of electrical / electronic / programmable electronic safety-related systems“ [2].

The IEC 61508 itself offers four procedures for the identification and classification of risks.

As within many fields the risk graph has shown to be a method which can be handled (requirement 6), and which seems to be a basis for automotive usage, this method originating from mechanical engineering is shortly outlined here (DIN V 19250).

#### 3.2.6.1 Quantification of risk

The accurate quantification of risks and concomitantly of partial risks is often not possible, however in any case very complex and difficult. Therefore, for simplification variables (parameters) are introduced which make it possible to describe kind and range of the hazardous situation. From a multiplicity of possible parameters, which have influence on safety requirements as well as on measures, DIN V 19250 uses 4 important (risk) parameters, which permit a meaningful risk gradation and which contain most substantial aspects of evaluation.

This simplified procedure justifies itself as follows:

$$R = f \times C$$

where

R is the risk without safety-related measures;

f is the frequency of the hazardous event without safety-related measures;

C is the consequence of the hazardous event (the consequences could be related to harm associated with health and safety or harm from environmental damage).

The frequency of the hazardous event f is considered to be made up of three influencing factors:

- Frequency of, and exposure time in, the hazardous area;
- The possibility of avoiding the hazardous event;

- The probability of the hazardous event taking place without presence of a protection device.

Under the “consequences” or “extent of damage” the following criteria are regarded:

1) Kind of the legal property, which has to be protected

- Persons
- (Environment)
- (Real values or comparable)

2) Extend of the damage (with persons)

- One person
- Several persons
- Very many persons (disaster):

3) Injury severity

- Light (usually reversible) injury
- Heavy (usually irreversible) injury
- Death

From this results the parameter “extend of damage” as follows:

C1: light injury

C2: heavy, irreversible injury of one or more persons, or death of a person

C3: death of several persons

C4: catastrophic effect, very many people killed.

Under “duration of exposure” the following criterion is regarded:

Frequency of, and exposure time in, the hazardous zone:

- Rarely
- More frequently
- Very often/permanently

From this the parameter F “duration of exposure” results as follows:

F1: More rare to more frequent stay in the hazardous area.

F2: More frequent to continuing stay in the hazardous area.

Under “danger prevention” the following criteria are regarded:

1) Operation of a process

- Operation under supervision (operated by specialist/ layperson)
- Operation without supervision

2) Development/developing of the danger (temporal)

- Suddenly, fast
- Slowly

(3) Recognition of the danger

- Direct observation
- With technical aids (measuring instruments)

4) Prevention of the danger (e.g. escape possibility)

- Possible
- Limited possibility
- Not possible.

(5) Practical safety experience, e.g. with process/plant/equipment

- With same process (known process)
- With comparable processes
- None (no safety-relevant experiences are present).

From this the parameter P “prevention of hazard” results as follows:

P1: possible under certain conditions

P2: hardly possible.

Under the “probability of occurrence of the unwanted event” the following criterion is regarded:

Probability of occurrence of the unwanted event without presence of a protection device.

- Very small
- Small
- Relatively high.

From this the parameter W “probability of occurrence of the unwanted event” results as follows:

W1: Very small probability of the unwanted event means that with the process or comparable processes regarded (without presence of a protection device) only very few unwanted events are to be expected.

W2: Small probability of the unwanted event means that with the process or comparable processes regarded (without presence of a protection device) a few unwanted events are to be expected.

W3: Relatively high probability of the unwanted event means that with the process or comparable processes regarded (without presence of a protection device) more frequently unwanted events are to be expected. If with the process or the comparable processes regarded no or no sufficient experiences are present, the probability of the occurrence of the unwanted event can be measured also by computation. It is advisable here to select the parameter W in such a way due to subjective estimates that one is on the safe side.

Further possible risk parameters:

The risk parameters specified above resulted from evaluation of a multiplicity of criteria, which have a substantial influence on the estimation of a risk situation. Beyond that there can be aspects,

which justify the additional introduction of further risk parameters. An example for this is the use of new technologies in the protection devices or in the process. Such additional parameters can increase or reduce the requirements.

### 3.2.6.2 Risk graph

Each combination of risk parameters leads to a "Risk evaluation package". Due to the selected gradations 48 combinations are theoretically possible, but not all are seen to be relevant.

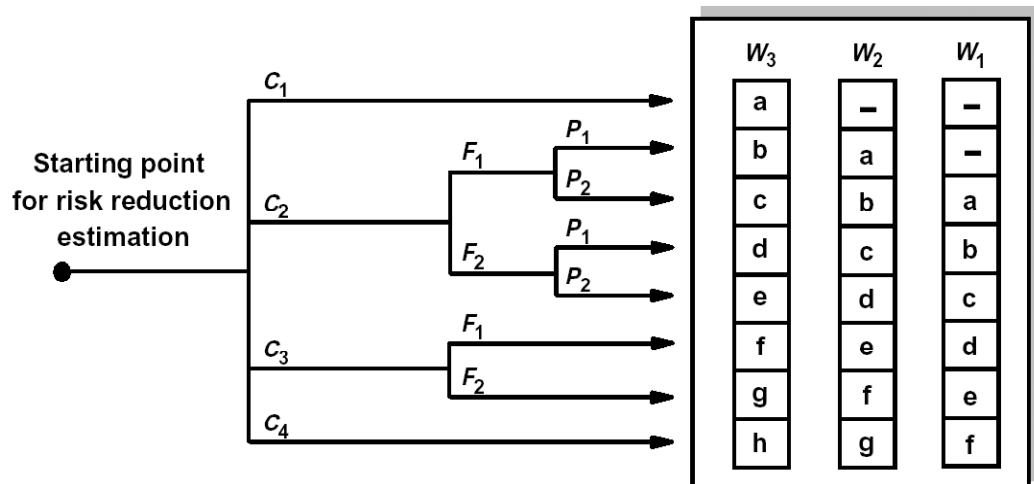


Figure 40: Risk graph and requirement classes

#### Risk parameters

- Damage extent
- $C_1$ : light injury
- $C_2$ : heavy irreversible injury of one or several persons or death of a person
- $C_3$ : Death of several persons
- $C_4$ : catastrophic effect, very many dead people
- Duration of exposure
- $F_1$ : rare to more frequent
- $F_2$ : frequent to permanent
- Danger prevention
- $P_1$ : possible under certain conditions
- $P_2$ : hardly possible
- Probability of occurrence of the unwanted event
- $W_1$ : very small
- $W_2$ : small
- $W_3$ : relatively high.

An examination on the basis of numerous examples showed that because of the dominance of certain risk parameters, clearly less than 48 combinations have a practical meaning. For the first 3 parameters C, F and P results that only 8 combinations are practically meaningful from all combinations of C, F, P. For example the practically resulting requirements for the protection device are relatively low for the risk parameter  $C_1$ , so that further gradations, which would be theoretically possible by variants of the risk parameters P and F, are practically no longer meaningful. With the higher accident effects, in particular with the risk parameter  $C_4$ ,

it results that the parameters P and in particular F play a subordinated role and do not or only insignificantly affect the requirements.

So far the remarks to DIN V 19250.

In the IEC 61508 [3] (and/or DIN EN 61508 [4]) now the above-mentioned 8 combinations and/or requirement classes are attributed exemplarily to the well-known SIL classes (Safety integrity level):

- Class a: no special safety requirements
- Class b, c: SIL1
- class d: SIL2
- class e, f: SIL3
- class g: SIL4
- class h: E/E/PES SRS not sufficient.

Application of this procedure in the automobile industry showed that parameter gradations, which worked satisfactorily in mechanical engineering, do not necessarily need to be meaningful for the automobile industry. As mentioned in IEC 61508-5, Appendix D.3, there may be applications, which have aspects that require the introduction of additional risk parameters (respectively other scaling). Therefore we suggest to introduce the following alterations:

The Boolean parameters “exposure time/frequency” and “danger prevention” prove as too rough and usually are estimated differently and not reproducibly by different persons. The parameter “exposure time/frequency” correspond to the driving situation during the respective endangerment.

The parameter “danger prevention” in the automobile field describes the possibilities, which road users have to cope with an endangerment or to moderate the effects of an endangerment. In the automobile field for this the term “Controllability” has come into use, a measure for whether and how the driver can deal with the dangerous situation. An at least three step gradation of these parameters is suggested here (Controllability e.g. 10%, 90%, 99% means that this fraction of all drivers can control the situation).

The frequency of exposure in the endangered situation requires a finer resolution in practice too. Here a three to four-level gradation is suggested (often-permanent, frequent, rare, very rare).

The parameter of Probability of occurrence showed to trigger a lot of discussions applying the Risk graph. Especially the reproducibility of risk assessments is not given looking at different evaluating persons, groups or companies. For this reason we propose to eliminate this parameter in future and to find a better solution to handle systems with operational experience which showed to be safe without any additional processes or measures.

Today's experiences show that nearly all safety-relevant vehicle systems are assigned to the demand for SIL-classes SIL2 and SIL3, also done differently by different assessors (contradicts requirement 8). In order to reach the goal of the reproducibility of

the method, we suggest inserting between SIL2 and SIL3 one more requirement class, which requires higher demands as SIL2, and smaller ones than SIL3 ("SIL2,5"). In order to exclude furthermore misunderstandings and errors, we suggest designating within the automobile field the requirement classes differently:

Requirement class A -> SIL1

requirement class B -> SIL2

requirement class C -> SIL2,5

requirement class D -> SIL3.

With definition of the map from the set of the combinations of the risk parameters C, F, P on the SIL-classes it must be respected that the boundary conditions given by DIN V 19250 and IEC 61508 hold. This will require a new risk graph, which has to be elaborated in future work.

### 3.2.7 Legal Relevance and Legal Implications of a Risk-Benefit-Analysis

The evaluation of possible methods to identify risks and benefits of ADAS shall be accompanied by an evaluation of the legal relevance of such a risk-benefit-analysis and - where it is relevant - an assessment of the possible requirements for it.

#### 3.2.7.1 Relevance of a Risk-Benefit-Analysis

Whether a risk-benefit-analysis is required/relevant under law, depends on the fields of law affected by the market introduction of ADAS. Whereas for some fields of law, a risk-benefit-analysis may be unknown, for others it may be highly relevant.

##### 3.2.7.1.1 Constitutional Rights

The mandatory introduction of ADAS by the German Legislature might affect Constitutional Rights ("Grundrechte"), such as Article 2 para. 2 phrase 1 (Right of Life and Physical Integrity) and Article 2 para. 1 (Freedom of Action) of the Constitution of the Federal Republic of Germany.

The assessment whether a Constitutional Right is affected by a law or regulation is undertaken in several steps. First, it must be assessed whether a law or regulation must be qualified as an interference with the scope of a Constitutional Right. Then, it must be investigated whether such interference can be justified depending on the type of Constitutional Right.

Some Constitutional Rights, e.g. the Right of Life and Physical Integrity, can be restricted by statutory law or other provisions on the basis of a statutory law. Even if this is the case, the statutory law or other provision must meet certain requirements, especially the principle of proportionality ("Grundsatz der Verhältnismäßigkeit"), which requires the following:

- the act or regulation must pursue a legitimate intention and must be suited to reach such intention ("Geeignetheit");
- the chosen measures to reach such intention must be appropriate ("Erforderlichkeit");



- the chosen measures must also be necessary and adequate ("Verhältnismäßigkeit im engeren Sinne"). This is especially not the case if less drastic measures are available, which would also be efficient.

In the context of admission of nuclear power stations, the BVerfG has, in a decision of 8 August 1978 (BVerfGE 49, 89 ss), established a principle applicable for the admission of new technologies in general: it has been said that the legislature is not requested to admit only such technologies for which dangers can be excluded with absolute certainty, because this would hinder technological progress to an unacceptable extent. Rather, the legislature must apply "practical rationality" ("praktische Vernunft") when deciding whether to allow for a certain technology or not.

Court decisions regarding the interference with Constitutional Rights and their justification (including the application of the principle of proportionality) in connection with vehicle equipment are rare. The German Federal Constitutional Court ("Bundesverfassungsgericht" - "BVerfG") has dealt with the issue of mandatory introduction of safety belts in a decision in 1987 (BVerfG NJW 1987, 180).

The BVerfG pointed out that safety belts reduced the risk of injuries considerably, whereas injuries were caused or aggravated only in 0.5 to 1 % of the cases. Even if such injury rate would have to be considered as an interference with the Right of Life and Physical Integrity, the Court held the view that this would be justified, because of the considerable benefits of safety belts. The clearly positive risk-benefit-analysis leads the Court to the conclusion that the mandatory introduction of safety belts was in accordance with Constitutional Rights.

In the above mentioned decision the BVerfG referred to an earlier decision by the Federal Supreme Court ("Bundesgerichtshof" - "BGH") (BGHZ 74, 25 ss) in which the BGH dealt in more detail with the risks and benefits of safety belts.

The BGH first referred to one of its previous decisions (NJW 1970, 944) where the Court had to decide whether a contributory fault of a driver for his injuries had to be accepted for not wearing a safety belt. This was denied as the BGH was not convinced that in 1965, when the accident occurred, there had been a general awareness that wearing a safety belt was necessary to avoid injuries, but rather that considerable risks were connected to its wearing. It was assumed that, based on relevant literature on this issue, in 10 to 15 % of the cases injuries were caused or aggravated by safety belts. This decision was based on the standard of safety belts at the time.

In the latter decision in 1979 the BGH changed its view and found that safety belts considerably reduced the risk of injuries. The Court relied upon medicinal and technical studies, some of which were published by the "Bundesanstalt für Straßenwesen" (BAST). Compared to the benefits, the Court was also convinced that only in rare cases, i.e. in 0.5 to 1 % of the cases, safety belts would aggravate or cause injuries. In addition it was found that injuries caused by safety belts were not severe. In light of the low risk and the high benefits connected to safety belts, the BGH therefore

found that the obligation to wear a safety belt did not constitute a disproportionate interference with the Right of Life and Physical Integrity.

Several arguments can be drawn from these decisions. Firstly, the underlying injury rates can give an exemplary view of what the Courts consider as a "positive" risk-benefit-analysis. Whereas 10 to 15 % of injuries caused by safety belts were found to be "considerable", 0.5 to 1 % were "rare cases". However, the BGH did not only consider this latter number but also the fact that even in these cases the injuries themselves were not severe. A risk-benefit-analysis should therefore not only consider injury rates, but should also focus on the severity of such injuries

Secondly, some indications regarding the quality of risks and benefits, which can be considered, might be drawn from the decision. For both, the benefits and risks of safety belts, the BVerfG only considered benefits and risks regarding life and physical integrity, which are the rights protected by Article 2 para. 2 phrase 1 of the German Constitution. The Court not only considered as a benefit the protection of the life and integrity of the driver and the co-driver, but also the fact that through the protection of a safety belt a driver might remain uninjured and therefore remains in control of the car avoiding injuries of other traffic participants. Thus, in the case of safety belts there had been various aspects of protecting life and physical integrity of the driver, passenger and other traffic participants. The same can be expected from many ADAS. Where ADAS might also have other benefits such as fuel savings, reduction of noise and pollutant emission etc., it is not excluded that such benefits may also be considered if the risks for life and physical integrity are rather low. Where the life and physical integrity of persons is endangered, benefits that are not directly linked to the protection of life and physical integrity (such as fuel savings, reduction of noise and pollutant emission etc.) might also be considered if the risks are rather low.

### **3.2.7.1.2 Rules on Admission of Vehicles to Public Road Traffic**

The rules on admission of vehicles to public road traffic must be observed in a scenario where a certain ADAS is not mandatory but can be used as an additional equipment in a vehicle. Currently, the German Regulation on the Admission of Vehicles ("Straßenverkehrszulassungsverordnung" - StVZO) does not provide for a risk-benefit-analysis to be conducted before admission of certain vehicles or vehicle equipped to public road traffic. The competent German authority ("Kraftfahrtbundesamt" - KBA) must rather assess (Section 30 para 1 StVZO) if a vehicle is manufactured and equipped so that

- 1) the ordinary operation in traffic does not damage anyone or endanger, hinder or disturb anyone more than to an inevitable extent;
- 2) occupants are protected as much as possible against injuries in case of accidents and the extent and consequences of such injuries must be as little as possible.

The most important issue regarding ADAS is under which circumstances the use of vehicles equipped with ADAS would be considered inevitably dangerous by the KBA.

#### *Traditional Assessment of Inevitable Danger*

A so-called "abstract" danger ("abstrakte Gefahr") is sufficient to deny admission. Such abstract danger is present if an ex ante assessment of certain behaviours and conditions results in the conclusion that damage is to be expected with sufficient probability. The assessment of "sufficient probability" must focus on two things:

- how likely is it that a certain damage will occur?
- what would be the extent of the potential damage?

Between these two factors, a certain interdependency exists insofar as a lower probability of a damaging event may justify the denial of admission if the potential damage is substantial. As in road traffic especially life and health of persons are at risk, i.e. legal interests of high value, the expectation of a rather low frequency of a damaging event might be sufficient to deny admission.

Sec. 30 para. 1 StVZO further stipulates that such danger must be inevitable. Dangers are only inevitable if they are common due to the nature of the vehicle and its operation. Here, the state of science and art is decisive, which shall be reflected in the building and equipment regulations, which the KBA must take into account.

#### *Risk-Benefit-Analysis in Other Fields of Law on the Admission of Products and Sites*

The above assessment of a danger in a legal sense represents a traditional model. Contrary to this, a risk-benefit-analysis may only be conducted in cases where the legislature has explicitly introduced such analysis. In Germany, a risk-benefit-analysis has been introduced in the fields of genetic engineering, use of nuclear substances, chemicals, substances for plant protection and drugs.

These fields of law are characterized by the existence of cognitive deficits that render a traditional assessment of probability of damage impossible. For example, in the field of drug use it is impossible in most cases to predict the frequency of intolerable side effects. Therefore, it is not an actually foreseeable danger but a "suspicion of danger" ("Gefahrenverdacht") that is sufficient to deny admission. The assessment of such a suspicion of danger takes place by means of a risk-benefit-analysis.

For example, in the explanatory statements of the German Government regarding the draft for a genetic engineering act, (BR-Drucksache 387/89, page 19ss) it was recognized that the opportunities of genetic engineering faced potential risks, which - to some extent - could not be excluded even if all precautions according to the state of science and art were taken.

In the view of the legislature, especially the risk of putting genetically modified organisms into circulation could not be quantified, because there had been very few precedents worldwide at the time. The various and not quite clear interactions of

organisms with the environment were also said to render a hypothetical prognosis of risks difficult.

The German Legislature has so far not introduced a risk-benefit-analysis for the field of motor vehicles especially not for ADAS. This might be an indication that the legislature currently does not take the view that a forecast of dangers is, even if difficult or expensive, impossible, for new technologies in vehicles. The legislature could, however, consider an alteration of existing laws, i.e. the introduction of a risk-benefit-analysis for ADAS if it could be shown that a forecast of dangers is impossible, i.e. that according to the state of science and art risks are not quantifiable but that on the other hand the benefits of such systems are large.

For ADAS, there are in principle two categories of risk factors. It could be argued that only for one of these factors a traditional assessment of danger is possible. The first risk factor might be the system itself, i.e. the technical functions of it. Insofar, a traditional probability approach of failure might be possible covering both random and systematic failures. However, especially for ADAS not only technical aspects must be considered but even more importantly the use of the system by human beings. Thus, "human factors" play an important role. It is said that especially the interaction between the human being and the technical system in a multitude of possible traffic situations is not deterministic.

If so, the situation might be comparable to the field of pharmaceuticals where risks, specifically side effects of pharmaceuticals cannot be fully excluded due to the individual condition of each human.

Even if the admission of ADAS might be eased through the possibilities of being granted admission on the basis of a positive risk-benefit-analysis rather than a traditional assessment of danger, this does not mean that such "easement" must also automatically apply regarding product liability.

In the field of genetic engineering, for example, the advantage for the manufacturer resulting from the fact that a positive risk-benefit-analysis is sufficient for an admission of genetically engineered products might be reversed to a certain extent. According to Sec. 37 para. 2 phrase 2 of the Genetic Engineering Act, the manufacturer of a genetically engineered product, which has been applied as a pharmaceutical for a human being may not rely on the so-called "development risk defense" (Section 1 para. 2 no. 5 German Product Liability Act) if through such pharmaceutical a human being has been killed or injured.

Thus, a product may be admitted for marketing even though it cannot be denied that certain risks are connected to it. However, if such risks "materialize", the manufacturer cannot argue that according to the state of science and art at the moment of marketing, the "defect" of the product could not have been detected. Especially for new technological products, this development risk defence often means a limited risk of product liability for the manufacturer. In the case of genetically engineered products, their admissibility might be eased through the possibility of providing a positive risk benefit-analysis to the authorities. However, the product liability risk is even higher for the

manufacturer as in certain cases he may not rely upon such "development risk defence".

On the other hand, for the field of pharmaceuticals, product liability is limited to a certain extent. According to Sec. 84 para. 1 no. 1 GPA, product liability only arises if the pharmaceutical, when used as intended by the manufacturer, shows negative effects which go beyond a dimension, which is reasonably acceptable according to the state of medicinal science. Thus, product liability is excluded if the benefits of the pharmaceutical are such that the damaging effects seem acceptable.

Whether the legislature would, in case of an introduction of a risk-benefit-analysis for the admission of ADAS, consider to intensify product liability as has been done for the field of genetic engineering, certainly depends upon whether in his view the admission of ADAS brings about risks which are only tolerable if the user is "protected" by the possibility to claim for compensation in any case of damage.

### 3.2.7.1.3 Product Liability

Product liability in Germany may be based upon two sets of rules: the general provisions on tort liability in Sec. 823 ss of the German Civil Code ("Bürgerliches Gesetzbuch" - BGB) and the specific provisions contained in the German Product Liability Act ("Produkthaftungsgesetz" - ProdHaftG).

Whereas the core matter under the provisions on tort liability is whether a manufacturer has observed the necessary "duty of care", the decisive question under the ProdHaftG is whether a product is defective. The assessment of a defective product depends on the standard applied with respect to the expectation of a "reasonable safety". Neither the BGB nor the ProdHaftG provides for a defense by the manufacturer based on a positive risk-benefit-analysis of the product in general (Kullmann, Produkthaftungsgesetz, Kommentar, 3. edition, page 113).

Other than, for example, § 402 A of the US-American Restatement (Second) of Tort, neither the German ProdHaftG nor the law of torts contains a criterion of "unreasonably dangerous", but only considers the reasonable safety expectations of the consumers. A risk-benefit-analysis can thus only be of importance, if the dangers presented in such analysis are known to and accepted by the consumer. Especially benefits are irrelevant regarding the question if a product is defective (Kullmann, loc. cit.).

A risk-benefit-analysis with regard to product liability is, as mentioned before, only known in the field of pharmaceuticals. Sec. 15 of the ProdHaftG especially stipulates that the provisions of the ProdHaftG are not applicable for pharmaceuticals, which are subject to admission or exempted from admission on the basis of a regulation. Liability may rather arise under Sec. 84 of the German Pharmaceutical Law if (1) the pharmaceutical shows detrimental effects although used as intended, (2) such detrimental effects exceed a scientifically justifiable degree and (3) such detrimental effects have their cause in the fields of development or manufacturing. Regarding (2) a risk-benefit-analysis is necessary between the benefits of a certain therapy and its risks. If the

benefits are lower than the risks, the detrimental effects are certainly not justifiable (Kullmann, Produkthaftungsrecht - Höchststrichterliche Rechtsprechung, no. 386).

However, although such risk-benefit-analysis is not relevant for the field of automotives and their equipment, a positive outcome of such analysis, i.e. an analysis that shows that no risks were present at the time of marketing, might be able to show to some extent that the manufacturer has observed his duties of care or that his product is reasonably safe. This might especially be the case where the risk-benefit-analysis mirrors the state of science and art regarding the respective product. The state of science and art plays a role for both, claims under the ProdHaftG and claims under the law of torts, although the observance of the state of science and art does not render a product "faultless" under all circumstances.

#### *Relevance of the State of Science and Art*

In order to design and manufacture a "reasonably safe" product and/or in order to comply with his "duties of care", the manufacturer must (as one requirement) observe the state of science and art. If such state of science and art does not exist, the manufacturer can be obliged to develop methods for defect analysis and risk assessment himself, especially if his product is safety relevant. The state of science and art is relevant in various aspects.

First of all, the EU-Directive 374/85/EEC of 25 July 1985, which has led to the enactment of the ProdHaftG, left the Member States with the option to provide for an exclusion of liability for those defects which, applying the state of science and art at the moment of marketing, could not have been detected (so-called "development risk defence"). Germany has implemented this option in Sec. 1 para. 2 no. 5 ProdHaftG. It is important to note that this exclusion of liability only applies if the defect could not have been detected by anybody. However, it does not apply if the defect could have been detected but could not have been controlled applying the state of science and art.

Although it had been discussed during the consultations for the above-mentioned EU-Directive to generally include into the wording that a product is not defective if it has been developed and manufactured according to the state of science and art, such general statement has not been accepted. Rather, all circumstances must be taken into account when assessing whether a product is defective. Thus, the compliance with the state of science and art can only be an indication that the product is reasonably safe (Kullmann, Produkthaftungsgesetz, page 109).

Regarding liability under the law of torts, the same applies with regard to the duties of care to be observed by the manufacturer. The manufacturer's duties are not restricted to the observance of the state of science and art, but the observance of it certainly belongs to his duties.

A risk-benefit-analysis, which shows that the manufacturer has applied all available methods for failure detection and that either no failures could have been detected or efficient countermeasures

(e.g. instruction of the user) have been taken to avoid risks, a risk-benefit-analysis could be useful in product liability litigation.

### *Burden of Proof*

The next issue is whether the manufacturer can prove in product liability litigation that he has observed the state of science and art by presenting such risk-benefit-analysis to a court. The burden of proof for the above mentioned development risk defence under the ProdHaftG, i.e. proving a certain state of science and art at the time of marketing, lies with the manufacturer. He must prove,

- which state of science and art existed at the moment of marketing
- if, considering such state of science and art, nobody could have detected the defect.

Also with regard to the argument that the manufacturer has observed his duties of care, he carries the burden of proof. Under the law of torts, the manufacturer must prove that

- the defective condition of the product did not result from a breach of duties of care and/or
- that the manufacturer did not act with fault regarding the breach of a duty of care.

Thus, the manufacturer also carries the burden of proof for the observance of the state of science and art and/or for a faultless non-observance under the law of torts.

### *Admissible Evidence*

In general, the question of whether a manufacturer has observed the state of science and art will be investigated by an appointed court expert at the request of the manufacturer. The statements of an appointed court expert regarding the state of science and art at the moment of marketing might be replaceable by presenting a risk-benefit-analysis to the court if such analysis can show that a manufacturer has observed all requirements established by the current state of science and art regarding the design, manufacturing and testing of the product and has even - where methods for testing have not been established before - developed new and appropriate methods.

The German Code of Civil Procedure ("Zivilprozessordnung" - "ZPO") is guided by the principle that only such evidence is admissible which is provided for by law ("Strengbeweis"). Next to the admissibility of expert opinions, also documents, including private documents can be presented to the court. However, the content of such documents is subject to a free evaluation of evidence ("freie Beweiswürdigung") by the court. This means that there are no fixed rules, which stipulate a certain evaluation for certain evidence. The judge is only bound by the laws of logic and nature and principles derived from experience. For example, if the court is not convinced that the analysis shows the state of science and art completely, an expert could also be appointed. The court might altogether not have the expert knowledge to actually evaluate such analysis. It is thus likely that the court would nevertheless demand the appointment of an expert, even though such risk-benefit-analysis would be presented. However, it is also

most likely that an appointed expert would take a risk-benefit-analysis into consideration when investigating the state of science and art. Thus, a positive risk-benefit-analysis, which shows that the state of science and art has been observed and that from this either no risks could have been detected or effective countermeasures have been taken, can help to support a manufacturer in a product liability litigation.

### 3.2.8 The Influence of Court Decisions regarding Product Liability on Public Opinion

The risks connected to court decisions on product liability against car manufacturers may not only be that, especially in the US, damages in a considerable amount might be imposed on car manufacturers. A more severe risk might be that a car manufacturer involved in a product liability litigation suffers from damages to corporate reputation. As regards ADAS the risk is even that not only one manufacturer might suffer from any product liability verdict by a court, but that after any incidents the public opinion in general might be influenced negatively towards the respective ADAS in general. The question, however, is what actually influences the public opinion: the court decision itself or rather the media coverage of the incidents that have lead to litigation?

In general, the public has no access to comprehensive and systematic information regarding the details of the litigation and the court decision itself and is usually not interested in the details of such verdict. It is even said that consumers do not typically become informed about verdicts, and when they do learn about a verdict, they typically do not think it conveys much new information (Garber & Adams, 1998) even found that verdicts on product liability have no measurable effect on company stock prices and on new vehicle sales.

It is rather mass media reporting of any incidents suggesting that a certain product has a defect that plays an important role in shaping public opinion. It is therefore important to look at two issues: (1) the way media reports on such issues and (2) the influence of the reporting on public opinion.

#### 3.2.8.1 Media Coverage on Product Liability Cases

It is argued by some writers that media coverage of plaintiff victories is considerably more prevalent than coverage of defendant victories and the coverage tends to focus disproportionately on trials where jury awards are larger than in average (Bailis & MacCoun, 1996).

Garber & Bower (1999) report that a search regarding product liability verdicts for the automotive industry between 1983 and 1996 added up to 259 "defendant verdicts" (no liability of a car manufacturer) and 92 "plaintiff verdicts" (liability of the car manufacturer). However, only 9 of the defendant verdicts were reported in the media, but 38 of the 92 plaintiff verdicts). Despite the outcome of a case, the plaintiffs version of events generally tends to be treated as more credible and the media often seems to be suspicious of stories that exonerate big corporations and shift



the blame for tragic mishaps to individuals making bad choices (Winter, 2001).

Thus, it can be concluded that media coverage for instances where a car manufacturer is held liable for a product defect, especially where the plaintiff is awarded punitive damages, are more likely to be discussed in media. It follows from this, that the public receives more information on such verdicts, so that public opinion is more influenced by such decisions although the number of cases where a car manufacturer is not held liable are considerably higher.

### **3.2.8.2 Influence of Media Coverage on Public Opinion**

That media coverage on cases where a car manufacturer has been held liable for a product defect, influences the public opinion, goes without saying. A further question is, however, if even such cases where it is reported that a product defect has not been present, can nevertheless lead to a negative public opinion and therefore to detrimental effects for the car manufacturer.

One prominent example of such detrimental effects even in the absence of a product defect is the Audi 5000 case that took place in the US in 1986. The initial case involved a 6-year-old, who had been killed in an accident, in which his mother had driven against the back wall of a garage with an Audi 5000. The mother claimed that the car accelerator had been suddenly stuck and that she had been unable to stop the car with the brakes. Assisted by a television report on this incident, Audi suddenly faced numerous lawsuits blaming an unidentified design defect for a sudden acceleration causing severe accidents. Although it could be proven by the National Highway Traffic Safety Administration and its counterparts in Canada and Japan that the problem was the drivers' error who were mistakenly stepping on the gas instead of the brake, Audi lost several lawsuits including one verdict in California of US \$ 3,7Mio. What is noteworthy, however, is the fact that Audi not only suffered damages from such verdicts, but also from a considerable drop of sales in 1986 although there had been no design defect detected. Under government pressure, the company ultimately even made one design modification and despite a complete vindication it took Audi 15 years to regain its sales momentum.

This case is an example to show that, even if it can be proven that a product defect is not present, media coverage on such incidents might lead to severe damage for the car manufacturer involved.

In the face of the severe economic damage that distorted media coverage can cause, the way in which companies handle such issues becomes critical. Johnson & Johnson, for instance, managed to turn the Tylenol scandal into a public relations coup. Though the company was not found to be at fault when someone added cyanide to a lot of Tylenol capsules, killing five people, it considered the mindset of its customers and made it clear it was dedicated to preventing any further tragedies by mobilizing quickly to recall the contaminated lot. As the Audi acceleration case and the Johnson & Johnson Tylenol case show, winning in the court of public opinion is at least as important as prevailing in trial.

### 3.2.9 Summary and Conclusions

Accelerated market introduction of Advanced Driver Assistance Systems (ADAS) is strongly linked to the management of risks. However, a focus has been laid on the usability of the various ADAS functions. This issue was highlighted in Deliverable D1 of the RESPONSE 2 project. An explanation of all the ADAS functionalities, which are already on the market, ready to be marketed or still under close consideration, has been included in that report. Market penetration rates of available systems demonstrate a major difference between the markets for passenger cars and for trucks. The most well-known examples of this divergence relate to the electronic stabilising program (ESP, DSC), which can now be ordered for many car makes; advanced cruise control (ACC), introduced for the first time in 1999 by Mercedes S-class; active front steering, recently introduced in the BMW 5 series; and lane departure warning system, available since 2000 for Mercedes trucks. While the electronic stabilising program and active front steering are already strong incentives for buying a car equipped with these technologies, advanced cruise control and lane departure warning systems do not often feature on the shopping lists of vehicle customers.

Two main groups of criteria must be considered in order to explain this disparity:

The fact that Mercedes introduced ESP as a standard equipment in 2000 is now reflected in accident statistics showing the major safety benefits by reducing the number of typical driving accidents. Furthermore, the ESP functionality is not difficult to explain. As a result, the safety benefit of purchasing it becomes obvious to the customer. This develops potential for the system to penetrate the market in such a way that further promotion is not necessary. On the other hand, a totally different attitude has been identified in the truck market. Safety systems for trucks will only be purchased if extra costs are not incurred on account of them in the overall price consideration, i. e. either through tax benefit, toll reduction or explicit permission to use the truck on particular transit roads etc. Therefore, the purchase of trucks installed with or without safety systems remains a purely economic calculation.

Secondly, there is a great difference between systems like ESP and ACC. It is quite easy to explain the functionality of ESP, but it is much more difficult to explain the ACC functionality due to system features and limits. For example, ESP comes into operation when needed, interaction (between the driver and vehicle) is however required in order to use ACC.

This consideration leads to two main topics that must be covered within the risk-benefit analysis. One topic covers the difference between in-vehicle sensors (i.e. measuring speed, acceleration, etc.) and environmental sensors (e.g. measuring the intensity of reflections, that have to be converted into variables by using some environmental hypothesis).

The focus of the second topic is on human machine interaction, which can manifold itself in the field of ADAS (e. g. ACC: setting headway distance, knowing the system limits to expect in order to control take-over situations etc.). The diagram shown below

explains that issue. It demonstrates a situation where a driver is faced with the system limits for the first time.

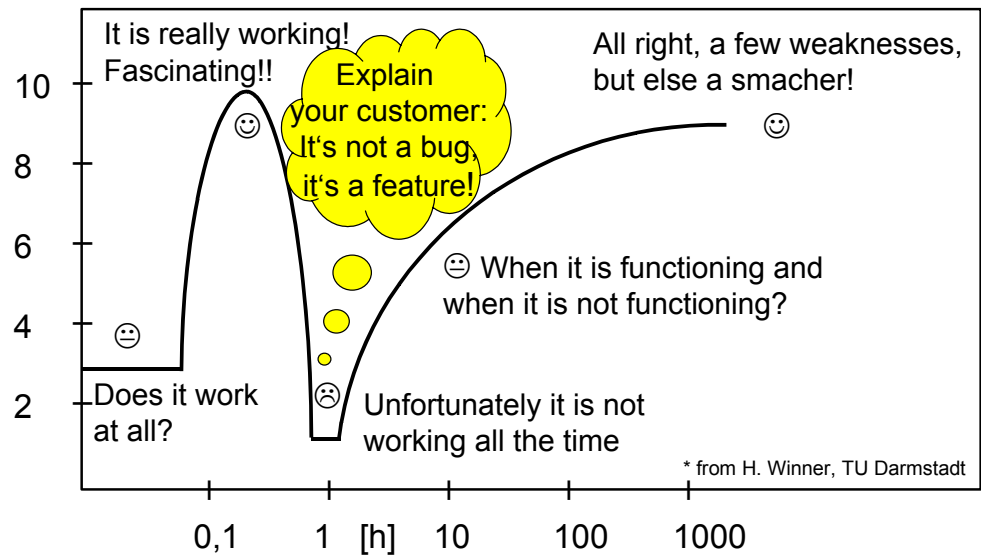


Figure 41: Satisfaction index (ACC) over time of usage

The fact that ACC has been developed as a comfort system must be taken into account as this determines the system design with respect to availability and safety. On the one hand, there is pressure for availability in order to keep customers satisfied with the system. On the other hand, the limits of the system's performance must be set in such a way, based on the physical limits, that no safety issues will arise, i.e. that the driver always has enough time to take over the control of the vehicle. At present, we do not have any indication to safety issues in this field, but we do know that acceptance of system performance is variable.

However, regarding further development of safety systems (based on environmental sensors such as radar, lidar, video etc.), different safety issues for the development and validation of relevant systems become evident.

These considerations lead to a wider interpretation of the term "Acceptability" of ADAS. The main topics are:

- **Technical Acceptability** (making complex technology safe, limits of sensor technology, **system safety**)
- **Safety of Usage** (fuzzy logic of human factors)
- **Reliability** (as a function of safety / customer benefit / cost)
- **Driving at the limits** - Overridability - Responsibility? Legal view; shift of liability to the manufacturer?
- **Risk Acceptance** - Public Opinion – Does one exist?

**Safety (Risk) Evaluation** - How safe is safe enough?

Once again, these topics lead to the missing link, namely conversion of "reasonable safety" and "duty of care" into a guideline for "safe" development and testing of ADAS. Indeed, this will determine the main content of the envisaged Code of Practice. This will provide the basis for an agreement on these development guidelines among all stakeholders as a basis for each company's

internal conversion and/or optimisation of system design specifications and complementary verification methods.

The risk-benefit analysis report focuses on the term “reasonable safety”. In retrospect, the differentiation between a micro-perspective and a macro-perspective view makes it clear that focusing on reasonable safety has been a necessary task. There are a number of different approaches to assess risks and safety issues with respect to an individual or to society as a whole. While the micro-perspective view concentrates on real risk-benefit analyses, the macro-perspective view involves a cost-benefit consideration for socio-economic evaluation. This is achieved by means of a certain amount of money to yield the best benefit for a society. In a macro-perspective evaluation, all of the resources considered are those that are linked to the safety benefit, which can be expected from a new technology. In the traffic environment, this also implies costs for time, fuel, emission, as well as costs incurred by accidents. This is not merely an extrapolation of a micro-perspective view, where the individual safety benefit constitutes the principal focus of consideration.

Regarding risk-benefit consideration for an individual driver, it is clear that, until now, there has not been an agreed procedure available for the automotive industry, nor even a common procedure for risk analysis. This can be explained by the fact that the automotive industry until recently has only had to deal with absolute hazards, that could be described without quantification of a probability of occurrence. In general, automotive technology has come to be considered as a technology without unknown side effects. In addition, most safety-relevant systems were based on mechanical and hydraulic technology with the possibility of assessing a defined safety margin for system design in the past. The failure analysis of technical failures can be considered as a cause for traffic accidents, we can state that the current status of automotive technology must be considered reasonably safe. Therefore, with all of the problems arising with respect to sensor limitations and human-machine interaction, why should we introduce a new technology that is much more difficult to assess compared to conventional automotive technology? It is the individual driver that requires support in his driving task, because the amount of human failures leading to accidents is close to 100 times higher than technical causes. The outcome of over 40,000 fatalities has been discussed, and has resulted in the Road Safety Action Plan and the e-Safety initiative of the European Commission.

It is now a societal issue, therefore, that we should develop technology to improve traffic safety. Efforts moving toward this end can be shown by the remarkable reduction of traffic accidents linked to the help of electronic stabilisation programs. But why does it seem to stagnate with all the ADAS systems that have been put forward as to offering to have a major benefit in accident reduction? ADAS will assist in relation to every task involved in manoeuvring the vehicle rather than only with stabilisation. So what are the problems that appear almost to block its market introduction?

A major concern has already been mentioned, namely the uncertainty of the risk-benefit consideration. A clear understanding of an acceptable risk that can be taken as a basis for decisions on system design is a prerequisite for a stable development process. Where do the relevant risks come from within the context of ADAS? There are the topics about safety-related failures caused by hardware (random failures and design errors) and also as to software (design errors and inadequate quality assurance). These topics have been discussed for a long time within the automotive industry and action has been taken to set up new standards on the safety of electronic systems. This will be accomplished by establishing working groups for a safety standard at an ISO level. Despite the fact that action has already been taken, however, a basic question must still be answered. What is an acceptable risk of technology that can be used as the basis to set up a corresponding safety standard for the automotive industry? Furthermore, in the field of ADAS, there is an additional need for agreement as to how to include the human factors issue into the risk considerations, as human factors are a potential source of side effects that cannot be predicted, not even by the use of the most established safety standard. Taking into account risk analysis known from other industries (also described in this report), we can see two different approaches. There are standards for all technology risk issues available, where comprehensive consideration of all risks is feasible, e.g. aviation, the railway industry, industrial process, the chemical industry and even the nuclear industry. Although it is not possible to determine how catastrophic a major failure could be, it is still plausible to establish a corresponding safety standard. In contrast, if there are side effects that cannot all be clearly assessed, we find that a Code of Practice approach has been adopted as in the pharmaceutical industry. Because a fully comprehensive risk assessment is not feasible, there is a need for an agreement of best practice to go forward. Regarding the human factors, this approach is in a way comparable to the situation of ADAS, but should be easier in the latter field, as the severity of possible side effects seems to be limited. Additionally, traffic effects can still be better controlled by other means than those used to control the effects of drugs.

So the question remains: How then to proceed? Considering the automotive industry, cars are mostly built for a worldwide market. Coming to an agreement for reasonable safety and acceptable risk requires an international collaboration. As Europe is a leader in the field of active safety systems, the code of practice could be the nucleus for the work that must be done in order to prepare such an agreement. The specific challenge is certainly connected to the fact that an accepted risk is strongly linked to the current "values" that exist within a society. Showing current mortality rates in Europe, the Figure 42 contains examples that illustrate this aspect dramatically.

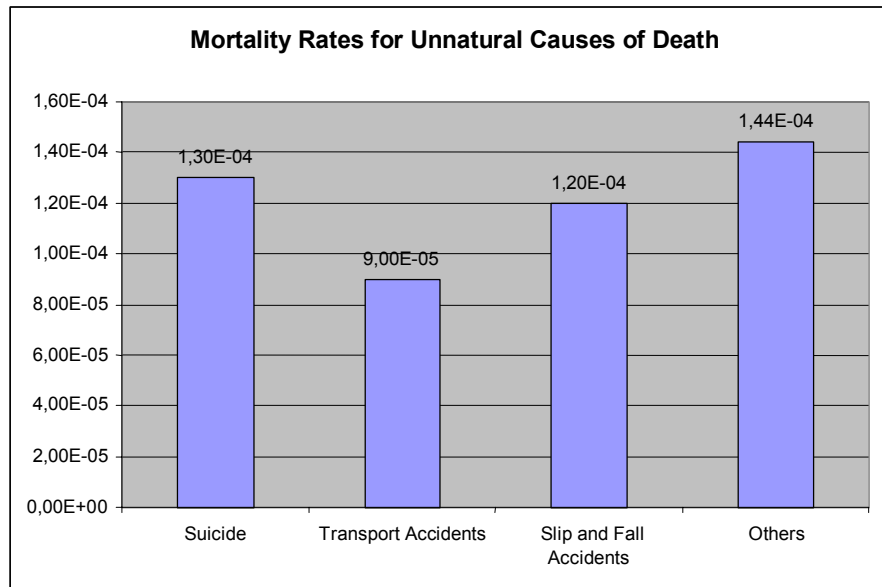
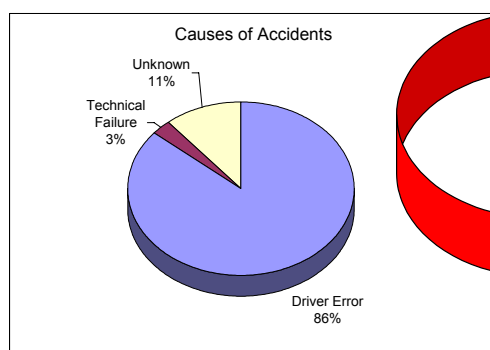


Figure 42: Mortality Rates for Main Topics of Not Natural Causes of Death

The comparison of natural causes (1 person out of 100 dies per year) and non-natural causes (1 person out of 2000), and even the comparison of the main non-natural causes (which are Highest = slip and fall accidents, Second = suicide, and Third = transport accidents) shows how difficult it is to determine the reasonable and acceptable risk level. This would be even more so if we included misuse issues like excessive consumption of tobacco and alcohol, which would, in comparison, show that the traffic safety issue as no longer in the same league. Figure 43 and Figure 44 below make that evident. A comparison with other industries like railways, where absolute risk levels do exist, shows that from a technical point of view (ETMR-technical means the European Transport Mortality Rate based on technical failures), automotive technology can be considered very sophisticated. In contrast, the bars on the chart for accidents caused by human factors are close to the acceptability limit.

$$EuropeanTrafficMortalityRate \approx \frac{40.000}{375000000} = 1,07 \cdot 10^{-4} / a$$



/a: means per year

$$ETMRate_{TechnicalFailure} \approx 5 \cdot 10^{-6} / a$$

$$ETMRate_{HumanFailure} \approx 1 \cdot 10^{-4} / a$$

Shows a typical distribution of accident causes in the last years

Figure 43: Figure: European Traffic Mortality Rate

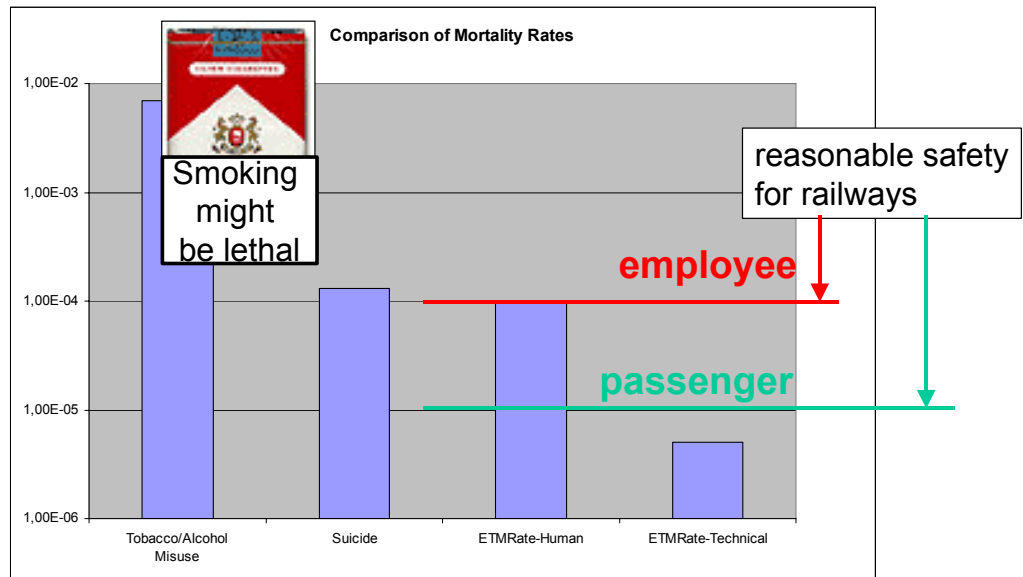


Figure 44: Comparison of Mortality Rates in the society

These figures clearly show that not the absolute value of an existing mortality rate should be discussed, but the acceptance of risk as a societal issue.

Thus, it can be concluded that the topics of discussion with respect to ADAS are on a very low risk level. Consequently, the reason why they must be discussed further is mainly associated with the emotional linkage inherent of automotive industry products. Although a major risk increase is not expected, it is necessary to find a way to discuss residual risks. This means promoting a positive public opinion concerning ADAS technology safety benefit may have a major impact on the system limit acceptance, caused by limited sensor performance.

Figure 45 shows the recognition pattern of radar and lidar sensors (top line) compared to the visible scenery (bottom line). This demonstrates the difference between human perception and sensor perception. It is difficult to explain the physical principles to customers in order to enable them to sufficiently understand the limitations of sensors.

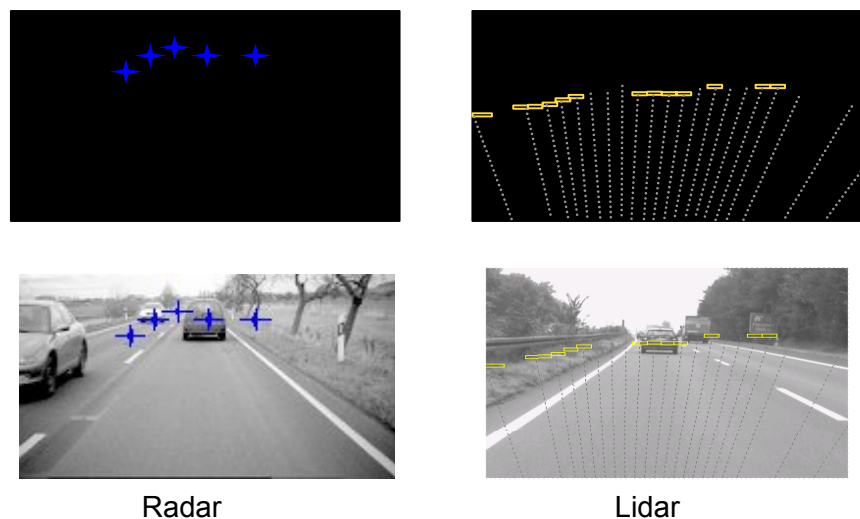


Figure 45: Environmental Sensor Capabilities

Forming a public opinion can also assist in instructing society about the limits of technology, and to gradually come to a common understanding of future technology in vehicles.

Besides the task of instructing society about the benefits of ADAS, there is still a need for agreement on an applicable procedure for a risk-benefit analysis for ADAS. This report covers relevant topics on retrospective and prospective accident analysis as a basis for potential benefits with respect to accident reduction. It also covers qualitative benefit determination for different ADAS functionalities, regarding human performance shortcomings. Many different approaches are available to achieve an evaluation of potential benefits, however, validating the underlying methods has been neglected. This is very strongly linked to the fact that there is still a significant lack of knowledge as to how to describe human factors issues.

In the field of ADAS, different interactions of system characteristics may lead to complex phenomena not easy to predict by using accurate measurement procedures. This leads to the conclusion that there is still a long way to go until a valid measurement procedure is found for all ADAS HMI issues, at present, their potential to be measured must be considered unsatisfactory. As a result, appropriate adaptation of regulations, in particular model approval with regard to HMI and human factors is hard to envisage in the near future, perhaps not even on the long term. How does this effect market introduction of ADAS? Despite the fact that the absence of regulations is usually considered as positive for the introduction of new technology, in the case of ADAS it is not only model approval, but also liability issues that may procrastinate market introduction. For ADAS a current state-of-the-art has not yet been established since we have only begun using ADAS on a broader basis. Therefore, the state-of-the-art will still be developing for some considerable time. It is always difficult for manufacturers to discuss the current state of the art if no standards or guidelines are available defining what it actually is. In this respect, a Code of Practice can also provide a big help, if it is reviewed in reasonable time frames. It can then be stated as the current state of the art. This is relevant for legal discussions that have been going on for a considerable time.

Concerning available methods of defining the benefits of ADAS, it is not possible to define specific parameters to allow a precise calculation of the risk-benefit value for a specific ADAS functionality, e. g., the introduction of system xyz will reduce fatalities by xx%. It is possible, however, to give a good description of its potential benefits. Thus, it should help to focus on the most promising ADAS functionalities, rather than on the risks involved. This means that we must focus on an agreement for risk analysis and risk assessment procedures. The requirements for the corresponding procedures have been described in the report.

To summarise, the conclusions as to the risk-benefit analysis of ADAS, which form the basis for a major part of a future Code of Practice, are:

- the automotive industry is capable of introducing high-quality active safety systems;



- examples are: ESP / DSC, brake assistant, active front steering; and
- quality can be assured by intensive test processes.

With increasing complexity, however, test processes become more and more difficult and consequently time-consuming. Therefore, there is a need for agreed procedures on:

- acceptable risk levels for different functions
- how to differentiate between a comfort and a safety system
- how to evaluate an HMI
- how to structure and carry out risk-benefit considerations
- how to perform risk analyses
- how to define safety goals
- how to specify safety requirements for ADAS with respect to
  - driver behaviour
  - system safety
  - legal requirements.

An agreement on these issues will help accelerate market introduction, but we can also clearly state that:

- The Code of Practice is not a prerequisite for market introduction, but it will help to accelerate ADAS development by -
  - helping to find a common procedure for risk evaluation (reasonable safety); and
  - considering a legal basis for ADAS (duty of care).

The discussion on a Code of Practice has also been mentioned in relation to the legal issues linked to ADAS. More explicitly, these issues are:

- Possible failures of the system can still lead to product liability as to which a code of practice is not itself a remedy.
- An agreement on risk consideration industry wide and acceptable to the public will assist in developing safe systems in terms of “reasonable safety” and “duty of care”.

### 3.3 Risk Benefit Considerations – Macroscopic Socio Economic Evaluation

The text below shortly summarises findings of the risk benefit considerations from the macroscopic perspective.

Everybody, who is interested in this socio economic evaluation, will be invited to read also the detailed studies in the **ANNEX I** of this report.

Economic evaluation of ADAS is mainly related to the interests of

- System users, which want to know if it is useful to spend money for ADAS-enhancement of vehicles.
- Transport policy, which wants to know, if traffic safety improvements by ADAS are cost-efficient because they have to justify their support.
- The OEMs, which bear financial risks, which they might can share with other groups, if all relevant benefits are considered.

The macroscopic approach proves that economic evaluation of ADAS - meeting the criteria of verifiability, efficiency of the evaluation procedure, trustworthiness, representative data, and transparency - is feasible. It is shown that economic evaluation methods are well-developed and well-defined, and cost-unit rates exist, which reflect the monetary impacts and consequences of ADAS. Furthermore, the cost unit rates are generally accepted values. With that the economic assessment of ADAS-technologies can be done on national as well as on European level; and an objective comparison of different ADAS-technologies, which enables a ranking by efficiency criteria, can be performed.

With Cost-Benefit-Analysis (CBA) and Break-Even-Analysis (BEA) two economic evaluation methods exist, which deliver information on ADAS for different stakeholders.

- The CBA is an adequate approach to prove the social desirability of ADAS and with that the general acceptance of ADAS can be enforced. Therefore, the CBA is an important tool for those who are involved in transport policy, transport planning and traffic safety issues and concerned with ADAS.
- The BEA provides information, which are relevant for the market introduction and the market success of ADAS:
  - The market introduction depends at least on the readiness and willingness of OEM to place ADAS into the market. The market introduction will take place if ADAS meets the private rentability objectives of OEM. The proof of private rentability is the key objective of the OEM related BEA.
  - Within the break-even analysis of the OEM the break-even points of ADAS-users have to be known, because they determine the possible market success for ADAS-technologies. Therefore, the OEM has self-interest to determine the break-even points for the users to get information about the reachable market demand.

- Obviously, the readiness of OEM to publish BEA-results will be relatively small. It is clear that the readiness will be the more limited the more systems will move from R&D to pre-competition stage.
- The information of the break-even points of different ADAS-user groups is important for themselves, because as an outside given information the willingness-to-buy ADAS can be strengthened. The recommendation is that results of break-even analyses for ADAS-users should be available and accessible for the public.
- Furthermore, the BEA for ADAS-users is afflicted with two serious uncertainties concerning the insurance premiums and the comfort benefits:
  - Until now the effect of ADAS-introduction on insurance premiums cannot be clearly determined. For some reasons it is possible that contrary to usual and normal market expectations ADAS could lead to an increase of insurance premiums. However, possible savings of insurance premiums represent an important decision factor for the ADAS-users. Clarity over the development of the insurance premiums due to ADAS-introduction - independent, whether insurance premiums decline or increase - is however necessary to get reliable figures on the market demand for ADAS.
  - One major black spot until now for the break-even analysis for ADAS-users is the economic assessment of comfort effects of ADAS. It is clear that comfort aspects have a decisive impact on the willingness of drivers to buy ADAS. However, the transformation of comfort benefits into monetary values is methodologically not well worked out. The recommendation is to put more effort on this topic, which should lead to a full integration of comfort benefits in the BEA of ADAS-users.

The Analysis has made clear that in the frame of the CBA the quantification of the effects of ADAS on traffic and safety plays a crucial and sensitive role for the overall efficiency. That refers to the modeling of the with-case, which defines the situation that ADAS is introduced on the market. The trustworthiness of the safety and traffic effects depends, first of all, on the workability and reliability of ADAS itself. The question is, if the expected traffic and safety effects determined by the system specification can be realized in the real-environment use of ADAS. This problem cannot be solved by the economic evaluation methods, but by the risk-benefit analysis as wider frame, where the technological aspects of ADAS are checked. Therefore, it is necessary that a methodological link between the technological-oriented risk-benefit analysis and the economical-oriented cost-benefit analysis has to be established and relevant data for both analysis tools are made available.

As mentioned above you will find the complete macroscopic socio economic evaluation of ADAS risks and benefits in ANNEX I.

## 4 Steps towards a Code of Practice for the Development and Evaluation of ADAS

It was now intended to translate the legal terms 'reasonable safety' and 'duty of care' into requirements for a Code of Practice (CoP) for the development and validation of ADAS.

The future Code of Practice shall be described regarding

- content and structure,
- processes and procedures which have to be defined and
- a clarification of the formal/ legal relevance.

### Approach to derive requirements for a Code of Practice

The idea was firstly to look at existing standards: Relevant **design and performance “standards”** which are representing the requirement of “reasonable safety” were reviewed. Also the existing **process “standards”** representing the requirement of the duty of care concept were analysed.

In a second step those elements were selected which can be adapted to a CoP for ADAS and those, which are missing in the existing “standards”.

The next step was to **derive the synthesis of content** and structure of the CoP. Design and process requirements were described.

Eventually steps towards a CoP were defined and necessary activities were outlined.

In addition the reader will find a description of the CoP scope as well as the discussion about formal requirements.

### 4.1 Scope of a future Cop

In the first place it is necessary to clarify to what kind of systems a future Cop shall be referring to.

The former RESPONSE 1 project worked with three classes of “intelligent systems” which are supporting larger parts of the driving task with a different level of automation (information systems vs. active support):

- Information on the traffic situation is evaluated by the system and leads to a suggestion or warning addressed by the system to the driver.
- Information on the traffic situation is evaluated by the system, which makes a decision on how to drive the car. The driver has the possibility of overriding that decision – technically and in practice.
- Information on the traffic situation is evaluated by the system, which makes a binding decision on how the car is driven, leaving the driver - conceptually and/or in practice – no opportunity to override that decision.

This definition was made in order to meet the requirements of a legal analysis. For the purpose of defining a CoP scope for

Advanced Driver Assistance Systems (ADAS) it is not practical and has to be redefined.

What types of systems are applicable?

The Code of Practice will be addressed towards vehicle manoeuvring systems, which are processing information from the driving environment. Both direct driver-system-interactions as well as indirect impacts on the driver will be covered by the CoP. In order to cope also all control systems the existence of a human machine interface is no explicit criterion for the application of the CoP.

So the Criteria for **ADAS definition** are

- Lateral and/ or longitudinal vehicle control and
- Environmental detection around the entire vehicle (using radar, infrared, camera, image processing or comparable technologies)

An application of the CoP beyond that to other “driver assistance systems” needs further clarification - especially to what extent the CoP is suitable.

But in the same way all in this document presented – non ADAS-specific - standards are also of relevance for ADAS systems (e.g. the EC Statement of Principles - 00/53/EC or the “Suitability” Standard - ISO 17287:2003) and have to be regarded as state of art and science, the applicability of the CoP to comparable systems shall be valid vice versa.

As long as the difficulties of various Transport Information and Control Systems (TICs) are comparable to those of ADAS systems, e.g. driver reaction in case of system failure or foreseeable misuse while operating a system, this future ADAS-related CoP will be of similar relevance for the development of these TICs. Particularly IVIS (In-Vehicle-Information-Systems) and cooperative systems (vehicle-to-infrastructure or vehicle-to-vehicle communication) will be affected and included by this focus.

Furthermore, the scope for the future CoP has to be described regarding the **development and evaluation process** of ADAS systems. For the applicability of the CoP the process shall be regarded

- Beginning with the first ADAS concept development
- Ending with begin of vehicle production (SoP - Start of production, Job one)
- Thereafter the common surveillance measures / feedback systems come into force.

Moreover the scope of the CoP shall include **traffic effects** and efficiency of ADAS usage. Especially the problem of compatibility of ADAS equipped vehicles with the existing traffic environment shall be regarded.

Finally the **regional scope** of the future CoP has to be described: Objective of the CoP is to reach global scope and not being limited to the European area. It is intended to create a guideline for

development and evaluation of ADAS for OEM and Tier1 suppliers with a global importance and relevance.

## 4.2 Formal Aspects

### 4.2.1 How does a CoP fit into the world of standards and regulations? - The legal perspective

#### 4.2.1.1 European and national legislation

Legislation concerning the area of product safety is divided into two fields of law: product safety law and product liability law. Whereas product safety law is directed towards providing means for public authorities to secure that only safe products are placed in and kept in the market, product liability law provides a direct claim of a damaged party against manufacturers and suppliers.

For both areas of law, Directives have been enacted by the European Commission in order to harmonize both fields of law within the European Union. Directives bind the Member States as to the objectives to be achieved within a certain time limit while leaving the national authorities the choice of form and means to be used. The Member States are obliged to implement the EU-Directives into their national law within a certain time to be specified within the Directive. This duty results from Art. 249 (2) and 10 of the ECT (Treaty establishing the European Community as amended by the Treaty of Amsterdam of 2 October 1997).

The European Commission can take legal action because of Treaty Infringement pursuant to Art. 226 ECT against the Member States if they fail to implement in time. Generally, as mentioned above, EU-Directives require the implementation by a national law in order to come into full force. However, in some exceptional cases certain provisions of a Directive can be directly applicable in a Member State without requiring an act of transposition.

Product safety law has firstly been regulated in the Directive 92/59/EEC of 29 June 1992 on general product safety (hereinafter "Old Product Safety Directive"). It was implemented into German law on 22 April 1997 (in the so-called "Product Safety Law" - "*Produktsicherheitsgesetz*").

Product liability law has been regulated in the Directive 85/374/EEC of 25 July 1985 on the approximation of the laws, regulations and administrative provisions of the Member States concerning liability for defective products (hereinafter "Product Liability Directive"). It was also implemented into law of the Member States within the following years, e.g. into German law on 15 December 1989 (in the so-called "Product Liability Law" - "*Produkthaftungsgesetz*").

#### 4.2.1.2 Safety levels according to the Old Product Safety Directive and the Product Liability Directive

Both, the Product Liability Directive and the Old Product Safety Directive provide for rather generic descriptions of a "safe product" which, in addition, differ from one another regarding the necessary safety level (due to the different objectives of product safety law and product liability law).

According to the product liability laws of most European Member States (with the exception of Finland, Luxembourg and Norway) product liability can be especially fended off using the so-called "development risk defence". This means that liability will not arise for defects, which could not have been detected before market introduction although considering the state of science and art. Thus, the required safety level in product liability law is defined by the state of science and art.

The Old Product Safety Directive on the other hand, lists the elements which define whether a product is safe, namely if it (1) conforms with specific Community provisions governing the safety of the product in question (European legislation) or, if such specific provisions do not exist, with (2) specific rules of national law. In absence of such specific rules the safety shall be assessed having regard to (3) national standards giving effect to a European standard, (4) Community technical specifications, (5) national standards, (6) codes of good practice in the sector concerned, (7) state of art and technology and (8) safety which consumers may reasonably expect.

Surprisingly, the "state of art and technology" is mentioned separately in the above list of elements for the assessment of safety under the Directive. Nevertheless, at least for the purpose of this Deliverable, it shall be assumed that the term "state of art and technology" is the generic term for the below listed elements. However, above all, safety is - as explicitly mentioned in the Directive - assessed with regard to Community legislation for specific products (such as ECE R13 brakes) and national laws where they exist.

It should also be mentioned that at the time the Directive was incorporated into German law through the "Product Safety Law" (*Produktsicherheitsgesetz*) instead of using this term provided for by the Directive, the Product Safety Law instead used the term "technical rules" (*Technische Regeln*).

It has been argued by some legal writers that by using this term the German legislator has not provided for a security level that has been requested by the European legislator in the Old Product Safety Directive. However, the term "technical rules" has only been used by the German legislator in order to ensure that a term well established in the German law and therefore known in his meaning is used, not in order to create a security level deviant from the security level provided for by the Old Product Safety Directive.

The term "code of good practice" thus has already been used in the Old Product Safety Directive but, however, did not appear, for example, in the German Product Safety Law. At least for the automotive sector, such code of practice is currently not known. Therefore, in product safety law, codes of good practice have so far not played a major role in defining the state of art and technology.

Below it shall be outlined which "elements" at present form part of the different safety levels "technical rules", "state of the art and technology" and "state of science and art" and how those elements are defined.

#### 4.2.1.2.1 Technical rules

Definition: An instruction to resolve a plurality of cases in the field of engineering, which is accepted among skilled persons in the relevant specialist area. Accepted means that the technical rule is known to the skilled persons and is used by them convinced that the rule is right, i.e. proven and tested.

This means that the technology concerned must already be realized in the overall practice of manufacturers to form a technical rule. Technical rules must not be necessarily written down. They can also exist as a common understanding between the skilled persons in the respective technical field.

The application of technical rules by any manufacturer is voluntary which means that the manufacturers can apply alternative procedures or technologies as long as they prove to be just as safe.

#### 4.2.1.2.2 State of the art and technology

Definition: State of the art and technology is the leading level of development, as of a device, technique, or scientific field, achieved at a particular time, which can actually be used in a production process. It has to be affordable meaning it can be realised if not by all at least by leading producers.

This can describe a higher level than the technical rules as the state of art and technology is orientated on progressive techniques, i.e. such techniques, which are at the step of technical evolution.

The state of art and technology can especially include international, European and national standards and recommendations from the European Commission. These terms need further explanation, too.

#### Standards

Definition: Standardization is the systematic unification of material and immaterial subjects among interested insiders for public benefit.

It must be distinguished between national, European and international standards. German standards are, for example, created by the DIN Deutsches Institut für Normung e.V., a non-public organization (within DIN, FAKRA is the body responsible for standardization in the field of automotives and is part of the VDA, VDE/DKE is the body responsible for drafting standards in the field of electronics and information technology). European standards are created by the CEN/CENELEC (European Committee for Standardization/European Committee for Electrotechnical Standardization) also a non-public organization to which the national standards institutes are members. European standards serve a voluntary technical harmonization in Europe and the creation of standards can be requested by any national standards institute. The competent authority for international standardization is the ISO (International Organization for Standardization) to which again the national standards institutes are members (whereby the IEC, International Electrotechnical Commission and SAC,



Semiconductor Assembly Council are specialized bodies for specific technology areas).

The application of a standard, whether it is national, European or international is voluntary even where such standard is specifically mentioned as safety standard in certain product safety laws. However, the application can create the presumption that a product is not defective and/or the manufacturer has observed the necessary duty of care. Through this assumption, a standard might be - despite being not legally binding - factually binding. The standards relevant for the area of driver assistance systems will be discussed in more detail below.

#### *Recommendation/Statement of Principles*

According to Article 249 of the Treaty establishing the European Community, the European Parliament, Council and Commission may, next to enacting binding regulations and issue directives, also act in the form of making recommendations. Such recommendations are not legally binding but aim at advising a certain behaviour. However, the effects of such recommendations can be manifold, e.g. some recommendations might have to be considered by national courts if they can attribute to the interpretation of national laws enacted in consideration of the recommendations.

One example of such recommendation is the "statement of principles on the design of human-machine-interfaces for in-vehicle-information" (Commission Recommendation of 21 December 1999 on safe and efficient in-vehicle information and communication systems in Official Journal of the European Communities L 19/64 ss, 25 January 2000) summarizing what are - in the view of the Commission - the essential safety aspects to be taken into account for such systems. In this recommendation it is explicitly said that the industry "should comply" with the principles set out and "is invited to enter into a voluntary agreement" on them.

#### *Technical Reports*

Next to issuing standards the ISO, for example, also delivers so-called "Technical Reports" (e.g. ISO/TR 15497 - Development Guidelines for vehicle based software). According to ISO, such Technical Reports are issued in exceptional circumstances, when a technical committee has collected data of a different kind from that which is normally published as an International Standard. Such Technical Report can be decided upon in a less formal procedure than an International Standard and is, according to ISO, "entirely informative in nature and does not have to be reviewed until the data it provides are considered to be no longer valid or useful".

#### *Guidelines of Interest Groups*

Last but not least many interest groups in the area of automotive, such as VDA, VDE and MISRA, issue guidelines dealing with many aspects of system design and process design. For example, the VDA has issued many guidelines on quality management, which are considered to be "industry standards".

#### 4.2.1.2.3 State of science and art

Definition: The best available technology independent of being well proven or affordable, although it has to be assured to some extent.

In addition to the elements described above, the state of science and art includes in particular the knowledge from national and international publications, which describe technological developments, which might not have been implemented yet. Each responsible engineer within a company must be informed about any current developments in his respective area at least through an analysis of publications in the most important developed countries and such countries which carry out intensive research in the field of driver assistance systems.

Furthermore, developments presented in expert workshops, developments made within scientific organisations and developments implemented by a competitor may form part of the state of science and art.

Not only is it important to analyse such developments in the same technical domain, but also to review comparable applications in other, related technical domains.

#### 4.2.1.3 Legislative developments

The Old Product Safety Directive has been replaced by the Directive 2001/95/EEC (hereinafter "the New Product Safety Directive"), which had to be implemented by the Member States until 15 January 2004.

It shall be analysed below whether through this European legislation the definition of "product safety" might have changed.

The New Product Safety Directive is based on the general concept of the so-called "new approach". According to the "old approach" legislative harmonization of safety aspects for specific products was tried to be achieved with very detailed technical descriptions in order to achieve safety. However, this principle was broadly criticized as being clumsy, inflexible, obsolescent and technically error-prone.

Directive 73/23/EEC on Low Voltage Electrical Equipment served as a role model for the "new approach". This directive heralded a farewell from a detailed regulation of safety requirements for certain products and introduced a goal-oriented and abstract description of the desired security level to be achieved. Already in this directive 73/23/EEC standards created by Standards Institutes were included into the overall safety concept. Art. 5 (1) of the directive stated that electrical equipment, which complies with harmonized standards, shall be regarded by the competent administrative authorities as complying with the provisions of Art. 2, for the purpose of placing on the market and free movement.

This meant that the compliance with standards remained voluntary. However, the conformity of a product with the standard lead to the assumption that the safety requirements of the directive were met.

The New Product Safety Directive follows this concept. However, the assessment of safety is quite similar to the Old Product Safety Directive: it is assumed that a product is safe if it conforms (1) with specific safety requirements that are set out by community legislation for specific products (European legislation) or, if such specific provisions do not exist, (2) with national laws. It is further assumed that in the absence of such laws, a product is safe if it conforms with (3) national standards incorporating European standards. It goes on to prescribe that if such standards do not exist, safety will be assessed considering especially one or more of the following elements:

- National Standards
- Recommendations of the Commission setting guidelines on product safety assessment
- Product safety codes of good practice in force in the sector concerned
- The state of the art and technology
- Reasonable consumer expectations concerning safety.

Again, the Directive itself does not give any definition of such a code of practice, i.e. whether this can be a voluntary agreement between various members of a certain industry or rather between public bodies or similar. As in some industries such codes of practice already exist (for example, in the pharmaceutical industry) as agreements between industry parties, there is reason to believe that this is also covered by the mention of such codes in the New Product Safety Directive.

This might lead to the conclusion that codes of good practice agreed upon between various industry members could contribute to the definition of the state of art and technology in the respective field of technology. At least this seems to be true from a European perspective. However, it must be awaited whether this is implemented into the national laws and how courts would interpret such a "code of practice".

## 4.2.2 Design, Performance and Process Standards

### 4.2.2.1 Types of standards

There are three types of standard or procedure, which can be employed for the evaluation of HMI (Parkes, 1995). They are:

- (1) Product or design standards. These take the form of specifying the physical aspects of the system, for example a minimum screen size or a particular layout of the control buttons. They are easy for the designer to follow, but they suffer from the drawback that they are technology-dependent and therefore tend to stifle innovation. They also do not guarantee the usability of the entire system or the safety of driving while using the system.
- (2) Procedural standards. These take the form of prescribing a programme of analysis and testing to be used in product development. They generally require an inspection or certification authority to enforce their use; they often require

extensive documentation; and they can be laborious to apply. In the case of HMI, they will not guarantee safe performance, but of course they can protect the system manufacturer who can show that rules, regulations and advice were followed in the system design process.

- (3) **Performance standards.** These specify a minimum level of task performance, which must be met while the system is being used. They might specify this level for the primary task of driving or for the secondary task of interacting with the in-vehicle system. Such standards are technology independent and do not limit innovation. If they incorporate an assessment of performance in the primary task of driving, they can provide an objective assessment of whether a minimum level of safety is met. However, they require research effort for their development and validation, and in actual use they may require testing by a particular test house or with specific equipment.

In the area of HMI, the primary focus in the last ten years at a European and also national level has been on the development of procedural guidelines and (pre)-standards.

### 4.2.3 Formal Characteristics of a CoP

Codes of Practice can be designed in many ways. There are no fixed formal rules for designing Codes.

The form should regard the aims and the relevance of the future Code as well as the target audience, which should be addressed. They can be very elaborate and expensive to set up or loose and informal or somewhere in the middle (see Figure 46).

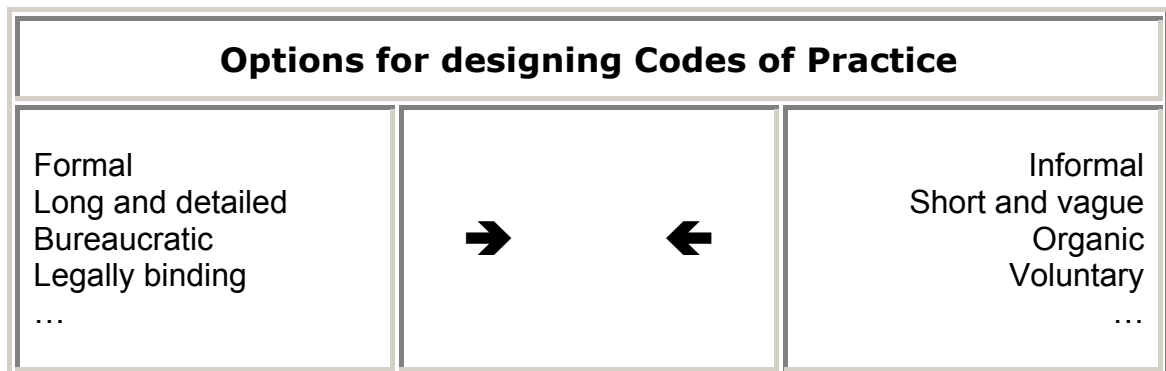


Figure 46: Options for designing Codes of Practice (Catalyst, 2002)

A generally approved Code of Practice should:

- be designed to provide practical guidance on achieving optimised system design and development
- be developed by representatives of manufacturers and science, legal bodies etc ...
- be agreed by stakeholders
- contain an application or 'scope' clause that clearly outlines the limits of the code

- be written clearly in plain English, without ambiguity, defining the terms used
- be relevant and up to date
- in most cases, be specific to an industry or sector
- be visual and practical
- be user-friendly in terms of
  - choice of words, writing style, language used and the format
  - information presentation e.g. the document should be broken up with visuals like diagrams, photographs and illustrations
  - brevity to produce a code that will be used to provide practical guidance
- be one cohesive document
- contain the following features (MCA 2000):
  - **a statement of purpose** or mission statement provides a clear and brief summary of the reason why the code is needed and what the operation of the code is intended to achieve.
  - the **objectives** of the code expand on the statement of purpose and describe specifically what the code is intended to achieve.
  - the **principles** set down the basic values, which the industry will apply to meet the intentions expressed in the statement of purpose and objectives.
  - **rules** apply the principles and spell out the specific actions and procedures required of industry members to ensure that the intentions expressed in the statement of purpose and objectives are achieved.
  - the **administration system** in the code ensures that the code will continue to operate as intended over a long period of time, will be publicised continuously, the operation of the code will be monitored continuously, reviewed regularly and updated if necessary.

#### 4.2.4 Synthesis of Formal Requirements

In order to meet the objectives and the defined scope of a future guideline for the development and evaluation of ADAS within the project of RESPONSE 2, the formal character of this guideline was already planned:

It was intended to create a Code of Practice, which means to establish “principles” for the development and evaluation of ADAS on a voluntary basis, as a result of a common agreement between all involved partners and stakeholders, mainly initiated by ADAS manufacturers.

Due to the fact that a lot of new regulations, standards and rules came into force recently or will be published in the near future, it became necessary to analyse and review these extensively. It had to be proven how far guidance is already given by other rules, standards and regulations and if a Code of Practice for development and evaluation of ADAS is still of relevance. This included the question if the formal role of a CoP is still appropriate.

From the legal perspective a formal order of stability of “elements” which are defining state of the art and science can be differentiated as following (see Figure 47 and also chapter 4.2.1). According to that Figure 47 Legislation (No 1 level) and Regulations (No 2) have the strongest implications but are not reflecting state of the art or science

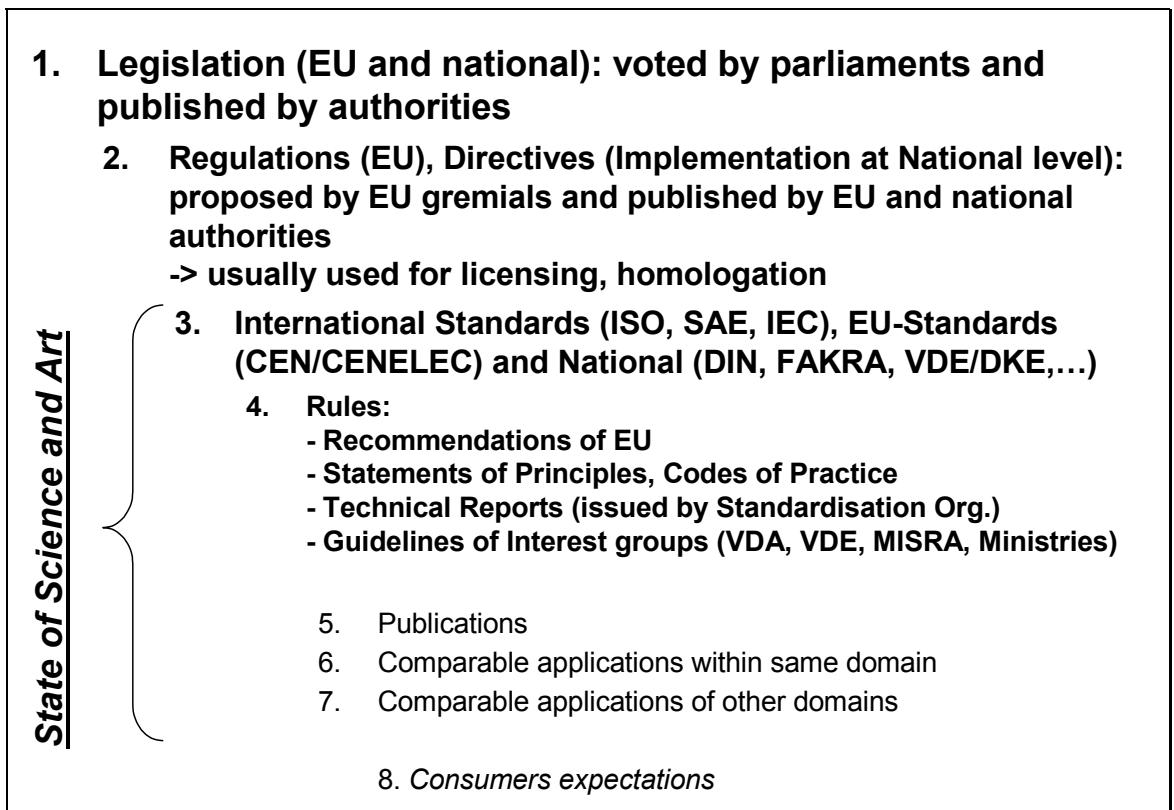


Figure 47: Overview: formal order of stability of “elements” defining state of the art and science

One example may explain what is meant by being on the “state of the art” level:

- The German legislation requires in the StVZO for the Homologation (No 2 level) of motor vehicles a deceleration capacity of  $2,5\text{m/s}^2$ . Modern motor vehicles (according to “state of the art”) are capable to brake more than three times better.

Standards (No 3) and Rules (No 4) will be consulted if Legislation and Regulations cannot give information about a specific issue.

Then you look at the publications (5) in scientific literature. If not you have to find information about comparable applications (No 6 & 7). If not available, customer expectations are the decisive source of information.

It could be derived that a Code of Practice would be the suitable framework to meet the purposes of the intended RESPONSE guideline

- reflecting state of the art and science
- reaching the intended relevance
- reflecting the voluntary approach initiated by OEMs and Tier1 suppliers.

Moreover a Code of Practice can cover both design and process requirements and can act as a practical and specific guideline for the development and evaluation of “safety-optimised” ADAS within the requirements of all other existing standards and regulations.

Formal requirements for a generally approved Code of Practice should be:

- to provide practical guidance on achieving optimised system design and development
- agreed by stakeholders
- containing an application or ‘scope’ clause that clearly outlines the limits of the code
- containing clear definitions for terms
- user-friendly in terms of
  - choice of words, writing style, language used and the format
  - information presentation e.g. the document should be broken up with visuals like diagrams, photographs and illustrations
  - brevity to produce a code that will be used to provide practical guidance
- one cohesive document
- containing
  - a statement of purpose or mission statement
  - objectives
  - principles
  - rules
  - an administration system.

### 4.3 "Reasonable Safety": Design and Performance Aspects

The expression "Reasonable Safety" is originally a legal term described in the European Product Liability Act defining a "defective product".

- Generally, the manufacturer must take all “necessary” and “reasonable” measures to avoid the danger caused by use of his product.

The following existing automotive and non-automotive standards, rules and guidelines were analysed in order to identify the relevant design and performance elements for the development of ADAS.

- Technical Papers regarding Brake and Steering
- ISO Ergonomic aspects of transport information and control systems 15005 - 15008 Standards
- Advanced Driver Assistance Systems – ISO Standards
- Standards for Software Ergonomics, Interface Design & Usability
- European HMI Statement of Principles
- AAM Guidelines
- MISRA Development Guidelines for Vehicle Based Software
- IEC 61508 Functional Safety of Electrical/Electronic/Programmable Electronic Safety-Related Systems
- ISO Standard “Safety of Machinery”

#### 4.3.1 Relevant Aspects/Elements of existing design “standards“ for ADAS concerning the development of a CoP

In the previous work those design and performance “standards” were identified, which were relevant for the development and evaluation of ADAS to a certain extent. It could be observed that not only automotive standards but also non-automotive standards (e.g. Dialog Principles, Safety of Machinery) contains relevant elements.

But also it has become obvious that some “standards” include elements, which are too application specific (e.g. ISO 9241 for Office Work with Video Display Terminals) and some others were very general, sometimes too general.

So all relevant design requirements that shall be addressed in the CoP were “filtered” and also those, who are missing, were identified.

By looking for useful and adaptable design requirements that fit into the world of ADAS, it is getting clear that the missing parts can be found rather in the design of functionality (what the user is perceiving, Human Factors Aspects of ADAS) than in the design of the function (technical realization and implementation of the functionality).

So in the context of a CoP for ADAS development and evaluation the concept of "Reasonable Safety" is affecting mainly the design of system functionality and its corresponding Human Factors aspects & elements.

Due to the fact that Human Factors Science combines various psychological, physiological and engineering aspects, some of the following relevant aspects/elements are

- more or less related to each other,
- on different levels of abstractness or
- focussing on different qualities.



Also the previously described standards use different Human Factors constructs and items corresponding to their different objectives and approaches. As an example the definitions of usability in the ISO 9241-11(1998) and the ISO 9126-1 (2000) can be contrasted.

<b>How usability is defined: Items in two different usability constructs (Öörni 2003)</b>	
<p><b>ISO 9241-11(1998)</b></p> <ul style="list-style-type: none"> <li>- Effectiveness</li> <li>- Efficiency</li> <li>- Satisfaction</li> </ul> <p>"The extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use."</p>	<p><b>ISO 9126-1 (2000)</b></p> <ul style="list-style-type: none"> <li>- Understandability</li> <li>- Learnability</li> <li>- Operability</li> <li>- Attractiveness</li> </ul> <p>"The capability of the software product to be understood, learned, used and attractive to the user, when used under specified conditions."</p>

Figure 48: Example of different Human Factors constructs and items used in ISO standards

In the following those ADAS design aspects are listed which are filtered from existing automotive and non-automotive standards and those elements, which are missing. An exact taxonomy as well as a clear distinction between all aspects will be part of the future RESPONSE3 project work.

CoP should address the following ADAS design aspects:

- **Suitability**

- ISO 17287:2003 focuses on:
  - interference (with the driving task),
  - controllability,
  - efficiency and
  - ease of use while learning about the system
- ISO 9241 distinguish between
  - suitability for the task
  - suitability for individualisation
  - suitability for learning

- **Self-descriptiveness**

- ISO 9241 dialogue principles (Part 10)
- ISO 15005: 2002
  - example of recommendation: It should be made obvious for the driver which input is required to reach the intended goal

- **Conformity with expectations**
  - ISO 9241 dialogue principles (Part 10)
  - ISO 15005: 2002
    - example of recommendation: Displays and controls should have content and style suitable for inducing understanding and appropriate reaction by the driver
- **Error tolerance**
  - ISO 9241 Software Dialogue Principles (Part 10)
  - ISO 15005: 2002
    - example of recommendation: When the Transport Information and Control System (TICS) is able to assess the likelihood of incorrect user input considering the present circumstances, it should request driver confirmation when there is an apparent deviation between input and circumstances
- **Robustness of system functionality**
  - ISO 12100 Standard “Safety of Machinery”
  - Robustness against misuse caused by slips<sup>18</sup> and errors
    - against incorrect inputs
    - against predictable misuse / erroneous behaviour as a consequence of inattention and lack of concentration (Slips - Right intention is incorrectly carried out)
    - against predictable misuse of specific user groups / risk groups
    - against misuse caused by relearning and familiarization
    - against reflex behaviour in case of a system failure (Avoiding inconsistency between reflex and operation requirement)
- **Controllability**
  - ISO 15005: 2002
    - example of requirement: The driver shall be able to terminate a dialogue at any step during an interaction and return to a proscribed state unless the dialogue is legally required or considered mandatory by the manufacturer
  - ISO 9241 dialogue principles (Part 10)

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<sup>18</sup> An error caused by an act where the intention was correct but the actual action was wrong.

- MISRA Development Guidelines for Vehicle Based Software
- **Predictability**
  - RESPONSE 1 Checklist
  - Predictability as a principle of learnability in common usability literature / guidelines
    - determining the effect of future actions based on past interaction history
- **Consistency**
  - RESPONSE 1 Checklist
  - Consistency as a principle of learnability in common usability literature / guidelines
    - likeness in input/output behaviour arising from similar situations or task objectives
- **Transparency**
  - Transparency as of common software design philosophy in literature / guidelines
  - Transparency for users of interactive systems to be able to create a mental model
  - Important especially regarding system status (on/off) and the mode of operation
- **Scalability**
  - e.g. brightness of displays, adjustable ACC headway control
- **Learnability**
  - ISO/IEC 9126
  - the degree to which an ADAS functionality and interface can be learned quickly and effectively.
  - the ease with which new users can begin effective interaction and achieve maximal performance
  - ease of use while learning about the system
- **Pace of interaction / Interruptibility**
  - EC-Statement of Principles
    - Pace of interaction refers to the rate at which the driver makes an input at any step of a sequence in the time allotted by the system to the driver for making such an input, as well as to the time during which outputs are displayed by the system before being automatically cancelled or deleted after a time-out period.
- **Comprehensibility, understandability**

- ISO 9241-11
- ISO/IEC 9126-1
- ADAS related importance towards functions, limits, operation, interface and user manual
- **Effectiveness**
  - ISO 9241-11
  - European statement of principles on human-machine interface
- **Efficiency**
  - ISO 9241-11
  - European statement of principles on human-machine interface
- **Distraction**
  - Attention to system surveillance and -operation
- **Priorisation of information and warnings** in normal and failure mode
- **Familiarization**
  - common usability principle
  - ISO 9241
- **Vigilance problems**
  - e.g. depending from the level of automation
  - ISO 15622
  - RESPONSE Checklist

#### 4.4 "Duty of Care": Process Aspects

Also the "Duty of Care" expression is originally a legal term used in the European Product Liability Law.

- "Anyone who creates a source of danger for third parties must ensure that the danger does not materialise in a given situation"

This "duty of care" applies to manufacturers and other persons or entities involved in the production and distribution chain at various stages, including design, manufacturing, instruction, warnings and product monitoring.

Again existing automotive and non-automotive standards, rules and guidelines were investigated in order to identify the relevant elements for the development process of ADAS.

- ISO 9001:2000 International Quality Management System Standard
- ISO 16949:2002: Application of ISO 9001:2000 for Automotive Production.
- VDA 3.1 and 4 et seqq.: „Measures for reliability at automobile manufacturers and suppliers development processes“

- VDI 4006 Human reliability analysis
- ISO 17287:2003 „Suitability“ Standard
- SAE „Papers“
- RESPONSE 1: Checklist for theoretical Assessment of Advanced Driver Assistance Systems

#### 4.4.1 Relevant Aspects/Elements of existing process “standards“ for ADAS concerning the development of a CoP

Various initiatives on national and international levels have been launched recently towards a functional safety process for automotive applications including ADAS system safety.

Based on the IEC 61508 and other standards, initial work has been started towards a future automotive specific functional safety ISO standard.

In the moment these approaches mainly focus on the error- and failures-minimizing specification-, implementation or realization of ADAS systems. The Human Factors aspects of operational errors and misuse are not fully covered.

These Human Factors aspects shall be addressed in the CoP. The “duty of care” requirement of the RESPONSE approach reveals the need for a Human-Factors-enlarged development process.

For human factors design to be most effective, you should consider it to be an essential part of a good design, not as something separate. Human factors science has the greatest impact when it is integrated into the total design process from start to finish.

To cope with the task to develop ADAS functionalities that are “safe of use”, there is the need to integrate a Human Factors design process into the entire ADAS development process. The structured design process shall contain system development phases and the corresponding Human Factors phases.

So content of the CoP is the description of **detailed phases** of the Human Factors Design Process for ADAS development, beginning with the very early phases of ADAS concept development including the assessment of customer needs and the discovering of new potentials for driver assistance applications, and ending with Start of Production.

The Process shall differentiate between

- Human Factors **specification** process and
- Human Factors **validation / sign off** process

Further requirement for the CoP is to describe also **methods** for HMI specification and HMI validation processes enclosing a sequence of tools from risk-benefit analyses to the testing of ADAS systems, which are close to market introduction.

Whereas the description of **metrics** shall be included, the definition of **criteria** will not be part of the CoP.

The Human Factors process can be divided into four parts (see Figure 49):

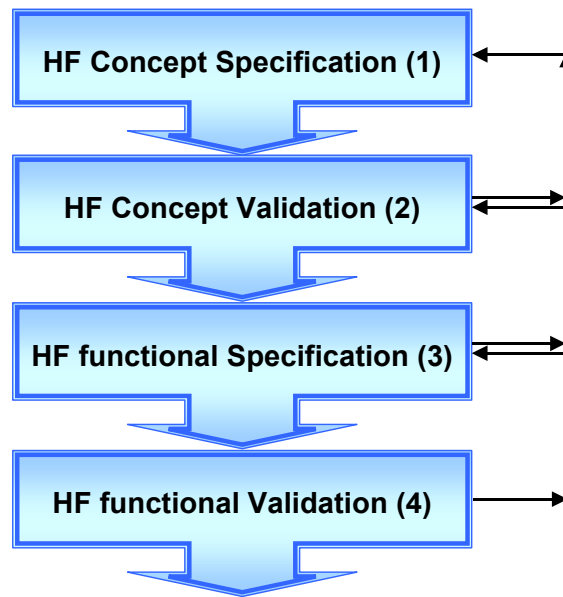


Figure 49: HMI Specification and Validation Process for ADAS

The **HMI concept specification process (1)** starts with the

- Identification of ADAS concepts (Possible future product contents and features)
- Development of "ideal"/ optimum ADAS concepts
- Performance of financial and technological feasibility
- Draft specification of "Golden Rules" for system understanding
- Development of functional models of ADAS (Draft concepts)

If this is done, it is necessary to assess and validate the preferred user concept in the corresponding **HMI Concept Validation (2)** phase.

In parallel to the design of the concrete ADAS architecture as well as the hardware and software components the implementation of a **HMI functional specification (3)** process ensures the specification and implementation of a concrete Human-Machine-Interface design solution.

In a last step **(4)** the **HMI functional validation** (again in parallel to the system design verification of the ADAS architecture as well as the hardware and software components) has to ensure the assessment and validation process of the ADAS, checking if its design requirements are met.

CoP will only describe major process requirements and the corresponding major steps but cannot provide a process in every detail. Every company has its individual development process and due to the different company internal processes, the HF process requirements have to be adaptable and easy to integrate. The company specific development process shall be enlarged regarding the corresponding HF process. But how the HF process requirements will be fulfilled is a company internal task.

## 4.5 Stakeholders and Roles

Looking forward to the development of the liability mitigation strategy through the development of the Code of Practice a number of stakeholders can be identified to which generic roles can be attributed. When examining the roles, attention is given to the following four ways of involvement:

Involvement in

- ADAS and preventive and active safety in general
- The conceptualization and development of the Code of practice RESPONSE 2/3 under the PReVENT umbrella
- The realization and real deployment of the Code of Practice
- The maintenance of the Code of Practice

First of all, the RESPONSE consortium has created a very recognizable identity. Experts are familiar with RESPONSE, and therefore the RESPONSE umbrella should be kept in the further development phase as well as in the realization and maintenance phase of the Code of Practice. .

The consortium responsible for developing the Code of Practice should consist of the representation of the groups and responsibilities identified below.

**Vehicle industry** including the automotive suppliers

This group consists of the vehicle manufacturers, including its Tier 1 and Tier 2 suppliers. The Original Equipment Manufacturers (OEMs) and the Tier 1 suppliers are bearing the financial risks of defective products, are responsible to research, develop and deliver safe products for the consumers to the market.

The vehicle industry, representing the main users of the Code of Practice, should lead the development of fail-safe preventive safety applications, and lead the development of the Code Of Practice, to ensure the voluntary implementation.

As experience for improvement will come from the engineers within the industry, initiatives for periodic review should come from this side too.

**Research** including public institutes and universities

The research sector will make use of the Code of Practice, through involvement in research and evaluation of preventive safety applications in conceptual stage. The sector's deep knowledge and experience with basic research and development of tools provides the opportunity for a strong contribution to development and evaluation of the effectiveness of the tool.

**Platforms and associations**

The platforms and associations mentioned below support the development of preventive and active safety at international and political level, by creating the political climate, common understanding, priorities and awareness within the industry as well as within regulating institutions.

With respect to the Code of Practice, the platforms and associations can contribute to ensuring early and effective implementation of the code of practice using its expertise, links and dissemination channels.

#### ACEA - European Automobile Manufacturers Association

ACEA represents the interest thirteen European car, truck and bus manufacturers at European level and throughout the world.

The Association readily provides this expertise as an input during the regular dialogues it maintains with legislators, regulators and other EU authorities. In this way ACEA contributes significantly to practical and effective law making.

#### CLEPA

CLEPA is the European membership organisation for the global Automotive Supply industry. It represents 80 of the world's most prominent suppliers for car parts, systems and modules.

CLEPA is a discussion partner on all issues regarding the automotive supply industry. As such, CLEPA represents a unified position on behalf of its members on legislative, technical and economic matters, which can influence the future of the automotive industry in general, and its supply chain in particular.

#### ERTICO - ITS Europe

ERTICO is a Europe-wide, not-for-profit, public/private partnership for the implementation of Intelligent Transport Systems and Services (ITS). ERTICO's mission is to promote and support the implementation of ITS in Europe, ensuring sustainable mobility, travel satisfaction and high economic returns.

ERTICO maintains direct contacts with its' partners project experts and political level experts. The relationships to (European) institutions allow ERTICO to monitor and influence political and strategic developments at the European and the global levels.

The variety of the ERTICO partners (industry, road and public authority, OEM, Suppliers, ACEA, user groups) ensures dissemination to the critical mass for RESPONSE

#### The Insurance industry

Insurers of owners/drivers of vehicles need to see adherence to a Code of Practice as a benchmark of risk recognition and containment and an objective element of consistency, on which they can base their offers of the most favourable terms and prices for insurance cover.

If, nonetheless, there is an alleged ADAS failure, those insurers and the insurers of any affected third party property can bring a subrogated recovery claim against the vehicle- and component-manufacturers, producers and distributors of ADAS-relevant telematics and associated computer hardware and software, etc., all of which parties will doubtless expect their insurers to respond. A Code of Practice will assist resolution of such recovery claims.

Reference to a Code of Practice will also be an important element in the process by which insurers can understand the root cause of



any ADAS failure. It will greatly assist the maintenance or restoration of appropriate insurance cover and pricing.

### **User groups** and user representations

With regard to preventive safety in general, user groups have the responsibility to ensure affordable and safe motoring and defending the rights of consumers with respect to and the use of the automobile.

To secure the best possible protection for consumers, User Groups are involved in activities promoting audits for safety design (EuroNCAP).

Regarding involvement in development and maintenance of the Code of Practice, the role for User groups is limited to validating its quality and explaining the existence to the consumer.

When further elaborating on the user aspects of RESPONSE, also regarding the risk perception and safety discussion – user groups are invited to contribute. RESPONSE in turn can provide valuable feedbacks for these organisation to further elaborate their role in this important and emerging field.

- National and international motor clubs:
  - FIA Fédération Internationale de l'automobile, representing the interests of motoring organisations and motor car users throughout the world
- EUROPEAN DRIVING SCHOOLS ASSOCIATION (EFA) This is an association of driving instructors throughout Europe, and aims to promote professional driving instruction, harmonised instruction throughout Europe, and compulsory professional training for driving teachers. It holds a Congress every two years.
- ARC EUROPE (ARC) - has been created by eight major automobile associations in Europe, namely AA, ACI, ADAC, ANWB, OEAMTC, RACE, TOURING and TCS. These "shareholder" clubs have soon been joined by approximately 17 "non shareholder" clubs to form a European-wide association representing some 30 million members.

### **Legislators and**, road and **public authorities**

Legislators are responsible for creating the climate to release safe products in a liveable society. Regarding preventive and active safety this group is responsible to develop regulations (with support from the research sector) and manage the political aspects of their implementation. The transport policy furthermore supports the evaluation of the effectiveness of safety applications, to justify (financial) support of deployment incentives and subsidies. With the role to protect the citizen, the authorities are further responsible for proactive information campaigns. Legislators, road and public authorities need to be well aware of the Code of Practice approach, and need to be involved in an advisory role.

From a worldwide perspective, regulations concerning road vehicles are drawn up in three regions:

- The United States,

- Japan and
- Europe.

The technical discussions for the European regulations are held primarily in Brussels whereas technical debates on a global level take place under the United Nations umbrella in Geneva.

Because all members of the European Community are contracting parties of the concerning UN Agreement as well, decisions taken in both bodies are mutually mandatory valid. As a consequence, UN regulations and the corresponding EU directives are equivalent. Since only recently, several parties (amongst which the United States, Japan and the European Community) have signed up a new United Nations Agreement aiming at establishing technical regulations, which are globally valid.

## 4.6 Follow on Activities & Implementation

This chapter gives an overview on all planned future actions and implementation activities.

The major planning is already documented in the project proposal of the following IP Preventive Safety project RESPONSE3: Code of Practice for development, validation and market introduction of ADAS. Begin of the project will be October 2004.

Key elements of the timetable (see Figure 50) are

- The workshop on the procedure to determine reasonable safety in month 12.
- Draft of a Code of Practice for the design and evaluation of ADAS in month 13.
- Workshop on consensus building for the Code of Practice in Month 22.
- Final Code of Practice for the design and evaluation of ADAS in month 24.

Work package	Year 1												Year 2												Year 3											
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12
WP11.100 - WP management																																				
WP11.200 - WP alignment & dissemination																																				
WP11.210 - Alignment within consortium																																				
WP11.220 - Dissemination																																				
WP11.300 - Code of Practice																																				
WP11.310 - Requirements for reasonable safety																																				
WP11.320 - Code of Practice for ADAS																																				

Figure 50: Program and schedule of the Preventive Safety project RESPONSE3, beginning in October 2004

Activities for the alignment of the involved RESPONSE 2 members towards a CoP have been outlined:

- Responsible key persons within the involved companies of the RESPOPNSE 2 consortium and the consulting team shall be integrated into the decision and alignment process.
- Planned steps and measures towards a CoP shall be attuned internally within the involved companies of the RESPOPNSE 2 project.
- After the company-internal agreement phase the transcription of the planned steps and measures shall be realized.

Furthermore a tuning process in cooperation with the eSafety Task Force HMI shall be put into practice.

To realize a future CoP whose relevance and scope is not limited only to the European region but which is also of international significance it is necessary to involve also global partners.

A process of information exchange with the USA national bodies, e.g. regarding the work of the Alliance of Automobile Manufacturers (AAM) or the National Highway Traffic Safety Administration (NHTSA) in the USA is envisaged. The same information exchange process shall be ensured with Japanese bodies (Japanese automotive research institute (JARI) or comparable national bodies).

During the last months it was getting clearer and clearer that there is an irreversible development towards a future automotive specific safety ISO standard (see Figure 51).

Based on the IEC 61508 and other standards, initial work has been started within the individual companies of car manufacturers and suppliers.

As well various initiatives on national and international levels have been launched towards this future ISO, e.g. the FAKRA working group, HIS, BNA and BSI.

## Roll Out of a Future Safety Standard

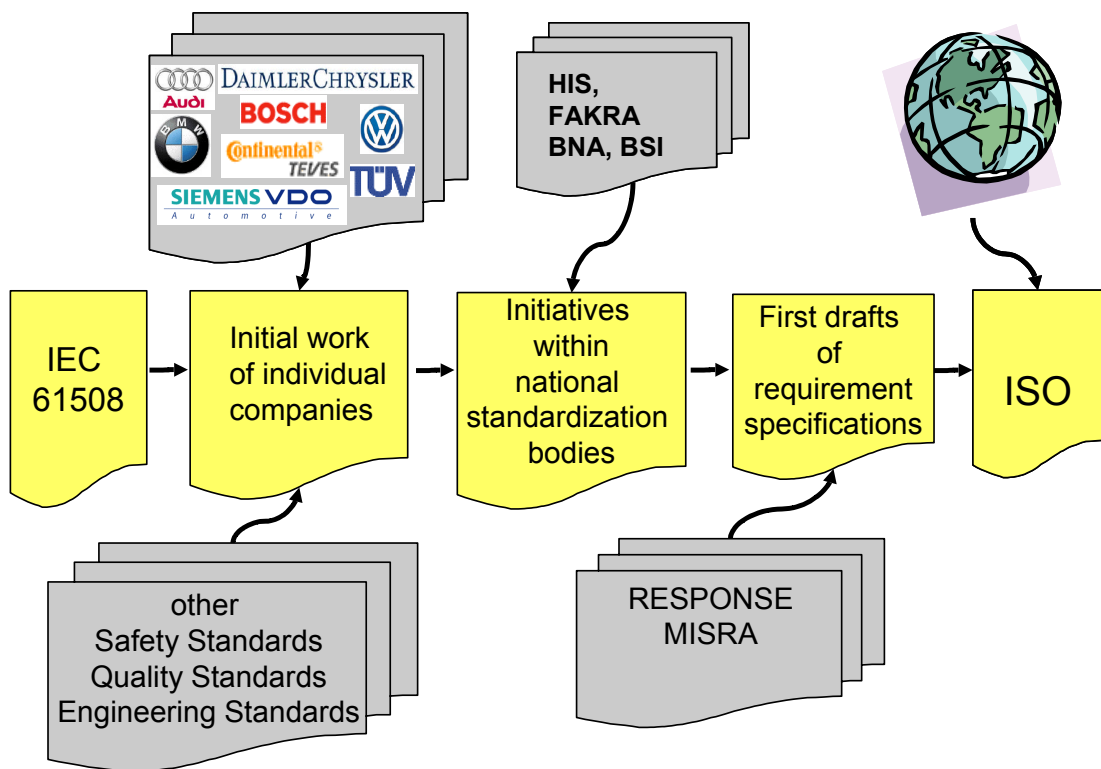


Figure 51: Roll out of a future ISO safety standard

The work on the ISO standard will start in near future also taking into account the RESPONSE Code of Practice.

### 4.7 CoP Consensus Formation Process

The overall objective of the RESPONSE project is not only the definition of a "safe" ADAS development and testing procedure within the CoP. This is only valuable if there is an agreement on these definitions as a basis for the company internal translation and/or optimisation of system design, specifications and corresponding methods.

The work package "WP11.200 Alignment and Dissemination" is a major task in the follow-on project RESPONSE3. It is intended to perform an "agreement" especially between industrial partners concerning the outcome of the work done in WP 11.300 (Code of Practice Definition).

The work performed in WP 11.300 (CoP) will be circulated and discussed between the core team of RESPONSE3 and a broader consulting team built up in the current RESPONSE 2 project as well as the relevant national and European authorities in order to reach an agreement on the processes described to form recommendations and a basis for company internal translation and/or optimisation of system design specifications and complementary verification methods.

In detail the Code of Practice consensus formation process is prepared in a two-step approach:

- (1) A draft of the Code of Practice will act as a basis for the project internal alignment process after one year. In this phase especially the in-house communication of the industrial partners plays an important part: The involvement of all ADAS designers, engineers and human factors specialists as well as the responsible managers of every OEM and supplier is essential. The CoP has to be checked regarding its company internal feasibility, applicability, usefulness and completeness as well as if the all-fundamental goals are met. In an iterative process the draft will be circulated and discussed between the involved partners.
- (2) After 2 years, the final version will be released. According to the need for disseminating and linking these agreements to a common European and even global level the Code of Practice will be communicated to the general public and legal bodies.

Also a comparison to the activities in USA and Japan has to be done to establish a basis for a common understanding and future standardisation efforts.

## 4.8 Research Needs

It has to be taken into consideration that the field of development and introduction of Advanced Driver Assistance Systems is characterized by

- New and innovative technologies with
- Complex interaction of system, driver and environment in multiple traffic situationsLack of experience and unknown user reactions (human errors in usage).So it is doubtless a field of action where this new challenges still require massive research activities in all relevant disciplines.

The follow up project RESPONSE 3 shall provide - on a generic level - descriptions of procedures and processes for analysis of user requirements, definition of systems according to these requirements, and validation procedures showing that these safety-related customer requirements are fulfilled.

Regarding this Code of Practice for ADAS only those tools and methods should be recommended for application, which are proved in practice. So the CoP is mainly based on already existing procedures (see also chapter 4.9: Synthesis of CoP Content and Structure).

According to this all hitherto described methods and procedure have to be checked regarding their applicability in the new field of ADAS. Especially the adaptation of Human Factors methods and validation procedures on ADAS should be in the focus of further investigation.

Common strategies for automotive product development have to be reviewed and possibly enlarged to meet the new challenges of ADAS development as well.

The classical methods of hazard and safety analysis (IEC 61508, etc) should be enlarged by integrating technological and Human Factors perspectives.

Validation procedures have to be enlarged and adapted in terms of determining whether the system is “fit for purpose”.

The analysis of relevant quality and safety assurance procedures (like ISO 9001-2000, EN, VDA, SAE...) has to be carried on.

## 4.9 Synthesis of CoP Content and Structure

The synthesis of the CoP content and structure is reflecting the discussion of the

- formal requirements,
- design requirements and
- process requirements.

Formal Requirements have been described in Chapter 4.2.

In Chapter 0 those design requirements were revealed which could be adopted from existing automotive and non-automotive “standards” to ADAS needs. Also those missing elements - which were not found in the investigated design and performance “standards” but should be addressed in a future CoP for ADAS - were listed.

Chapter 4.4 summarized the key elements of process “standards” pointing out the necessary aspects, which have to be addressed in the CoP regarding the ADAS development and evaluation process.

On the basis of these chapters the description of content and structure of the future Code of Practice was outlined:

- CoP assigns all **technical reliability** and **system safety** issues to the future automotive specific ISO. Various initiatives on national and international levels have been launched towards this future ISO, e.g. the FAKRA working group, HIS, BNA and BSI.
  - Technical reliability and system safety is – beside the initial work of individual companies - addressed via national standardisation bodies firstly.
  - In Germany the FAKRA working group is initiating this work towards a future ISO safety standard.
  - FAKRA working group was founded in January 2004
  - Dealing with an adaptation of IEC 61508 to automotive applications
  - Work at ISO will start in near future.
- The main subject of the CoP will be the Human Factors design and process aspects regarding **safety of functionality (safety of use)**
- **CoP describes a Human Factors Design process** as a part of the whole ADAS development process
  - There is the relevance for corresponding phases of the structured design process

- CoP describes **detailed phases** of the Human Factors Design Process for ADAS development process
  - This also includes the early phases of ADAS concept development
    - Assessment of customer needs / User Needs Analysis
    - Discovering new potentials for driver assistance applications
- Human Factors Design Process **differentiates between**
  - Human Factors **specification** process and
  - Human Factors **validation / sign off** process
- CoP **describes methods** for HMI specification and HMI validation processes
  - Description of methods shall enclose a sequence of tools from risk-benefit analyses to the testing of ADAS systems which are close to market introduction
  - Description of **metrics** shall be included
  - Definition of **criteria** will not be part of the CoP
- **ADAS specific design requirements** which shall be addressed in the CoP are
  - Suitability
  - Self-descriptiveness
  - Conformity with expectations
  - Error tolerance
  - Controllability
  - Predictability
  - Consistency
  - Transparency
  - Scalability
  - Learnability
  - Pace of interaction, interruptibility
  - Comprehensibility
  - Effectiveness
  - Efficiency
  - Distraction
  - Familiarization
  - Vigilance problems
- The CoP demands the consideration and involvement of **specific user groups** in testing which were already identified in the RESPONSE 1 project as the least informed and most endangered user

- persons with limited perception, information processing, attention and psycho-motor performances, e.g.
  - elderly people
  - inexperienced young beginners
  - drivers only using cars very occasionally
  - persons who are novice drivers regarding a specific vehicle type (e.g. as a result of renting a car without having received certain operating instructions)
- CoP shall describe what is the **least informed and most endangered user**
  - This requires to identify bandwidths with
    - minimum levels and
    - maximum levels
- CoP shall enclose a **glossary of terms**
- The **scope** of the CoP shall be described within defined boundaries
  - Beginning with the first ADAS concept development
  - Ending with begin of vehicle production (SoP - Start of production, Job one)
  - Thereafter the common surveillance measures / feedback systems come into force.
- Criteria for **ADAS definition** are
  - Lateral and/ or longitudinal vehicle control
  - Environmental detection (around the entire vehicle using radar, infrared, camera or image processing technologies)
- The main focus is on ADAS. Of course it is not limited to ADAS. Other TICs (Transport Information and Control Systems), especially the IVIS (In-Vehicle-Information-Systems) and cooperative systems (vehicle-to-infrastructure or vehicle-to-vehicle communication) may be affected by the principles and rules of the future CoP as well. So these systems will not be excluded from the scope. It is explicitly desired to have the enlarged focus also on these non-ADAS-systems.
- Both direct driver-system-interactions as well as indirect impacts on the driver will be covered by the CoP
- **Traffic Effects and Efficiency** of ADAS usage will be part of the CoP as well including the problem of compatibility
- The CoP shall be a guideline for development and evaluation of ADAS with a worldwide importance and relevance.



## 5 Evaluation of CoP Acceptance - Questionnaire at the Final Workshop of RESPONSE 2

The final workshop of this project was carried out on April 29<sup>th</sup> & 30<sup>th</sup> 2004 at Ford Werke GmbH in Cologne as a two days conference with 125 participants. The work done in the workpackages 2 – 4 was presented.

The present experts (mainly representatives from car manufactures, suppliers, public authorities and research institutes, but also from law firms, insurance companies and other special interest groups) discussed the outlined steps towards the CoP incorporating the Japanese and United States perspective.

At the end of the session, they were asked to fill in a questionnaire to answer the question

- If they agree with the planned content of the Code of Practice and why?
- If they miss certain aspects, which should be part of the future Code of Practice and which are these?

All in all 73 of the 125 workshop participants gave their “vote”.

The sample size can be explained with the attendance of the project partners, the members from Core and Consulting Team. Those, who actively worked on the project and contributed to the future CoP structure and content, were not taking part in the inquiry. They did not want to assess their own work.

The questions were addressed to those participants who had no stake in the RESPONSE2-project so far and also to all “passive” RESPONSE-partners and consultants, to get their feedback about the RESPONSE 2 work and the planned CoP.

## 5.1 Agreement with the CoP

The first question was, if the participants of the RESPONSE2 project final workshop would agree or disagree with the idea of a Code of Practice in general. Surprisingly the outcomes were more or less consistently positive:

- The vast majority, 60 of the 73 interviewed persons (82%), agreed with the Idea of a CoP.
- 12 persons (16%) were not willing to give an answer at that moment and
- only one dissenting vote was counted (see Figure 52).

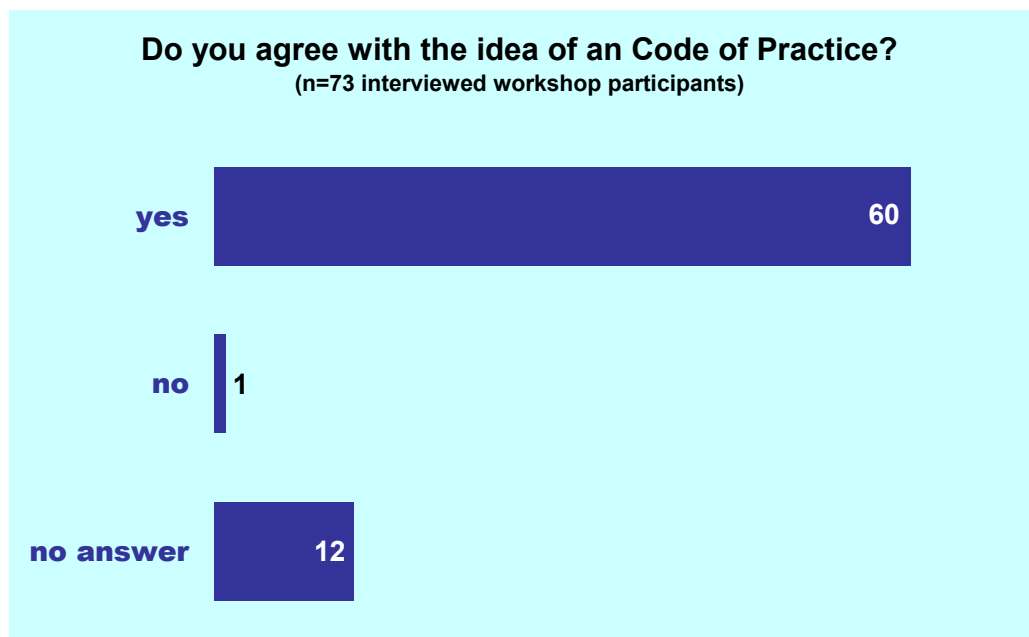


Figure 52: Results of the questionnaire: agreement with the CoP

Then the interviewees were asked to give reasons for their choice. The great variety of different opinions and argumentations is listed in the Figure 53 below.

**Yes, I agree with the idea of a CoP – Why? Comments?**

- definition of ADAS, are systems with vehicle-infrastructure interaction/communication included?
- it should be voluntary as a help to develop specifications. it also should be flexible and open to easy future enhancement/revisions
- necessary: it is a pre-requisite condition
- yes, I think it is a good way to standardize, but it must be flexible and let someone to move in his own direction if he considers it's worth it
- government guideline would be good (like in Japan)
- with the open question of CoP in design or/and CoP in evaluation
- should be slimmer, .. will produce not much or not appropriate contribution to the "Wertschöpfungs"-process (value-added-process)
- why not set up criteria, it is still quite vague, be more specific, more focus on human and law instead of system
- in general
- critical checks of procedures applied in essential. (function of "devils advocate)
- but as car manufacturer we have no interest in new regulations which are not flexible enough in times of high research progress
- but if I well understood, it seems that technical reliability will be apart of the CoP and takes into account into an ISO standard. How can we ensure that time schedules will comply.
- CoP should be international to include USA as it has a very large market potential and has one of largest legal exposure
- two years seem not realistic; more time needed
- highly recommended to ensure the safe development of the products
- even this general structure was detailed enough
- HF issues need specification, CoP is a quite abstract matrix
- should get a largest ....as possible

**No answer – Why? Comments?**

- can it really have the contents needed to help and can the industry then really adopt it? I think it should have come real contents. it should really be a cook book
- no option
- not my business
- USA based should not answer
- good idea have to think about it, consequences and positive aspects
- no expertise

**No, I don't agree with the idea of a CoP – Why? Comments?**

-

Figure 53: Results of the questionnaire: opinions and comments regarding the idea of a CoP

## 5.2 Agreement with the planned content of the CoP

Furthermore it was questioned about the agreement with the planned content of the CoP. Again the results were predominantly positive:

- The majority agreed explicitly with the content of the CoP (which were 49 of the 73 respondents, 67%)
- About one fourth of the subjects (20 persons, 27%) were not willing to give an answer at that moment and
- Four participants (5%) explicitly disagreed with the planned CoP content (see Figure 54).

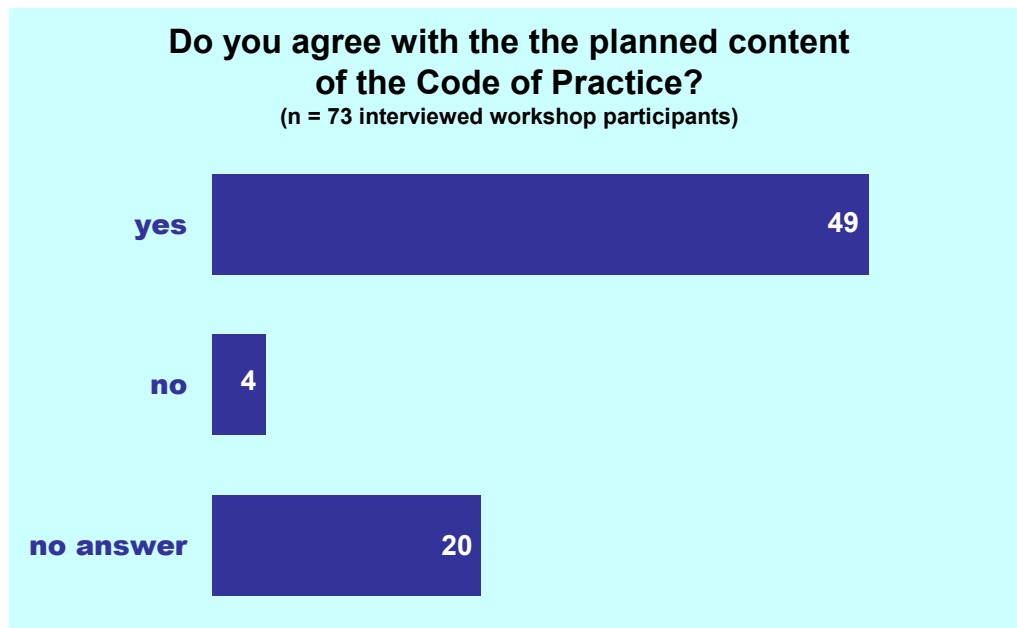


Figure 54: Results of the questionnaire: agreement with the content of the CoP

Again it was interesting to hear about the reasons for the specific positive or negative response.

**Yes, I agree with the planned content of the CoP – Why? Comments?**

- yes provided it may be easily revised
- good as it is, there should be a parallel effort to educate road authorities, courts, & public, & possibly the establishment of incentives to purchase
- point out more clearly the separation, between ADAS and active safety (which systems/functions belong where) IEC 61508 is not for technical reliability that is up to the system engineer
- CoP should be general, not only HF, structure: 1. Automotive systems safety standard under way FAKRA -->ISO 2. HF/HMI standard (tbc) 1+2 --> CoP interpretation adaptation to ADAS application example for 1+2
- if not too strict
- I don't believe that it is possible to involve universities & research institutes and to follow CoP
- the quality of the noted content must be included enough possibilities for the OEM to design their products and HMI
- will need further scope. TRW automotive would be interested in involvement of at least systems safety engineering standards development e.g. IEC 61508
- yes agree but need to have USA market involved. USA is behind Europe in this area so if CoP is difficult to apply to USA it will not be applied and then manufacturers will not support and it will become difficult to apply ADAS worldwide
- should not be limited to existing systems
- even this general structure was detailed enough
- Include Veh to Veh & Veh to Infrastructure communication in scope, Rental car issues will be included in Endangered, need to refer to the factors of different driving license tests in various countries
- description of content still not detailed, technical requirements
- generally speaking
- need to carefully judge the implications of potential not compiling with CoP and the legal consequences. --> target should be that we have to comply with CoP
- HF issues need specification, CoP is a quit abstract matrix
- potential to include more system reliability data to give quantified benefit,

**No answer – Why? Comments?**

- too premature to answer at this time
- well, we will love to discuss before we give an answer
- some what
- why not set up criteria, it is still quite vague, be more specific, more focus on human and law instead of system
- it appears that the CoP is going to exist in addition to the standard (IEC Group modifies for automotive purposes) this seems strange, because both the CoP and the standard will cover the complete lifecycle of the product
- not yet
- not my business
- maybe, need to think about

**No, I don't agree with the idea of a CoP – Why? Comments?**

- tends to be dominated by human factors aspects
- Japanese analyses prior knowledge for evidence

Figure 55: Results of the questionnaire: opinions and comments regarding the planned content of the CoP

The discussion about the planned content varied between the both extremes whether it is far too general or already too specific. On the one hand, detailed, specific “rules” and advices are favoured by one part of the workshop participants. On the other hand, the

CoP should be widely applicable and there has to be enough space for the development of individual, company specific products.

All in all the presented level of differentiation seems to be somewhere in the middle and it can be stated that there is a major consent about the direction of the RESPONSE2 work.

### 5.3 Missing Aspects

Do you miss certain aspects, which should be part of the future Code of Practice? Which are these?

With this question, the content discussion should become more specific to gain detailed feedback. In the following all different responses are listed.

#### **Do you miss certain aspects, which should be part of the future Code of Practice? Which are these?**

- Linkages to Japan & US, Items above should be pursued in a parallel project
- ADAS definition unclear weak
- telemetry systems for drivers assistance
- will see later as case progresses
- measurables for fulfilment, answers to open questions in CoP, cascading and integration in engineering development areas (system engineers) How do we get to a common sense of what is a feature and what is a bug
- ISO HF standard (tbc) should be prepared in an national/international standardisation group with experts, 3 ISO typical EC projects can be handled in RESPONSE 3
- the integration of systems, knowledge and teams in the companies
- no, seems more than sufficient
- why not set up criteria, it is still quite vague, be more specific, more focus on human and law instead of system
- intensive the contact with lawyer with concrete results to be prepared for any discussion about system influence in accidents
- reusability of prior practices. Study of prior Art. Update of design based on field usage. There should be worldwide input. What is VM practice what is supplies process
- Would like to see HMI Code of Practice flowing into the "V"-cycle in the same way as safety engineering. Last presentation seemed to isolate the process a little from other engineering design process HMI needs to be integrated in design cycle
- clear interfaces for infrastructure based systems
- more detailed, possibility to check & quantify, more future orientated (ADAS Systems first generation are ready)
- outline, that just guidelines and example of good practice
- deeper dive into safety and risk/benefit assessments
- no
- what happens in other EU countries
- fully support IEC 61508

Figure 56: Results of the questionnaire: Missing Aspects, which should be part of the future CoP

Eventually there was space left for other comments:

#### **Other Comments?**

- this Workshop has been an important event for our industry, &RESPONSE 2 has made an important contribution to ADAS
- thanks
- a forum to collect comments/suggestions might be useful
- identify those areas where the motor insurance industry are concerned about loss and see the ADAS will help reduce such loss
- good overview of issues and possible methods to address them
- this was an excellent workshop
- I missed the legal perspective relevance of a CoP for the current type approval system and an analysis of the relations with the general product safety directive
- I have been impressed by the positive cooperation between representatives from Japan & the USA
- excellent workshop, very productive and informative
- well organized WS, congratulation also to the staff
- keep up the excellent group of experts, networking very valuable. Include VDI Reps, invite SAE European based expert ->good MOV with SAE USA
- thx for a good conference
- very well organized & comprehensive
- excellent work, congratulation
- overall very good conference & Workshop
- all presentations too focused on Germany, RESPONSE European project
- excellent workshop, TRL working in this area since 80. good to compare ideas
- link to information/data exchange not fully explored, is there a role for value added service providers. More could be done to inform potential customers without raising expectations beyond what can be delivered.

Figure 57: Results of the questionnaire: Other comments

Summarizing, the feedback of the audience of the RESPONSE2 final workshop was principally very positive in terms of confirming the previous work done in the RESPONSE2 project and supporting the steps towards a CoP.

Valuable feedback and input was given, which will be very useful for the work of the future RESPONSE 3 project in order to meet the requirements of all stakeholders.

## 6 Relations to IST-Programme - CarTALK 2000

Within the framework of ADASE (Advanced Driver Assistance Systems in Europe) RESPONSE2 was basically related to all existing projects. Co-operation with these projects was automatically given by participating in the common meetings (concertation meetings and expert workshops).

Some specific IST projects,

- PEIT – Powertrain equipped with intelligent technologies,
- CarTALK 2000 – Safe and comfortable driving based upon inter-vehicle communication, and
- Safe Tunnel

have linked their work to results of Response 2. For this reason the connections to these projects were explicitly integrated into the Response 2 work plan.

Especially there was a strong link and a close co-operation between the CarTALK 2000 project and the RESPONSE2 activities. Due to the fact that Car Talk 2000 - apart from technological goals - also addresses market introduction strategies including cost-benefit analysis, the project could benefit from the RESPONSE2 work.

For the preparation of future ADAS market introduction scenarios the legal effects of the CarTALK 2000 applications had to be investigated. Therefore, it has been agreed with the European Commission that CarTALK 2000 will provide system information to the Response 2 project based upon the descriptions of the Car Talk 2000 Deliverable D 1 of 28. January 2002 (version 1.0) for common evaluation.

On the general basis of this CarTALK 2000 Deliverable D 1 this legal analysis was carried out. RESPONSE2 project partner Dr. Christine Kanz from the international law firm Clifford Chance discussed and analysed the most important legal aspects of the provided CarTALK 2000 systems. The legal analysis covered questions of traffic law, civil law liability of drivers and keepers, car manufacturers and suppliers, product liability as well as public law issues regarding radio frequencies and standardization.

In the following we firstly like to give a short introduction of the CarTALK 2000 project (chapter 6.1) and then come to a summary of the related legal and liability analysis (chapter 6.2).

Everybody, who is interested in the detailed analysis, will be invited to read also the final version of this RESPONSE2 special report:

Legal and Liability Issues regarding Inter-Vehicle-Communication - CarTALK 2000

issued on the 22. April 2004 and available on the RESPONSE2 websites << <http://response.adase2.net> >> and << <http://www.response2.org> >> as PDF-download.



## 6.1 Introduction CarTALK 2000

The primary goal of the CarTALK 2000 project is to design, test and evaluate co-operative driver assistance systems, based upon vehicle-to-vehicle communication, to improve the safety of all traffic participants. Many traffic situations or conditions create a hazard for the driver, which could be overcome by a vehicle-to-vehicle communication system.

Car Talk 2000 distinguishes the following application clusters: information and warning functions, communication-based longitudinal control systems, and co-operative assistance systems (see Figure 58).

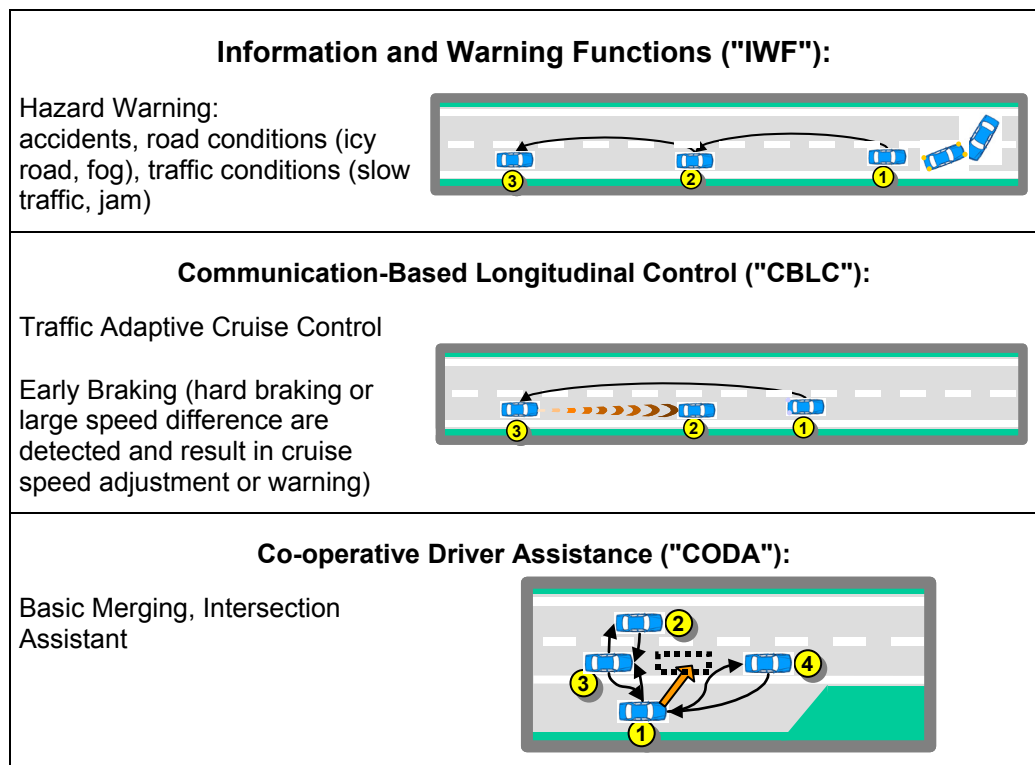


Figure 58: Driver Assistance Applications within Car Talk 2000 project

The systems are partly mere warning and information systems, and partly overridable intervention systems. Thus, legal problems connected to intervention systems in main driving activities (accelerating, steering, braking) must be investigated, however, not legal issues with regard to non-overridable intervention systems.

## 6.2 Summary: Legal and Liability Issues regarding Inter-Vehicle-Communication of CarTALK Systems

In order to make the legal analysis more vivid, typical traffic situations for which the specific system is designed are described firstly. On the basis of these scenarios the report assesses the most important legal aspects of the Car Talk 2000 systems<sup>19</sup>.

<sup>19</sup> Please note that this report is not intended and cannot replace detailed legal advice on specific systems and specified matters also in respect of the various jurisdictions in Europe. In the Response 1 project it has been found that legal issues are quite similar in many European countries. However, this report must not be seen as a

The analysis can be concluded as follows:

- Vehicles equipped with Car Talk 2000 systems require admission to public roads as every other vehicle either under the provisions of the STVZO or by means of an EEC type approval. In this context, the design of the Human-Machine-Interface is crucial in order not to distract or disturb the driver unduly, but to provide clear and reliable information. Showing convincing testing results in regard of reliability and error frequency as well as a user profile, showing that overreactions are not likely, may help to overcome safety concerns.
- The drivers of vehicles equipped with CarTALK 2000 systems must keep control over their vehicles at any time, regardless if the system operates in a warning/information mode or an active assistance mode. The drivers are therefore generally responsible for safe driving, i.e. driving in accordance with the rules on public road traffic (STVO). This means that drivers must avoid the unjustified sending of messages, for example through activating the warning flashers without reason. The driver must also stay alert if there actually is a hazard and must not rely on warnings and information alone. Also, the drivers must not overreact to warnings/information or a system intervention and must override the system if necessary.

In this context a precise instruction of the drivers is essential as regards potential misuse as well as the description of functional limits of the system.

- Liability of the driver regarding accidents in connection with Car Talk 2000 systems arises mainly in the cases of driver's misbehaviour identified above. For the sending driver a liability risk emerges especially from the activation of the warning flashers and thus the system without reason.

The driver receiving a warning/information faces an increased level of caution as soon as his vehicle is equipped with a Car Talk 2000 system and he has knowledge of a hazardous situation. Ignoring a message may even lead to liability for accidents that other drivers would not have been held liable for.

- Technical failures of the vehicle-based system leading to false information can establish the vehicles keeper's liability without regard to personal faults. Therefore, the process of data evaluation and processing and consequently the risk of mal-functions in the emitting vehicle have to be kept limited to the best possible extent.
- Regarding product liability, manufacturers of Car Talk 2000 systems and suppliers of components to the system might be liable under tort laws and product liability law. Liability under the latter requires not a negligent behaviour of the manufacturer but rather a defective product. Design, production as well as instruction defects are imaginable, which might lead to liability.

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detailed analysis of the legal situation in Europe altogether, but as an exemplary analysis on the basis of German law.

Different from the strict liability under product liability law a liability under tort law requires a negligent infringement of a duty of care referring to the design, production, instruction or monitoring the product by the manufacturer. Since the manufacturer must prove that he observed all relevant duties, which might be difficult in many cases, liability under tort law cannot be excluded.

## 7 Final Recommendations of RESPONSE 2 and Outlook

Corresponding to the objectives of the eEurope / eSafety initiative the Response project is intending to force the market introduction of safety relevant, actively intervening systems into future vehicles.

Up to now there is very little experience in the field of ADAS market introduction. A common uncertainty relating development procedures and evaluation requirements can be obtained.

The work of both RESPONSE projects faced this new challenge by using an integrated approach towards **user, system, and legal perspectives**.

The key messages of the project **RESPONSE 1** were:

- Based on the European Product Liability Directive the term „**defective product**“ has not only a technological but also a human factors meaning.
- Differentiation whether a driver is able to overrule an operating system or not.
  - For systems, which **can be overruled** by the driver liability depends on driver failure except design failures of the product.
  - For systems, which cannot be overruled by the driver, the OEM or the supplier respectively is fully liable for the whole time frame the system is in charge.
- System safety oriented towards the „**least informed and most endangered consumer**“
- The key concepts of „**reasonable safety**“ of the product and „**duty of care**“ of the development process stress for an integrated system and user safety perspective in designing and validating systems.

Resulting from that the creation of a **Code of Practice (CoP)** for the development and validation of ADAS was proposed. This implies to establish “principles” for the development and evaluation of ADAS on a voluntary basis, as a result of a common agreement between all involved partners and stakeholders, mainly initiated by ADAS manufacturers.

After evaluating possible methods to identify the different risks and to quantify **risks and benefits of ADAS**, the first “surprising” result of the RESPONSE 2 work were drawn. It could be shown that for the ADAS systems safety, powerful tools are existing to develop a “safety case”, which ensure a **highest-level functional safety** like for conventional technology. Moreover there are already wide-ranging standardisation activities on national and international levels to cope with functional safety of automotive applications including ADAS by **adapting the IEC 61508**: Functional Safety of Electrical/Electronic/Programmable Electronic Safety-Related Systems. This work will result in the development of an ISO standard in the very near future.

According to this initiatives the aspects of technical reliability and functional safety are already addressed and should not be part of

the CoP. Rather it is intended that CoP and future ISO standard shall complement each other with different levels of commitment and with different accentuation.

A further result was the identification of need for methods to cope **safety of functionality** aspects of ADAS. Due to new ADAS challenges - characterised by intensive Human-Machine-Interaction, environmental "interaction" and safety criticality – the **safety-of-usage problem** has become more and more obvious. The relevance for Human Factors integration into the design process and the provision of applicable Human Factors tools and methods have to be part of the CoP content.

So one major subject of the CoP will be **Human Factors design and process aspects** regarding safety of use of ADAS.

In the ideal case Human Factors methods and validation procedures addressed in the CoP should be applicable, practical, valid, efficient and effective as well as providing clear decision criteria.

Unfortunately, this is not an easy task. The problem is: Human Factors is dealing with the interaction aspects of deterministic systems and non-deterministic humans. This implies **unpredictable behavior of humans in man-machine systems**.

At the 10th ITS World Congress 2003 in Madrid, Neil Bowerman (2003) from the Automotive Industry Unit of the Enterprise Directorate-General, labelled the part of Human-Machine-Interaction (HMI) as an **immature science, which is still not fully understood**. The question whether HMI regulations should be incorporated into the vehicle type approval system was answered by him with "not yet!" and "maybe never!".

Thus he would not recommend to include Human Factors requirements into 'hard' legislation.

Also regarding ADAS design and development the Human Factors part is to a certain extent vague and user's future operating **behaviour or misuse is not fully predictable**.

But there are various Human Factors tools and methods available, which have their individual strengths and weaknesses and are applicable in different stages of the development process. Therefore the reasonably combined application of those tools and methods is requested taking into account the specific requirements of every individual ADAS system.

Accordingly there is need for flexibility regarding the specific application of those HF-tools and a consequent **user-centred development process** from the early beginning of concept definition until start of production.

Designing a system to work well with the driver - particularly in regard to safety and usability – has to be a **fluid and iterative process**:

- Human Factors design is most effective when considering it to be an essential part of the design process, not as something separate.

- Human Factors has the greatest impact when it is integrated into the total design and development process from the beginning to the end.
- The Human Factors design and development process will be a **stepwise approach** with iterative experimental specification as well as validation and sign-off elements.

Defining such a process in the CoP will reduce the existing uncertainties of ADAS developers and will **provide a guideline to ensure a high safety level** of ADAS functionality aspects.

The voluntary agreement towards a Code of Practice shall help to **accelerate ADAS development**, to **promote positive public opinion** concerning ADAS technology and corresponding safety benefits and eventually helps to **improve significantly traffic safety** in Europe.

During the intensive discussion about ADAS and the Code of Practice, the whole range of **actual problems** of ADAS development and market introduction was raised. It has to be discussed which are the **negative influencing factors** (disablers) of ADAS market introduction.

The automotive **safety standard** has reached a very **high level** (which is one of the core messages from workpackage 3, see chapter 3 and Schwarz et al. 2004) but there is still an uncontrollable **liability and financial risk** for the market introduction of ADAS systems remaining.

Possible failures of the system can still lead to **product liability** – it cannot be avoided. But an agreement on the consideration of risks, that will be used by all manufacturers, will help to defend these cases, if the probability of occurrence is not showing evidence, that there is a major concern.

But even worse than the liability risk are the **financial risks, which** could result from

- expensive **recall campaigns** and above all
- the damage of the manufacturer's **brand image**.

As an example, Audi had to bear a massive financial loss caused by (doubtful) liability claims in the US market in the middle 80's. In the following years, the market-share loss for Audi in the US was catastrophic. The company needed about 10 years to reach again the previous level of sold cars per year.

And the fact that all competitors offered similar technological solutions at the same time, reveals another possible problem for the ADAS market introduction: the first in market, the first in media, and the first with a possible negative public perception bears the greatest risk.

The **risk of being first in market** with an innovative product is getting obvious by regarding another example: When BMW launched their new I-Drive system, they met with criticism in public and media across a broad front. After one year every car of the luxury class was equipped with a comparable system and meanwhile the competitors (who were followers) were suddenly receiving compliments for their systems.

To be a follower and not the first in market can be an advantage, especially when the innovation comes along with an implementation of a new functionality and a break with the tradition. The market innovator has to “break the ice”, and bears the risk of seriously **damaging its brand image**, if public perception is negative.

**Public opinion**, especially **risk- and safety perception** plays an important role in the acceptance of new applications. And this public risk - but also benefit perception is mainly depending on media presentation.

ADAS benefits are evident. The example of ESP systems, which are decreasing the accident rates significantly, proves the benefits of ADAS. But **media focus mainly on risks**, not so much on benefits.

But why is the media presentation often so biased?

It could be observed in the last years that the headlines presented in different media are commonly focussing more and more on sensationalism and are straining after effect. And unfortunately, it seems to be a media reality that bad news sell better than good news.

It would be helpful to **promote a positive public opinion** concerning ADAS technology and corresponding safety benefits. The discussion on **residual risk** should be continued.

Another question is **why a Code of Practice** is preferred and not new regulations or standards? What's the advantage?

The current status of research on ADAS cannot tell all possible developments that will be possible in future. We expect therefore the Code of Practice to be a **living document** over several years.

Many implications of ADAS will only be evident after some experience in everyday use with many users.

Standards / Regulations can be counterproductive, if they include already design regulations that prohibit certain solutions, although the effect of these systems is not completely considered.

The state of the art dealing with human factors and ADAS will evolve gradually in that area. There is **need for a platform** that is **flexible enough** to react on new results.

All in all the self commitment approach of a commonly agreed CoP is a powerful strategy and a model for future arrangements between different stakeholders integrating public authorities, society, manufacturers and users interests.

The **concluding question** was - if there is the **stakeholder's acceptance** on this self-commitment approach and an agreement about the necessity for a CoP?

So at the final workshop of the RESPONSE2 project held on April 29<sup>th</sup> & 30<sup>th</sup> 2004 at Ford Werke GmbH in Cologne, the 125 conference participants (from European automotive industry, authorities and other possible stakeholders) were asked to fill in a short questionnaire. The results were unmistakable: the vast majority gave an explicitly **positive vote for a future CoP** (see chapter 5).

And also the question, if they **agree with the planned content** of the CoP, was answered predominantly positive by the interviewed participants.

What are the final recommendations deriving from the work of RESPONSE 2?

First results on accident reduction due to Active Safety systems are very promising. Further Active Safety Systems may add a major benefit on accident reduction (like Brake assistance...).

The quality level of car safety technology is already very high. But it is difficult to compare conventional in-vehicle sensor technology to environmental sensor technology. We will have to accept first ADAS systems to be equipped with environmental sensors of limited capability. But still they have an enormous potential to a further reduction of accidents.

ADAS must be used, but it is very difficult to make precise prognosis on accident reduction by means of accident analyses. Although there are too many fatalities in EU, a single accident has to be considered as being a very rare event with often extreme complexity.

Due to its complexity, accident statistics are giving only a very simplified insight. Comparably better are accident reconstruction methodologies. But also they are not made for the analysis of driver-ADAS-interaction. To predict accident reduction, which is caused by ADAS usage, we have to refine those methods.

Regarding the market introduction of ADAS the main influencing factors (descriptors) for ADAS market introduction are

1. The usability of ADAS
2. The financial risk for the OEM

In order to support and enhance ADAS market introduction regulators should

- Concentrate on the most effective fatality reducing ADAS technology, taking into account actual technical possibilities and cost efficiency
- Accept certain levels of functional system safety
- Accept a Code of Practice as a guideline for the development of safe systems
- support OEMs by providing tools for ADAS assessment
- promote a positive public opinion concerning ADAS technology in general
- Inform about ADAS safety benefits as well as functional limits
- Continue the discussion on residual risk

And the advice for OEMs would be to:

- Increase Usability of ADAS by optimizing perception (detection) of environment as well as by creating transparent functionalities



- Improve organisational processes and establish guidelines (CoP) for development and validation (methods) to ensure reasonable safety of products and duty of care of the development process
- Carry out Risk - Benefit Analyses overall traffic impacts
- Provide information for customers and public

The work towards a Code of Practice for development, validation and market introduction of ADAS shall be continued. On the background of this broad support the follow-on project RESPONSE 3 will then fix the contents of the future CoP by coordinating the necessary consensus building process.

### **Outlook RESPONSE 3**

RESPONSE 3 will start 1st October 2004 as a horizontal subproject within the integrated EU-project PReVENT (preventive safety, see Figure 59). Duration is 2 years.

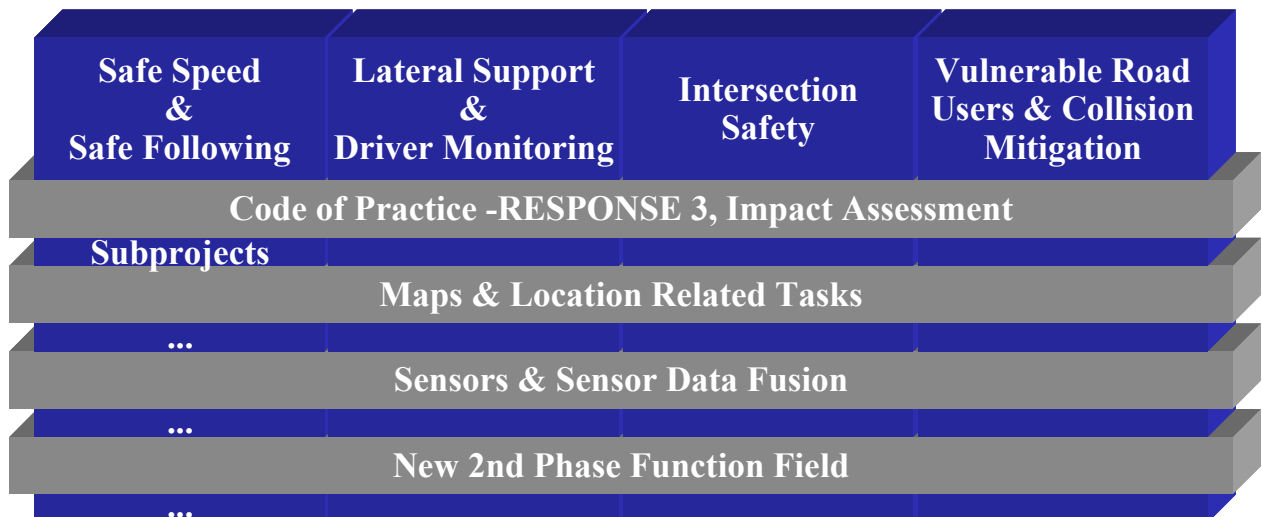


Figure 59: Organizational structure of the integrated EU-project PReVENT

RESPONSE 3 focus on one hand on aspects of reasonable safety, building a framework of risk assessment for ADAS with

- Environmental sensors
- Human Factors due to Human Machine Interaction
- Proposal for international discussion.

On the other hand the project focus on duty of care aspects, by working towards an agreement on development guidelines between all stakeholders as a basis for the company internal translation and/or optimisation of system design specifications and complementary verification methods.

On the way towards the Code of Practice, further research activities on risk assessment procedures for next sensor generation as well as further analysis of existing (Human Factors-) standards and methodologies will be necessary parts of the project content (see also Figure 60).

A draft CoP can be expected in month 13. The final Code of Practice is scheduled for Month 24.

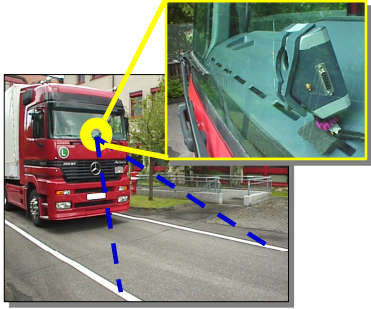
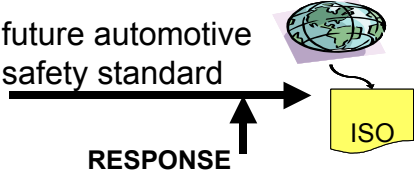
	<p>Risk assessment procedure for next sensor generation within ADAS (PReVENT-technology)</p> <p>situation analyses including human factors and sensor limits</p> <p>qualitative / quantitative risk metrics</p>
<p>future automotive safety standard</p> 	<p>Specific input for ADAS safety issues to a future automotive safety standard</p>
<p><b>Code of Practice for ADAS</b></p>	<p>Guidelines to find a way through existing standards and methodologies concerning human factors</p>

Figure 60: Content of RESPONSE 3 project

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## 9 Acronyms

<b>AAM</b>	<b>Alliance of Automobile Manufacturers</b>
<b>ABS</b>	<b>Anti-lock Brake System</b>
<b>ACC</b>	<b>Adaptive Cruise Control Systems</b>
<b>ACEA</b>	<b>Association des Constructeurs Europeens d'Automobiles (European Automobile Manufacturers Association)</b>
<b>ADAS</b>	<b>Advanced Driver Assistance Systems</b>
<b>ADR</b>	<b>United Nations Economic Commission for Europe European Agreement concerning the International Carriage of Dangerous Goods by Road</b>
<b>ALARP</b>	<b>As Low as Reasonably Practicable</b>
<b>BCD</b>	<b>Benefit-Cost Difference</b>
<b>BCR</b>	<b>Benefit-Cost Ratio</b>
<b>BEA</b>	<b>Break-Even Analysis</b>
<b>BGB</b>	<b>Bürgerliches Gesetzbuch (German Civil Code)</b>
<b>BGBI.</b>	<b>Bundesgesetzblatt (Federal Law Gazette)</b>
<b>BGH</b>	<b>Bundesgerichtshof</b>
<b>BGHSt</b>	<b>Entscheidungssammlung des Bundesgerichtshofs in Strafsachen</b>
<b>BNA</b>	<b>French Standardization Body</b>
<b>BSI</b>	<b>British Standards Institution</b>
<b>BVerwG</b>	<b>Bundesverwaltungsgericht (Federal Administrative Court)</b>
<b>CBA</b>	<b>Cost-Benefit Analysis</b>
<b>CD</b>	<b>Committee Draft</b>
<b>CEN</b>	<b>European Committee for Standardization</b>
<b>CENELEC</b>	<b>European Committee for Electrotechnical Standardization</b>
<b>CLEPA</b>	<b>European Association of Automotive Suppliers</b>
<b>CoBA</b>	<b>Cost Benefit Analysis Model</b>
<b>CoP</b>	<b>Code of Practice</b>
<b>DIN</b>	<b>Deutsches Institut für Normung e.V.</b>
<b>DOT</b>	<b>Department of Transport</b>
<b>DSC</b>	<b>Dynamic Stability Control</b>
<b>EACC</b>	<b>Enhanced Adaptive Cruise Control Systems</b>
<b>EC</b>	<b>European Commission</b>
<b>ECR</b>	<b>European Court Review</b>
<b>EEC</b>	<b>European Economic Community</b>
<b>EFA</b>	<b>EUROPEAN DRIVING SCHOOLS ASSOCIATION</b>
<b>EN</b>	<b>European Standard</b>
<b>ERBA</b>	<b>Extended Range Backing Aid Systems</b>
<b>ERTICO</b>	<b>Intelligent Transport Systems – Europe</b>
<b>ESP</b>	<b>Electronic Stability Programme</b>
<b>ETMR</b>	<b>European Transport Mortality Rate</b>
<b>EU</b>	<b>European Union</b>
<b>EuroNCAP</b>	<b>European New Car Assessment Programme</b>
<b>FAKRA</b>	<b>Fachnormenausschuss Kraftfahrzeugindustrie</b>

	<b>(German Motor Vehicle Authority for Standards)</b>
<b>FCAAS</b>	<b>Forward Collision Avoidance Assistance Systems</b>
<b>FDIS</b>	<b>Final Draft International Standard</b>
<b>FIA</b>	<b>Fédération Internationale de l'automobile</b>
<b>FMEA</b>	<b>Failure Mode and Effects Analysis</b>
<b>FMVSS</b>	<b>Federal Motor Vehicle Safety Standard</b>
<b>FVCWS</b>	<b>Forward Vehicle Collision Warning System</b>
<b>GAMAB</b>	<b>Globalement Au Moins Aussi Bon</b>
<b>GNP</b>	<b>Gross National Product</b>
<b>HEP</b>	<b>Human Error Probability</b>
<b>HMI</b>	<b>Human Machine Interaction</b>
<b>HRA</b>	<b>Human Reliability Assessment</b>
<b>IEC</b>	<b>International Electrotechnical Commission</b>
<b>ISO</b>	<b>International Organisation for Standardisation</b>
<b>IST</b>	<b>Information Society Technology</b>
<b>ITS</b>	<b>Intelligent Transport Systems</b>
<b>IVIS</b>	<b>In-Vehicle Information Systems</b>
<b>JAMA</b>	<b>Japanese Automotive Research Institute</b>
<b>KBA</b>	<b>Kraftfahrt Bundesamt</b>
<b>Km/h</b>	<b>Kilometres per hour</b>
<b>LCDAS</b>	<b>Lane Change Decision Aid Systems</b>
<b>LDWS</b>	<b>Lane Departure Warning Systems</b>
<b>M.O.T.</b>	<b>Ministry of Transport</b>
<b>MALSO</b>	<b>Maneuvering Aid for Low Speed Operation</b>
<b>MEM</b>	<b>Minimal Endogenous Mortality</b>
<b>MIL-STD</b>	<b>Military Standard</b>
<b>MISRA</b>	<b>Motor Industry Software Reliability Organisation</b>
<b>NF</b>	<b>Norme Française</b>
<b>NHTSA</b>	<b>National Highway Traffic Safety Administration</b>
<b>NP</b>	<b>New Proposal</b>
<b>NPRM</b>	<b>Notice of Proposed Rulemaking</b>
<b>OEM</b>	<b>Original Equipment Manufacturer</b>
<b>OLG</b>	<b>Oberlandesgericht</b>
<b>ProdhG</b>	<b>Produkthaftungsgesetz</b>
<b>ProdSG</b>	<b>Produktsicherheitsgesetz</b>
<b>RBA</b>	<b>Risk-Benefit Analysis</b>
<b>SAC</b>	<b>Semiconductor Assembly Council</b>
<b>SAE</b>	<b>Society of Automotive Engineers (USA)</b>
<b>SC</b>	<b>Subcommittees</b>
<b>SILs</b>	<b>Safety Integrity Levels</b>
<b>SoP</b>	<b>Statement of Principles</b>
<b>SOP</b>	<b>Start of Production</b>
<b>StGB</b>	<b>Strafgesetzbuch</b>
<b>StVG</b>	<b>Straßenverkehrsgesetz</b>
<b>StVO</b>	<b>Straßenverkehrsordnung</b>
<b>StVZO</b>	<b>Straßenverkehrszulassungsordnung</b>



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<b>TC</b>	<b>Technical Committees</b>
<b>TICS</b>	<b>Transport Information and Control System</b>
<b>UDC</b>	<b>Urban Drive Control</b>
<b>UK</b>	<b>United Kingdom</b>
<b>UNECE</b>	<b>United Nations Economic Commission for Europe</b>
<b>VDA</b>	<b>Verband der Automobilindustrie e.V. (Germany)</b>
<b>VDI</b>	<b>Verein Deutscher Ingenieure</b>
<b>VO</b>	<b>Verordnung</b>
<b>WG</b>	<b>Working Groups</b>
<b>WHO</b>	<b>World Health Organisation</b>
<b>WP</b>	<b>Workpackage</b>
<b>WTP</b>	<b>Willingness-to-Pay</b>
<b>ZPO</b>	<b>Zivilprozessordnung</b>

## **ANNEX I: Risk-Benefit Analysis - Macroscopic Perspective**

<b>1</b>	<b>Introduction .....</b>	<b>174</b>
<b>2</b>	<b>Cost-Benefit Analysis .....</b>	<b>175</b>
2.1	Necessity of Monetary Evaluation .....	175
2.2	Methodology of Cost-Benefit Analysis .....	176
2.3	Traffic Impacts of ADAS .....	179
2.4	Analyzing Traffic Safety Impacts (Safety-Critical Effects) .....	181
2.5	Traffic Flow Impacts (Non-Safety Critical Effects) .....	188
2.6	Monetary Evaluation of Traffic Effects .....	191
2.6.1	Accident Costs .....	192
2.6.2	Pain and Grief Premium.....	193
2.6.3	Accident Costs Analysis.....	193
2.6.4	Time Costs .....	197
2.6.5	Vehicle-Operating Costs.....	199
2.6.6	Emission Costs .....	200
2.6.7	CO <sub>2</sub> -Costs .....	202
<b>3</b>	<b>Break-Even Analyses .....</b>	<b>203</b>
3.1	Break-Even Analysis for ADAS-User.....	203
3.2	Break-Even Analysis for OEM .....	210
<b>4</b>	<b>Conclusion .....</b>	<b>214</b>
<b>5</b>	<b>References Macroperspective .....</b>	<b>216</b>
<b>6</b>	<b>Acronyms Macroperspective.....</b>	<b>218</b>

## **1 INTRODUCTION**

The enhancement of road traffic safety plays more and more an important role in European transport policy. Road traffic accidents cause in 2001 about 40,000 deaths and 1.3 million road accidents involving personal injuries a year in the EU. Accidents remain the most important category of external cost of transport in Europe (€158 billion a year or 2.5–3.0% of GDP in 17 Member States). In Germany for example, the economical costs of traffic accidents amount in the year 2000 to 35.6 billion €.

Advanced Driver Assistant Systems represent a bundle of technological solutions, which can contribute to the enhancement of road safety. Therefore the ADAS-development meets high priority political goals as well as market requirements, which favour new safety technologies for vehicles. Driver-airbag, front seat passenger-airbag, side-airbag, ABS and ESP belong to equipment characteristics, which are demanded as standard by the customers. Hence, a clear trend for additional safety equipments is recognizable.

Before ADAS will be introduced into the market it has to be proven that the usage of ADAS will lead to the promised benefits for the users and the overall economy. The market introduction, furthermore, will only take place, if ADAS will contribute to the private rentability objectives of the automotive industry.

The key issue of this paper is to work out, how an economic evaluation of ADAS can be performed. The economic assessment is the cornerstone for public and private decisions on ADAS. The economic evaluation can be embedded in the wider frame of the risk/benefit analysis, because risk/benefit analysis covers also aspects of safety, reliability and convenientness of ADAS, which are relevant as input for the quantification of monetary effects of ADAS.

Therefore, this paper develops a framework for the economic evaluation of ADAS. It includes an extensive review of the methods and procedures for a cost-benefit analysis (CBA) of ADAS. The methodological approach for private rentability issues is the break-even analysis (BEA). The market success of ADAS depends on the rentability gains of the ADAS-users. This aspect is covered by the BEA for ADAS-users. The market introduction of ADAS depends on the fact that the rentability objective of OEM can be achieved. Therefore, the methodological frame for the BEA of OEM is discussed in detail. Within the conclusions the main findings are summarized.

## **2 COST-BENEFIT ANALYSIS**

### **2.1 *Necessity of Monetary Evaluation***

Advanced Driver Assistant Systems (ADAS) represent innovative technologies, which promise significant potentials to enhance traffic safety and to improve traffic flow. Prerequisite for a successful market introduction is the rentability proof of ADAS. Normally, the decision on introduction of new products, new technologies depend on the private rentability considerations of the investor. In the case of ADAS, however, the proof of the private rentability is not sufficient, because there are several aspects of economic relevance:

- First, users want to know, which advantages they will have by using ADAS and whether it is useful to spend money for buying such systems. Whereby user groups have different price sensitivities. Especially, transport industry is more focused on possible cost-savings by ADAS, because of their business. Private car users can be more attracted by the safety and comfort aspects. Within this group drivers of upper class cars are less interested in other cost-savings than drivers of medium class cars.
- Second, transport policy might be interested in fostering market penetration of ADAS because of the promised safety and traffic enhancements.
- Third, financial risks related to the development and usage of ADAS might be a barrier for the willingness of OEM to introduce ADAS into the market. Considering all relevant monetary benefits of ADAS could lead to a reasonable risk sharing between all parties interested in introducing ADAS.

The cost-benefit analysis (CBA) represents an economic assessment tool, which provides the methods for an overall rentability proof of ADAS.

Cost-benefit analysis is a welfare economic based simulation of the market solution. The social desirability is proved by the welfare criteria of Pareto and Kaldor and Hicks [1]. ADAS is desirable from the point of the overall economy, if the benefits are higher than the costs. The difference between benefits and total costs has to exceed the value zero, or the benefit-cost ratio surpasses one. These monetary terms are necessary to form benefit-cost-ratios for each measure so that it is possible to say whether a measure is economically justified (benefit-cost-ratio  $> 1$ ) and whether one measure has a greater net effect than another one. This ranking is important to find out investment strategies with highest efficiency.

Furthermore, it is important that the wider-approach of the CBA can be used as basis for private rentability analyses (break-even analysis) for the users of ADAS and the original equipment manufacturers (OEM).

## 2.2 Methodology of Cost-Benefit Analysis

The following Figure 61 presents the steps of the monetary evaluation of ADAS.

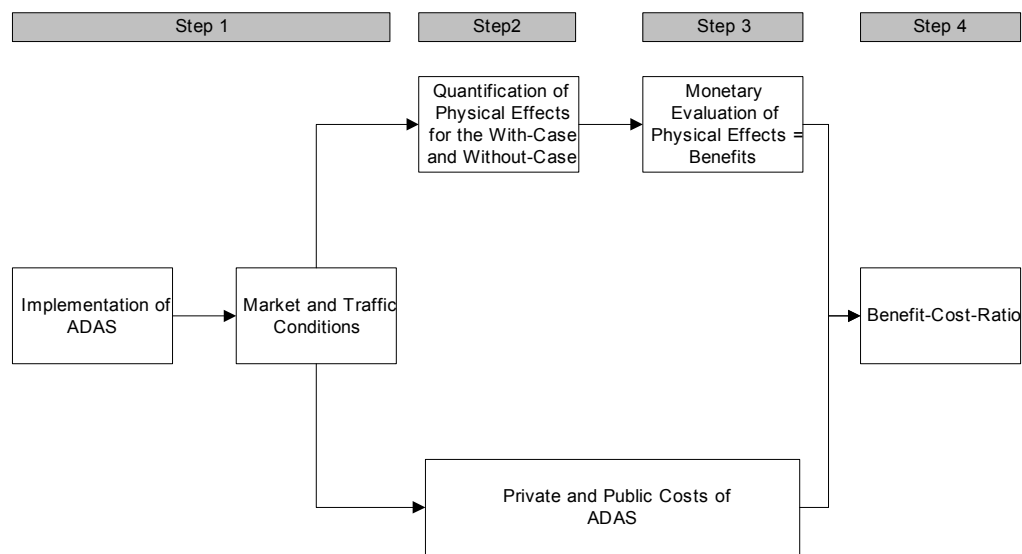


Figure 61: Steps of Monetary Evaluation of ADAS<sup>20</sup>

### First Step

The characteristics and functionalities of the system have to be specified in a comprehensive manner. That includes the description of the system components as well as the behavior of the system in real traffic situations. Furthermore, it has to be clarified under which circumstances the system will work or will not work in real traffic situations. With the description of the functional range (e.g. sensor range, reaction time) it is possible to determine on which road types (e.g. motorway, trunk roads, rural roads, urban roads) the system can be used. Clearly this is a matter of specification, but it has to be considered that this work is important for any kind of impact analysis, because it determines, which data is needed. Additionally, the vehicle categories (e.g. passenger cars, trucks, only new vehicles, only used vehicles), which will be equipped with the system, must be determined. Especially for the traffic effects the expected overall equipment rate has to be agreed on.

The following Figure 62 gives an overview how the system specification contributes to traffic effects and change of traffic parameters.

<sup>20</sup>

Own figure.

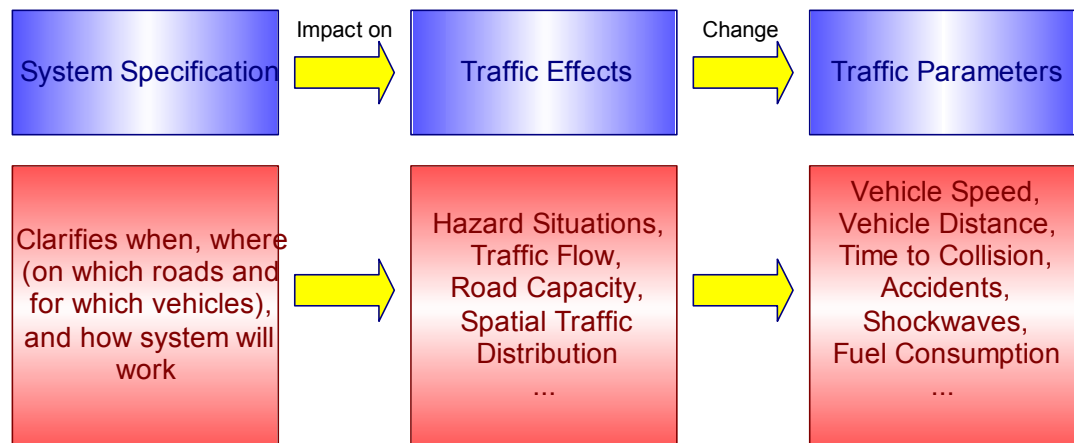


Figure 62: Linkage between System Specification, Traffic Effects and Traffic Parameters<sup>21</sup>

### Second Step

The traffic effects of ADAS have to be quantified. The traffic effects determine if ADAS lead to overall benefits or not, because the traffic effects determine how the economic factor resources of traffic are affected by ADAS. The economic factor resources for traffic are time, energy, accidents, and environment.

ADAS have an effect on the traffic conditions in the road system. Normally, ADAS unfold the traffic effects, however, not direct, but indirect over the change of traffic parameters (e.g. vehicle-speed, vehicle distance, time to collision, number of accidents, number of shockwaves, fuel consumption) as inter-mediate variables.

The traffic parameters have a direct impact on the factor resources. However, each traffic resource has a different functional relation to the traffic parameters. Therefore, the changes of traffic parameters caused by ADAS affect differently the components of traffic amount (time, energy, accidents, and environment). The directions of reaction possibilities are increasing, decreasing or unchanging. With four components and three directions of reaction, we get 81 combinations of reaction patterns. For example, ADAS lead to an increase of vehicle speed. With that travel time will decrease, but at this stage, it is not possible to determine the change of the energy amount (fuel consumption). In this case, additional information is necessary about the traffic situation before the introduction of ADAS.

In another case, it is possible that ADAS lower only one traffic component while the others will increase. The various traffic components are measured in different quantity units. Therefore, they have to be transformed in monetary units. The cost unit rates for the different traffic components make it possible to find out which effect will dominate.

### Third Step

Altogether the change of traffic parameters caused by the traffic effects of ADAS reflect themselves in the time-, vehicle operating-, accident and emission costs for both road freight transport and passenger transport, which are the bases for the cost-benefit analysis.

<sup>21</sup> Own figure.

To get the benefits of ADAS it is necessary to define two possible cases:

- The with-case, which means ADAS will be introduced.
- The without-case, there will be no-introduction of ADAS.

The difference between the costs of the without-case and the with-case is the benefit of ADAS. This approach to determine social benefits is called the cost-savings approach. The evaluation of the costs has to be done for every year of the life-cycle of ADAS. The annual social benefits over the life cycle of ADAS will be summed up and then the total sum of benefits will be transformed by the discount rate to one actual value of social benefit for the starting date of the traffic measures.

Beside the benefit evaluation the costs of ADAS have to be determined. The costs of ADAS cover thereby the capital outlays, the operating costs and also further costs, if additional expenditures (e.g. costs for supplemental equipment of road infrastructure, implementation of a traffic guidance center) are necessary for the functioning of ADAS.

#### Fourth Step

The benefit-cost ratio can thus be expressed as follows:

$$BCR = \frac{\sum_{t=0}^{T-1} Bt(1+i)^{-t}}{\sum_{t=0}^{T-1} Ct(1+i)^{-t}}$$

where

BCR	:= benefit-cost ratio
T	:= time horizon pre-defined
Bt	:= benefits estimated for the year t
Ct	:= costs estimated for the year t
i	:= discount rate

Setting absolute numbers of costs and benefits into relation, the BCR is a reliable indicator of cost-effectiveness of ADAS. This proceeding implies information about the economic objective of maximization/minimization of benefits/costs and helps to avoid false decisions and bad investments.

In opposite of this, the criteria benefits, costs and benefit-cost difference (BCD) contain absolute numbers. Their usage could lead to a misjudgment of ADAS. The following example (Figure 63) demonstrates that the BCR is best criteria for ranking and comparing various ADAS-technologies.

	ADAS 1	ADAS 2	ADAS 3	ADAS 4	ADAS 5
Benefit	40	10	120	600	0,5
Cost	10	2	100	200	1
BCR	4	5	1.2	3	0.5
BCD	30	8	20	400	-0.5
Ranking Criteria	Ranking				
Benefit	3	4	2	1	5
Cost	3	2	4	5	1
BCR	2	1	4	3	5
BCD	2	4	3	1	5
BCR: Benefit-cost-ratio; BCD: Benefit-cost-difference;					

Figure 63: Examples for Ranking by different criterions<sup>22</sup>

The example shows a simplified comparison of hypothetical ADAS-technologies. For hypothetical systems (ADAS 1 to ADAS 5) with different benefits and costs a ranking based on the different criteria (benefits, costs, BCR, BCD) is done. It is easy to see that the BCR-criterion combines the evaluation of costs and benefits. ADAS 4 is a good example for evaluating problems in absolute quantities. On the one hand ADAS 4 leads to the highest benefits and on the other hand it causes the highest costs. Using the benefits as absolute ranking criteria ADAS 4 will be the best system. Focusing on the difference between benefits and costs as ranking criteria ADAS 4 will be also the best choice. However, the BCR as ranking criteria indicates that ADAS will be only on rank 3. As overall results the ranking criteria BCR shows that ADAS 2 will be the system, which is the best choice from the societal point of view. By setting benefits and costs of a project into relation the use of the BCR enables a reliable selection.

### 2.3 Traffic Impacts of ADAS

A preliminary step for the CBA is the identification of the traffic effects by ADAS.

ADAS primarily system specification is to enhance traffic safety. Therefore, the main traffic effect is the reduction of hazard situations. Furthermore, in dependence of the overall system characterization additional traffic effects can be caused.

#### Hazard Situations

Figure 64 gives an overview over the general impact channels of ADAS on hazard situations.

<sup>22</sup> Own table.



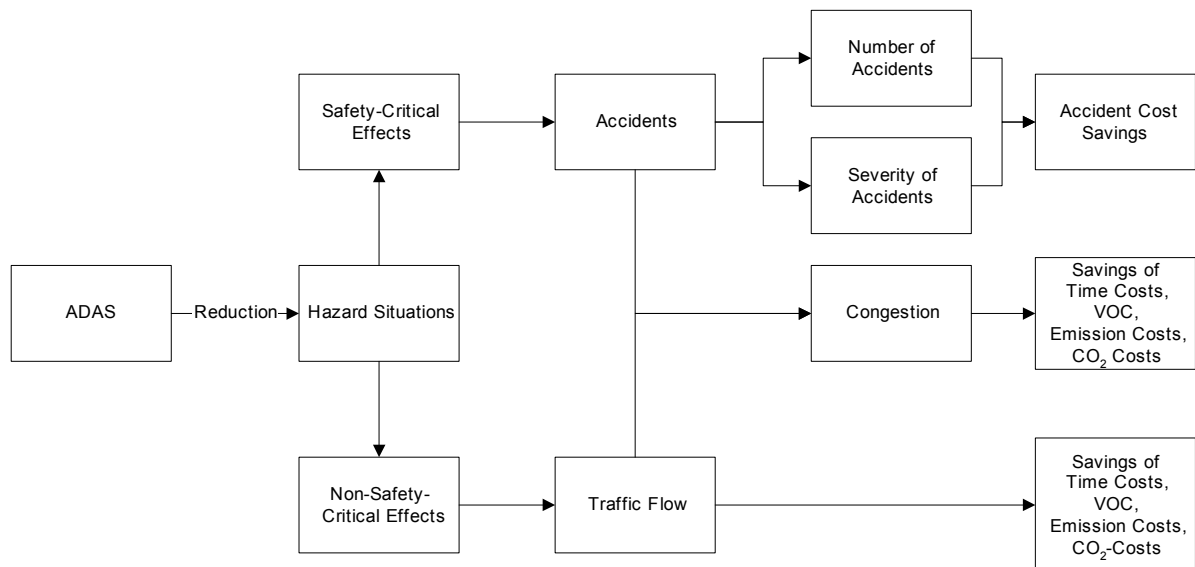


Figure 64: Impact Channels of ADAS on Avoiding Hazard Situations<sup>23</sup>

The relevant economic impact of ADAS is first the avoidance of accidents (safety critical effects of hazard situations). The usage of ADAS compared to a situation without ADAS will lead to different consequences of hazard situations. With ADAS, it might be possible that hazard situations, which normally lead to accidents, will be defused.

In the best case, it will be possible that an accident can be avoided. That means that ADAS reduce the number of accidents. The results are lower accident costs. The avoiding of accidents as best case has, furthermore, additional traffic effects, because the number of congestions due to accidents can be lowered, too. Avoiding congestions reduces time costs, vehicle-operating costs, emission costs and CO<sub>2</sub>-costs.

In a second best case an accident will not be avoided, however, the severity of an accident will be lowered (e.g. lower crash speed because of earlier braking). A lower accident severity also reduces the accident costs.

In the case, that hazard situation without usage of ADAS has no safety critical effects the advantage of ADAS-usage could be that due to changed speed deceleration traffic flow could be smoother (e.g. congestion due to unsteady time gap distances between vehicles can be avoided). This kind of capacity effect has to be evaluated separately.

**Additional Traffic Effects** Beneath the reduction of hazard situation the usage of ADAS can lead to further traffic effects, whereby these traffic effects depend on the concrete system characteristics. The relevance of these traffic effects must be proven therefore on the basis of the technical system specification. Figure 65 shows the impact channels of the additional traffic effects on economic costs.

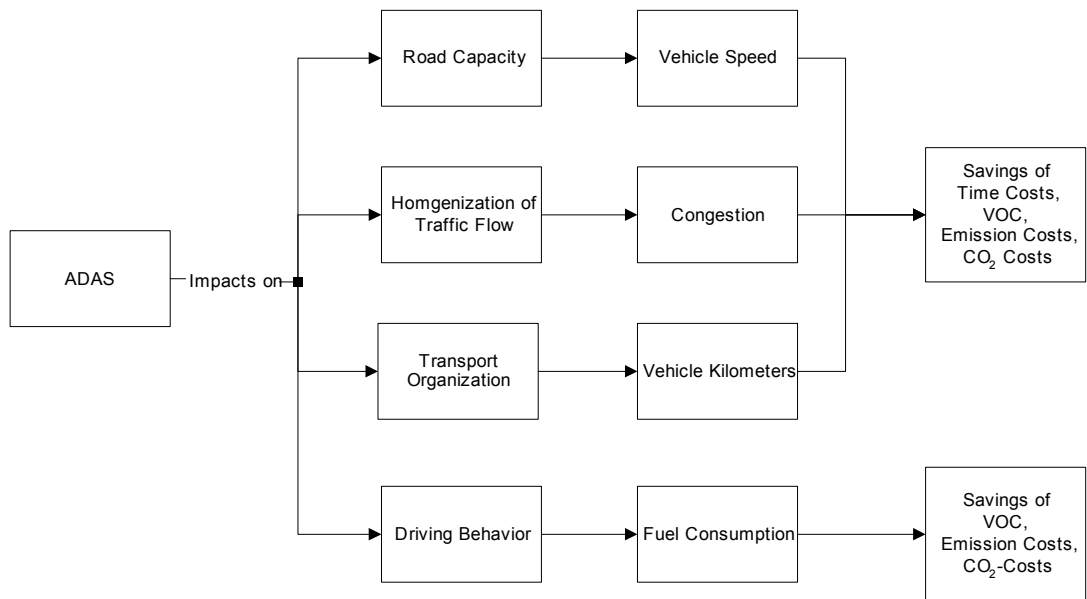


Figure 65: Traffic impact channels of ADAS<sup>24</sup>

Differences in the driving speeds between vehicles improve the efficiency of net sections. Substantial speed differences cause frequent lane changes and overhauling maneuvers. ADAS might lead to a reduction of the speed variances. This means that in the comparison to the without-case more vehicles under given traffic conditions can pass through. It comes to an increase of the vehicle throughput on the road section.

Furthermore, the reduction of speed variances leads to more homogenous traffic flow, which means that the number of congestions caused by unsteady driving could be avoided.

A noteworthy effect of ADAS comes up, if ADAS is used in road freight transport. The traffic improvements and possible cost savings of ADAS for the transport industry can lead to a restructuring of the transport organization. Therefore for example fleet management and route choice of transport industry can be effected, which can lead to changes of vehicle-kilometers. In the case of decreasing vehicle-kilometers cost savings can be realized. Increasing vehicle-kilometers have a reverse effect.

Road users might reach direct cost savings, if ADAS lead to lower fuel consumption by influencing the individual driving behavior. Furthermore, lower consumption reduces also emission costs and CO<sub>2</sub>-costs.

## 2.4 Analyzing Traffic Safety Impacts (Safety-Critical Effects)

The possible **accident cost savings** are one crucial component of the overall cost-benefit-analysis of each safety related vehicle-technology. However, the monetarized accident effects can be only estimated, if the effects of vehicle-technologies on accidents are clear and determined.

Economic assessments of the accident costs are regularly accomplished for the European Union member states. Traffic

24 Own figure.

accidents cause in 2001 about 40,000 deaths and 1.3 million road accidents involving personal injuries a year in the EU. The number of injured persons may be even higher, by a factor of two, due to under-reporting of minor incidents [1a].

Figure 66 gives an overview over the **development of fatalities** due to road accidents in the EU-15 between 1991 and 2002. Complete accident data for the EU-15 including personal injuries are available in the CARE database, but only since 1997. However, the development of fatalities shows specially for the period between 1991 and 1997 a clear slowdown of fatalities by – 23%. Since 1997 the fatalities were also reduced but the decrease is more slowly by -8%.

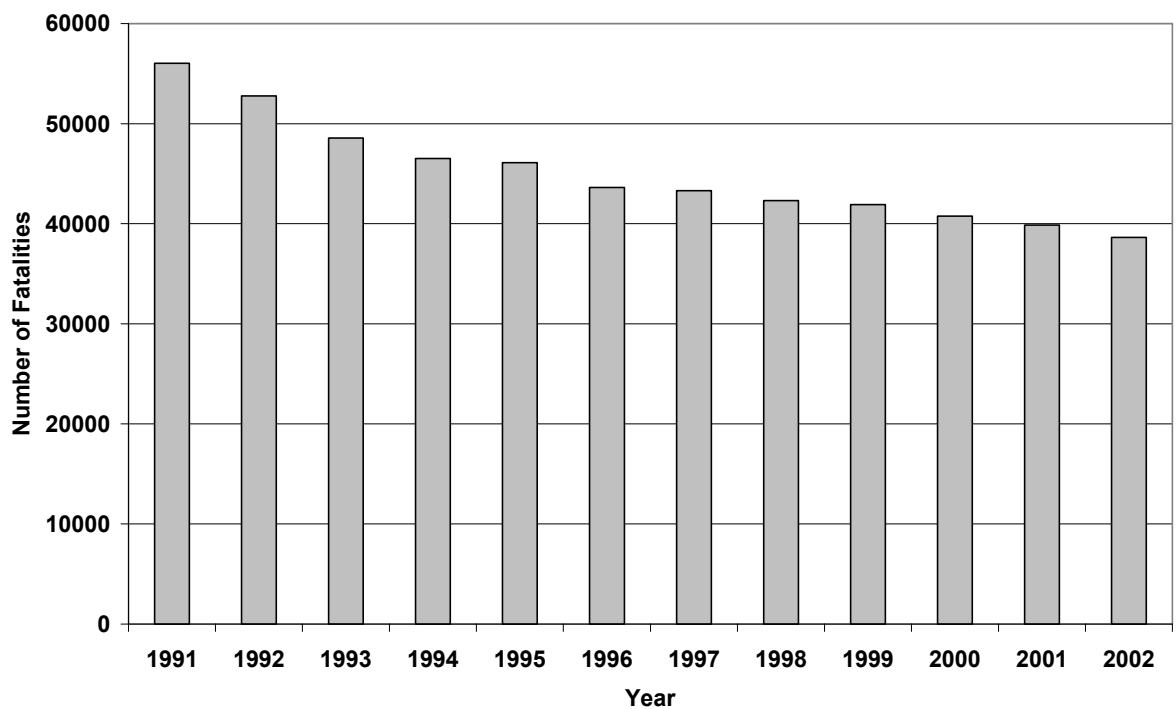


Figure 66: Number of Fatalities in the EU-15 (1991-2002)<sup>25</sup>

Accidents remain the most important category of external cost of transport in Europe (€158 billion a year or 2.5–3.0% of GDP in 17 Member States; WHO 2003 [2]; EC 2003 [3]). In Germany, the economical costs of traffic accidents amount in the year 2000 to 35.6 billion € (Höhnscheid and Straube 2002 [4]).

Therefore the European Commission has proposed the target to reducing by 50% the number of road fatalities by the year 2010 (White Paper on the European Policy for Transports, September 2001). In order to contribute to achieving this target the Commission has published a European Road Safety Action Programme, which aims at following points:

- stimulating road users towards a more responsible behavior (e.g. better respect of existing rules, initial and continuous training of drivers and reducing dangerous behavior) ;

25 CARE, Community Road Accident Database, <http://europa.eu.int/comm/transport/care>.

- making vehicles safer through improved technical performance standards;
- improving the road infrastructure (e.g. identification and diffusion of best practices and the elimination of black spots).

ADAS applications can give a contribution to the common objective to reduce traffic accidents. The main issue is to predict the safety effects of vehicle-technologies before the systems are on the market and accident data will be generated.

Beneath the economic costs resulting from the accident, the **congestions due to accidents** cause also major economic losses. The overall external costs due to road congestions for the EU are estimated approximately 0.5% of GDP. This represents in 2001 a value of 30 billion € a year, whereby by 2010 the congestion costs are expected to increase by 150% up to 80 billion € [4a].

The total external costs of road transport in the EU-15 in 2001 are approximately 260 billion €. Figure shows the share of accidents, congestion, air pollution and noise on the external costs of road transport. The most important costs are the accidents costs with a share of 58%. The second important costs are the congestion costs with an overall share of 19%. The congestion costs due to road accidents have an own share of 4%. That means that 20% of traffic delays and congestion are crash-related. This shows that the congestion costs due to traffic accidents are an important part of the overall congestion costs. The emission costs reach a share of 15%, and the noise costs due to road traffic have a share of 8%.

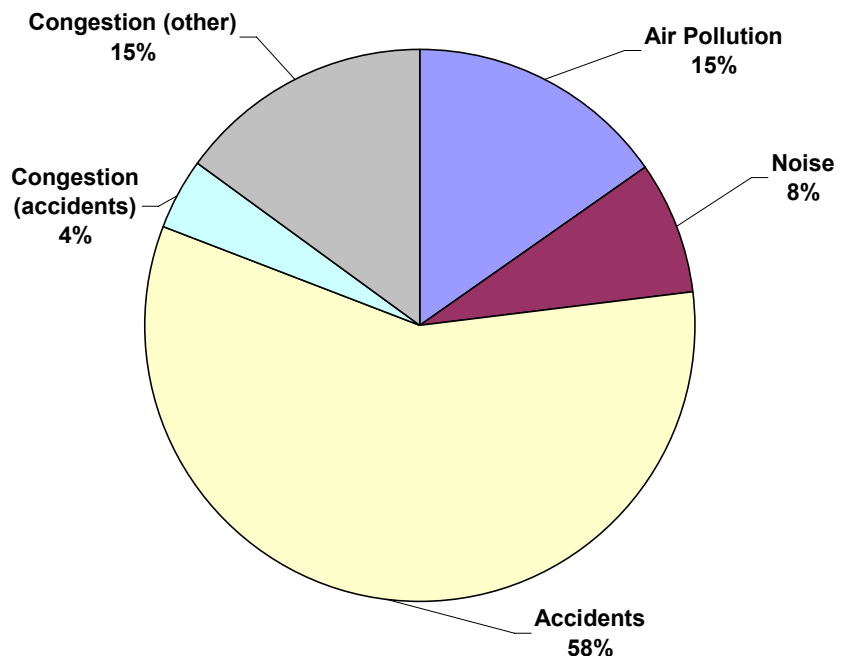


Figure 67: Percentages of Accidents, Congestion, Air Pollution and Noise on the External Costs of Road Transport in the EU-15 in the Year 2001<sup>26</sup>

For crashes with fatalities the assumed average congestion costs are 15,000 €. 5,000 € are the average cost unit rate for congestions due to accidents with personal injuries [4b]. That means that in 2001 the congestions costs due to accidents have a share of 20% on the total congestion costs in the EU and represent 7 billion €.

ADAS safety specification can lead to following economic benefits:

- Savings of value of life;
- Cost savings of avoiding injuries,
- Savings of road congestion costs.

At this stage it is clear that ADAS as safety technology can lead to enormous economic saving due to the effects on road safety. However, the possible traffic effects of ADAS-technologies will furthermore have an evident impact on the overloaded traffic situation on the roads. Therefore, their traffic effects can play beneath the safety effects of ADAS also an important role, because they can lower significantly the economic losses due to road congestion. Therefore, the traffic effects of ADAS are discussed separately from the safety effects of ADAS.

Incorporating safety impacts of ADAS in the CBA requires namely following types of data:

- evidence of ADAS on the level of all accident types and accident severity (historical statistical accident data bases);
- evidence of the impact of different ADAS characteristics and specifications on accident occurrence (accident prediction);
- evidence on the values of expected reduction and transforming them into monetary values (monetary accident evaluation).

Historical statistic databases for traffic accidents normally represent no information bottleneck, because they are available for most EU-Member States. However, it is evident that for the CBA the actual accident data represent the without case. The without case describes the situation in terms of accident occurrence before ADAS is introduced. Accident cost savings can be only calculated if knowledge on this reference case exists.

**Prediction of safety effects** of all kind of ADAS related technologies always have to overcome methodical challenges. The crucial point is that information about the safety effects of such system must be known before this system will be used. Therefore, the determination of the accident effects of such systems seems always abstract and unrealistic. Nevertheless, without the certainty that ADAS leads to an improvement of the road safety market introduction will not be possible. Due to this actual dilemma the following methodical proceedings were developed, in order to measure the safety effects of new technologies:

- Near misses-approach (retrospective approach);
- Field trials;

- Determined accident reduction because of system specification (static approach);
- Microscopic traffic simulation of accident occurrence (dynamic approach).

### Near Misses

Near misses are the best available proactive predictor of safety. Near misses occur more often than accidents. Figure 68, known as Heinrich's Triangle [5], shows for hypothetical values what kind of dependencies and interrelations between driver errors and accidents with fatalities exist. The hypothetical values mean that in the case of 1 Million driver errors without the occurrence of hazard situations it can be assumed that 100,000 driver errors exist with hazard situations. If 100,000 driver errors with hazard situation exist, 10,000 near misses, 1,000 accidents with minor injuries, 100 accidents with serious injuries, 10 accidents with disabling injuries, and 1 accident with a fatality will happen.

These relations based on empirical numbers are often used in other safety studies to estimate future accidents by counting the number of missings. Unfortunately, an analytical relationship between driver errors without hazard situations and driver accidents does not yet exist. However, the main conclusion from this triangle relations is that prevention of accidents avoid injuries and, furthermore, prevention of unsafe practices and/or unsafe conditions avoid accidents and therefore also injuries.

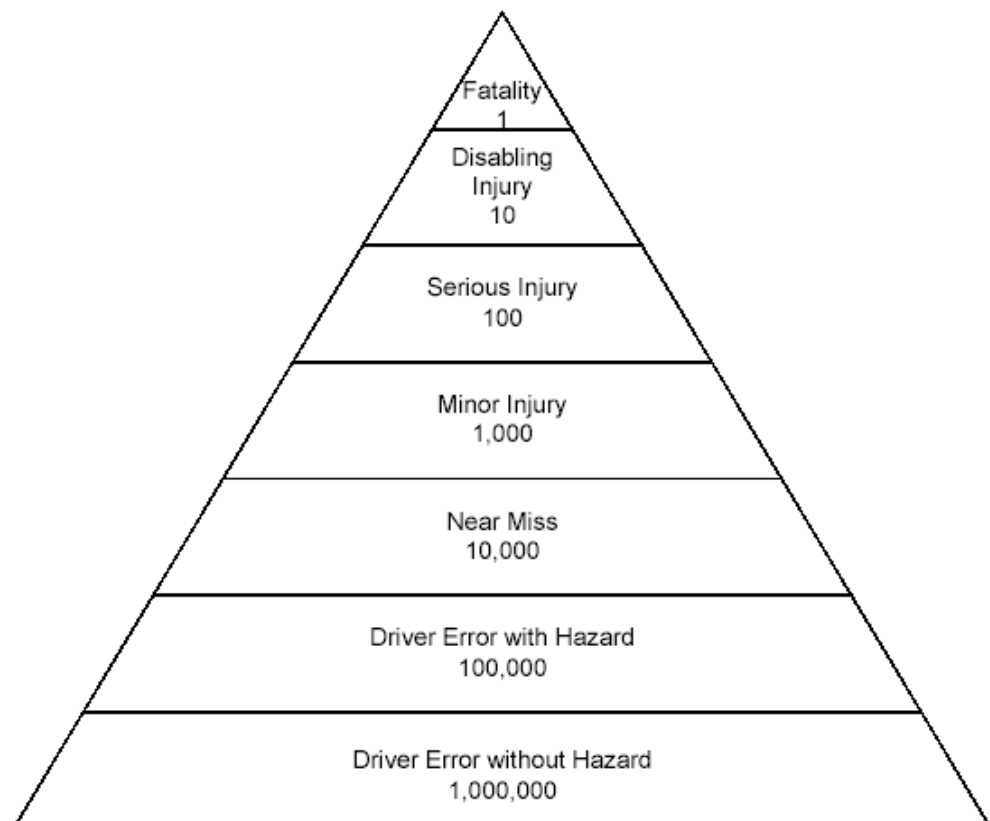


Figure 68: Example of Heinrich's Triangle with hypothetical relative frequencies for driving<sup>27</sup>

27 Own figure.

This approach presumes that driver errors are related to crash occurrence. Exceeding the lane can logically be considered as critical event that leads to a lane change crash or a roadway departure crash or a head-on crash (for undivided roadways). It can be shown statistically that speed variance is correlated with crash occurrence (Garber and Gadiraju 1989 [6]). It can be demonstrated that close car following greatly increases the risk of a rear-end crash if the lead vehicle brakes suddenly and that such aggressive driving is correlated to traffic violations (Evans and Wasielewski 1982 [7]). An initial link between visual demand associated with in-vehicle devices and crash incidence has been forged based on analysis of crash records (Wierwille and Tijerina 1995 [8]). Example results of this study are: 1 driver error leads to 0.06 near misses, and 1 near miss leads to 0.001 accidents. However, these results have not an according-to-law character and cannot be applied without further information and adaptations to traffic conditions in other countries.

Field trials, determination of accident reduction by system specification (static approach), and microscopic traffic simulation of accident occurrence (dynamic approach) can be characterized as follows:

#### Field trials

- Field trials could be another approach to find out the safety impacts of new ADAS-technologies (for example "Lane Departure Warning Assistant" field trial by Netherland Ministry of Transport, Public, Works and Watermanagement 2003, "The effects of in-car speed limiters. Field Studies" by Varhelyi and Makinen 2001 [9], Field trials for implementing Intelligent Speed Adaptation in the UK by Carsten 2000 [10]). However, field trials bear unknown risks for the drivers of the "field vehicles" and for other road users, because of unexpected system behavior. In order to receive representative results, a large number of vehicles has to be equipped with ADAS. That leads once to the fact that the costs of field trials are relatively high. Also in the case of a representative number of equipped vehicles the results might be not trustworthy by the fact that the driving behavior of the test drivers does not correspond due to their training to the driving behavior of normal drivers. Altogether, field trials might be useful to prove the workability of ADAS in a real driving environment. They are useful for the prediction of traffic safety effects, but they will be too expensive.

#### Static Approach

- A more traditional approach is the determination of accident reduction by system specification (static approach). The static approach presupposes that the system specification of ADAS is trustworthy, which means that the consequences on the driving situations because of the system characteristics are well-determined including the possibilities of system failures and unexpected behavior of the system. With the information how the system will affect the driving situation it is possible on the basis of historical static data for traffic effects to predict the accident reduction potential and the impacts on accident severity by ADAS for a base year. Examples for this approach are CHAUFFEUR 2 [11] and the study "Estimating the Potential Safety Benefits of Intelligent Transportation Systems" by McKeever 1998 [12]. The

historical accident situation (historical values for the number of accidents and the severity of accidents) can then be confronted with the hypothetical accident situation in the case of introducing ADAS (new values for the numbers of accidents and the severity of accidents). This proceeding corresponds to the modelling methodology in the context of the CBA. The historical accident situation is within the CBA the without-case. The hypothetical accident situation due to the introduction of ADAS represents the with-case. Therefore, this approach is a practicable approach to determine the accident effects of ADAS. The only objection, which can be made, is that this approach is too theoretical because the dynamics of real driving situations are not explicitly considered.

#### Dynamic Approach

- The microscopic traffic simulation of accident occurrence (dynamic approach) focuses on the real driving situations (for example van Arem 1996 [13], Widodo and Hasegawa 2000 [14]). This approach considers like the static approach the impacts of system specification but with respect to the traffic situation. Typical indicators of that procedure are time-to-collision and number of shockwaves. Therefore, the derived traffic safety impacts are more realistic. The disadvantage is that the simulation can be done only for representative network sections, because considering the total road network would lead to an exceeding number of simulation runs and to an exhaustive need for calibration of traffic data. Therefore, the simulation has to be normally restricted to representative numbers of traffic scenarios. The scenario results must be projected for the total road network. With this projection it is possible to determine the with-case, which can be used in the evaluation process of the CBA.

As an input for the CBA the prediction of safety effects has to deliver figures, which represent the avoiding of accidents. The likelihoods for the avoidance of accidents should be differentiated following the official accident categories (accidents with fatalities, accidents with personal injuries, accidents with property damage). Furthermore, a likelihood for the reliability of ADAS should be also performed, because it is necessary to know to what extent a malfunctioning of ADAS can be expected with a statistical significance.

Altogether, as best practice for the prediction of traffic safety effects by ADAS the stepwise combination of the static approach and the dynamic approach can be proposed. The advantage of the static approach is that with relatively low effort accident safety effects of ADAS can be predicted. Whereby, the results of the static approach can be interpreted as a maximum reachable safety effect. This proceeding is particularly suitable, if ADAS are still in the development process, because information on presumed accident effects can be used as feed-back information for improvements or changes of system specification. If system specification is finalized, it is for the determination of the expected traffic safety impacts useful to accomplish a microscopic traffic simulation.



## **2.5 Traffic Flow Impacts (Non-Safety Critical Effects)**

Beneath the safety critical effects of ADAS further non-safety critical effects of ADAS have to be identified, because these traffic effects could be relevant for the users of ADAS, and for other road users. Moreover, they could be relevant for the society, if they lead to emission reductions, too. For the overall efficiency approval of ADAS it is necessary to consider them in the CBA. Therefore, these traffic effects have to be quantified in a first step. Then, in a second steps, the traffic effects of ADAS have to be monetarized (see 2.6).

ADAS might have impacts on the travel time, fuel consumption, emissions, and CO<sub>2</sub>.

If ADAS enlarges road capacity, homogenize traffic flow, and lead to a reduction of vehicle-kilometers by changes of transport organisation savings of time can be realized. Reduction of time expenditures for the traffic processes means that therein-bound time resources will be lowered. The time delays due to insufficient traffic conditions are an important overall economic matter, which can open considerable productivity reserves. ADAS affect the expenditure of time over several impact channels (see Figure 69).

- "Derived" savings of time arise as a result of reduced vehicle kilometers due to traffic measures. Reduced traffic volumes in passenger and freight transport increase the average speeds. With given distance savings of time are realized.
- "Original" savings of time arise as a result of traffic measures, which change the expenditure of time directly. The vehicle kilometers are not reduced. To these measures belong for example telematic measures, building site management, bottleneck removal and purposeful net additions in the road infrastructure.

Both time effects have to be considered for calculating the effects of ADAS. Between traffic volume and vehicle-speed exist a functional-relation. For original savings of time, there are no standardized calculations possible. These effects must be examined individually for each kind of ADAS.

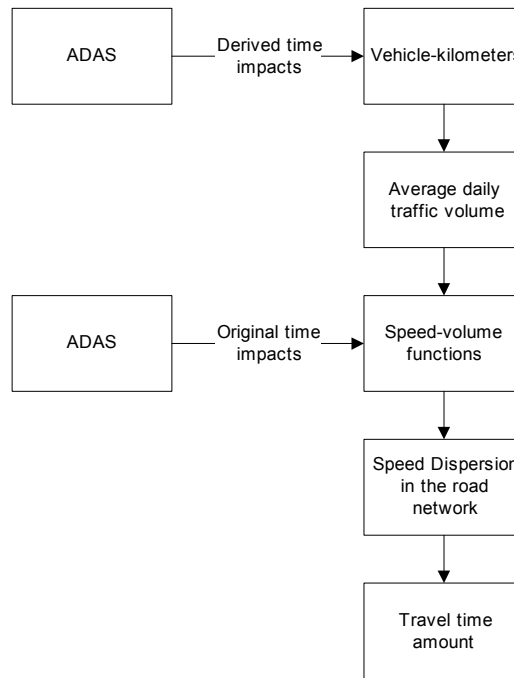


Figure 69: Impact channels of ADAS on travel time<sup>28</sup>

Starting point of the determination of time savings is the change of the vehicle kilometers. Savings of time are calculated over the following steps:

- The reduction of vehicle kilometers is transformed into reductions of the hourly daily traffic volume by using the standardized traffic flow pattern.
- Then it is calculated how the reduced hourly daily traffic volume affects the hourly average vehicle speed. Therefore, the speed-volume functions are used.

ADAS can also affect directly the travel time. Formally, this kind of timesaving leads to a right-shift of the speed-volume function. Using ADAS the same traffic volumes  $Q_0$  are possible with higher speeds on a net section respectively more vehicles with the same flow of traffic can drive with  $v_0$  on the net section (see Figure 70).

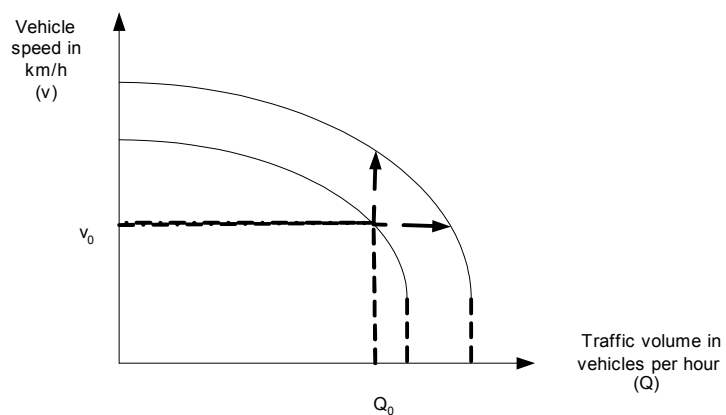


Figure 70: Capacity effect of ADAS<sup>29</sup>

Similar to the time effects of ADAS the impacts on fuel consumption, emissions and CO<sub>2</sub> can be summarized (see Figure 71).

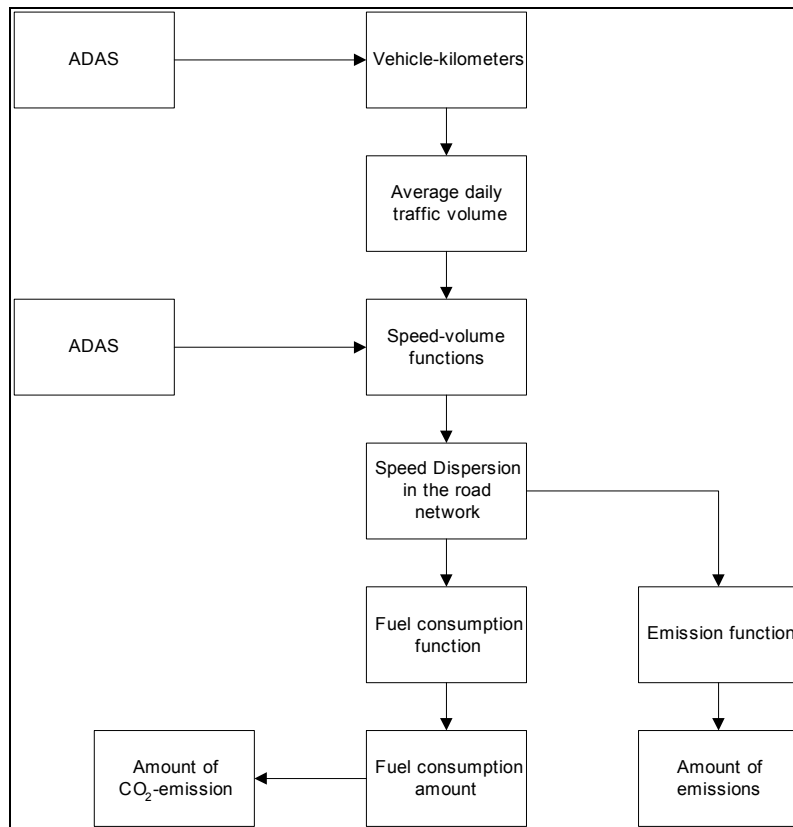


Figure 71: ADAS impact channels on fuel consumption, emissions and CO<sub>2</sub><sup>30</sup>

The impact of ADAS on these effects depends like the impact on the travel time on the fact, how ADAS change the speed dispersion in the road network. The changed speed is an input variable for the fuel consumption functions, which are normally given for each vehicle category (passenger car, trucks, semi-trailer, bus). On that basis the changed fuel consumption can be calculated. The CO<sub>2</sub>-emissions is directly correlated to the fuel consumptions.

The vehicle-speed is a further input for the emission-speed functions, which can be used for the calculation of the emission for each vehicle category.

Analyzing the impact channels of ADAS on time, fuel consumption, emissions and CO<sub>2</sub> leads to following resume:

- First, for the overall efficiency judgment of ADAS it is necessary to quantify all kind of possible effects and not only the effects on which are prime targets of ADAS.
- Second, crucial for the non-safety critical effects is how ADAS affects the speed dispersion in the road network. How vehicle-speed changes are related to time, fuel consumption, emissions and CO<sub>2</sub> is normally defined by given functional relations. The more critical part is how

29 Own figure.

30 Own figure.

ADAS affect vehicle-speed. Therefore, the prediction of speed-impacts of ADAS has to be considered in the same manner like the accident-impact analysis.

## 2.6 Monetary Evaluation of Traffic Effects

The quantification of the changes of resource inputs for transportation by ADAS (=changes of traffic amount in terms of time, energy, accidents, environment) supplies the physical data for the determination of the costs and benefits. The monetary evaluation of the physical effects leads then to the cost statements and benefit statements. The monetary evaluation has therefore a crucial influence on the amount of the costs and benefits.

In the monetary evaluation process the focus on the monetarization of accident savings plays an important role, because ADAS specially aim at the reduction of current accidents. Therefore, the part on the monetary evaluation of accidents has an outstanding meaning and is in detail worked out. As said before in the frame of the "Traffic Impact Analysis" introduction of ADAS might lead to a reduction of the number of accidents and/or to a reduction of the accident severity. Coming up with the calculation of accident cost saving means that economic theory has to evaluate the loss of human life and the costs of personal injuries.

In general the specification of cost unit rates for all traffic effects can be done with different evaluation methods. The following Figure 72 shows which kind of evaluation methods are practically in use.

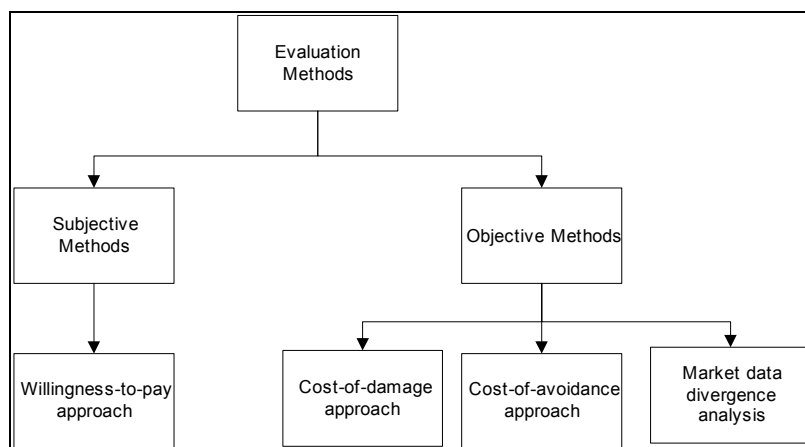


Figure 72: Overview of evaluation methods<sup>31</sup>

The **willingness-to-pay approach** as subjective method questions, how much the victim of an accident will pay to be able to avoid the accident or what compensation amount will be accepted by the victim to approve the damage.

In the frame of the **cost-of-damage approach** the damage caused by an accident is assessed; basic criteria is the decline of gross product because of the accident.

The **cost-avoidance approach** determines the amount that has to be paid so that an accident does not happen or could be lowered in its consequences (e.g. change from fatality to personal injury).

31 Own figure.

Within the **market data divergence analysis** the costs of given effects are indirectly determined; different damage produces different prices on other markets (e.g. real estate market); the difference is calculated as the equivalent value of damage.

### 2.6.1 Accident Costs

Associating a monetary value to the loss of human life may appear repugnant to some one. However, it has to be clear that resources are limited and governments are regularly not willing to commit unlimited resources to road safety improvement. Obviously, a trade-off exists in the allocation of resources between major governmental activities including road safety.

On the other hand as shown before ADAS introduction on the market needs governmental support. Depending on the financial risk distribution between OEM and the public this support of governments can cover thereby beside informational actions, legal measures (e.g. technical regulations) also financial support. However, financial support will be limited. The reachable societal benefits of ADAS, however, represent at least the maximum willingness of governments to pay for the introduction of ADAS, whereby it can be assumed that an actual financial contribution of governments will be lower than this maximum value.

Monetary evaluation of accidents is therefore important for two reasons:

- to ensure that safety is consistently considered in the resource allocation for the research and development of ADAS;
- to ensure that any expenditure for ADAS can be justified because of their accident cost savings, which guarantees the cost-efficiency of ADAS.

The economic assessment of traffic accidents is based on the "cost-of-damage approach". The resource cost calculations can generally corporate following elements:

- current resource costs as consequence of the accident (e.g. policing, hospitalization, medical treatment, vehicle repair costs, road repair costs);
- loss of future output because of the victims: a temporarily loss in the case of injured victims or a permanently loss in the case of fatalities;
- "pain and grief premium" as monetary expression for the suffering of victims and for those who care for the victims.

The first two elements of the resource cost calculation normally can be generated from official statistics, because they focus on the economic output and the resources involved in an accident. The assembling of this gross output validation of accidents requires normally following cost positions:

- loss of output,
- costs of medical treatment,
- costs of damages to vehicles and other property,

- administrative and other costs,
- subjective costs.

The monetary evaluation of the “pain and grief premium” is more difficult due to methodological problems.

### 2.6.2 Pain and Grief Premium

An attempt to quantify the “pain and grief premium” is proposed in the literature in the way that the “resources” approach is replaced by the “value of life” (pretium vivendi) approach (INFRAS, IWW 1995 [15]). A comprehensive evaluation of human life (the “human” as well as the economic aspects) is thereby made. Such an attempt goes beyond establishing the contribution to economic output of the accident victim. It may be an appropriate way of highlighting the personal consequences of accidents, but it does not reveal the economic loss, which is the basis of the cost concept here. The “value of human life” concept should not therefore be pursued as a means of establishing the human cost.

An international comparison (see Figure 73) reveals diverse findings with respect to human costs (=pain and grief premium). The main causes of this diversity are the different assessment methods (“willingness to pay” approach, “cost-of-damage” approach) used in different investigations. The results obtained from the “costs” approach used in Germany, based on the cost-of-damage approach, are the lowest (Baum and Höhnscheid 1999 [16]). The American and British calculations use the “willingness to pay” method. The value for the USA was calculated as the average of the costs for individual injuries of different severity, weighted by the frequency of accidents.

Country	Human Costs in Euro
USA (all injuries)	23,266
UK (minor injuries)	8,031
UK (serious injuries and fatalities)	99,698
Germany (minor injuries)	869
Germany (serious injuries and fatalities)	25,488

Figure 73: International comparison of human costs in Euro<sup>32</sup>

Altogether the Figure 73 shows that there is a need for methodological research to come up with a calculation of the “pain and grief premium”, which is more reliable and trustworthy.

### 2.6.3 Accident Costs Analysis

The derivation of the other cost positions in the frame of the resource cost calculation is not afflicted with such methodical

32 Baum, H., Höhnscheid, K.-J., Ermittlung der volkswirtschaftlichen Kosten der Personenschäden im Straßenverkehr in Deutschland, Berichte der Bundesanstalt für Straßenwesen, Reihe Mensch und Sicherheit, Heft M 102, Bergisch Gladbach 1999.

problems. Figure 74 gives an overview over the elements, which are regularly incorporated in the accident cost analysis.

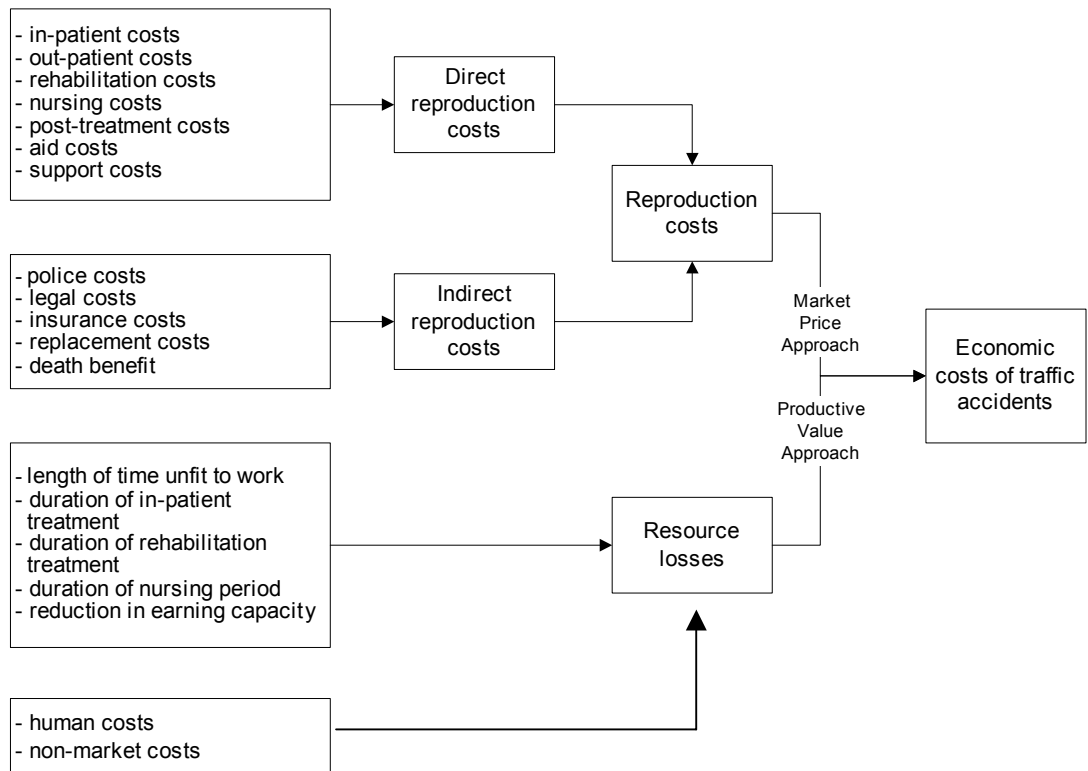


Figure 74: Elements of accident cost analysis<sup>33</sup>

The accident cost unit rates for example for Germany are based on the resources involved in the accident (cost-of-damage approach). The Federal Highway Administration (Germany) gives an annual update of the cost unit rates. Figure 75 shows the cost unit rates for accidents for the year 2000.

Accident consequences	Personal damages (related to the victims)	Property damages (related to the accident)
Accidents with fatalities	1,187,652	26,586
Accidents with serious injured victims	82,937	13,165
Accidents with minor injured victims	3,720	9,534
Serious accidents only property damage	---	12,769

Figure 75: Cost unit rates for the evaluation of accidents for Germany in Euro<sup>34</sup>

In international studies of road accident costs the major source of differences comes up by the costs assigned to fatalities. For the quantification of fatalities the two most common approaches are:

- human capital and production losses based on gross output validation (cost-of-damage approach);
- willingness-to-pay approaches (WTP).

33 Own figure.

34 Höhnscheid, K.-J., Straube, M., Volkswirtschaftliche Kosten durch Straßenverkehrsunfälle, loc. cit. S. 3.

The **cost-of-damage approach** includes all direct economic losses associated with accidents. Several objections have been made to this approach (INFRAS, IWW 1995):

- It is argued that the “cost-of-damage” method, which is based on lost output, would send out the wrong signal with respect to welfare. Although a greater number of accidents leads to an increase in reproduction costs (e.g. repair of property damages, net product from hospital treatment, etc.), the social product will turn out to be higher, the greater the number of accidents. Against this argument, it can be objected that accidents cause a reduction in the productive factors of labor and real capital, which, according to the used production function, leads to a decline of gross product. Losses of resources through road traffic accidents are accordingly reflected in a reduction and not in an increase of gross product. The argument that it causes an increase of gross product could therefore apply at most to the reproduction services, which are included in the statistical records of the national economy’s net product. However, it must also be noted that the factors of production used in reproduction services would have been used in other applications if no accident had occurred. The increase of the gross product does not stem specifically from reproduction work following accidents but from the production potential of available resources.
- The “cost-of-damage” method does not cover all damages, but only such which cause a reduction of economic net product. This point seems reasonable; however, this is the whole purpose of the evaluation procedure. It is supposed to determine costs by accidents, and these costs are derived from an economic assessment of accidents. Any damage that is not relevant to the market can also be taken into account in the assessment.
- The “cost-of-damage” method can lead to ethical problems in that way that injuries may be assessed differently, depending on the individual injured and his/her contribution to production. For example, the value of a human life would be assessed differently depending on whether the victim of the accident was a full-time or part-time worker. It is possible to avoid the kind of value distinction that depends on working arrangements by establishing the individual’s potential productive value, i.e. what could be achieved with normal use of the factors of production.

Under the WTP method, estimates reflect the direct and indirect costs incurred by the involved individuals as well as those of the larger society. In WTP models, injury and fatal accident costs are ultimately defined in terms of what society and individuals are willing to pay to reduce, by given magnitudes, the probability of serious injuries or fatalities.

The following objections have been made to the “**willingness to pay**” approach (Baum, Höhnscheid 2000 [17]):

- Willingness-to-pay analyses are conducted using surveys (“stated preference approach”). The results depend on the



way the survey is designed and conducted. The extent to which the methods of evaluation are comparable in different cases is therefore questionable.

- In establishing their “willingness to pay”, false estimates may be made by the respondents. Expressing a willingness to pay is one thing; actually having to pay is another. Even on the question of human health, it is necessary to be aware of the danger that hypothetical and actual willingness-to-pay are at variance.
- The “willingness to pay” concept sets out to determine the cost of accidents in terms of the market price the road user would be prepared to pay to prevent accidents. In the “willingness to pay” analyses, however, only the evaluation of the demander is considered and there is no assessment of the price at which the supplier would provide certain services. If, however, the “willingness to pay” expressed in the survey is used as a basis for calculating costs; the costs in structural terms are overestimated. The “willingness to pay” approach goes further than the market price level approach as it includes an assessment of consumers’ incomes.

Figure 76 compares cost unit rates for fatalities derived on the basis of the cost-of-damages approach and the willingness-to-pay approach for the U.S.

<b>Accident severity</b>	<b>Cost-of-damages</b>	<b>Willingness-to-pay</b>
Injury Level 1 (Minor)	\$12,200	\$13,418
Injury Level 2 (Moderate)	\$39,759	\$43,655
Injury Level 3 (Serious)	\$114,771	\$120,018
Injury Level 4 (Severe)	\$202,141	\$221,951
Injury Level 5 (Critical)	\$685,781	\$752,988
Fatality	\$962,440	\$3,580,536
Only property damage	\$3,397	--

Annotations: Injury Levels correspond to the accident severity scale of the American Association of Automotive Medicine

Figure 76: Comparison between cost-of-damages and willingness-to pay (1996)<sup>35</sup>

The comparison between cost-of-damages and willingness-to-pay shows that the deviation between the cost unit rates for injuries are negligible. The willingness-to-pay cost unit rates are only slightly above the cost unit rates of the cost-of-damage approach.

On the other hand for the fatalities a substantial deviation exists. The cost unit rate of the willingness-to-pay is more than three times higher than the cost unit rate of the cost-of-damage approach.

However, the “willingness to pay” approach to evaluate the cost of accidents is fraught with problems and disadvantages. The cost of accidents should be calculated by means of a completely objective process, geared to actual economic loss. The “cost-of-damage” approach fulfils the claim to provide the most objective

35 Peck, R. C., Healey, E. J., Accident Costs and Benefit Cost Analysis, Los Angeles 1996.

representation of accident costs. Investigations involving more subjective survey methods provide additional information, which increases what we already know of the complexity of calculating the costs of accidents. However, their disadvantages make them less suitable for planning purposes.

#### 2.6.4 Time Costs

Travel time costs seem from the ADAS point of view not so important, because the safety enhancement is the actual objective. However, travel time savings are often the greatest potential benefit of transport improvements [18]. Time costs and the benefits of time cost savings vary widely depending on factors such as the type of trip, traveller and travel condition. For someone, who dislikes travelling or driving by car, the subjective time costs might be zero or negative. Under some circumstances travel time costs can be very high, for example when travelling to an emergency, rushing to catch an air flight or pick up a child at daycare center. Independently from the subjective or individual assessment of time most of travel/transport time represents from an overall economic standpoint costs. Travel time costs refer to the value of time spent in travel. Therefore, it includes costs to businesses of time by their employees, vehicles and goods, and costs to consumers of personal unpaid time spent on travel. For a complete efficiency analysis the effects of ADAS on the travel/transport time have to be incorporated. In order to be able to evaluate the time in monetary terms, the concept of opportunity costs is used.

The time costs represent the economic value of the opportunity use of one-hour travel time. Figure 77 shows the proceeding how time costs are calculated. Vehicle-kilometers and vehicle-speed determine the amount of travel time. Beneath the traffic variables length of relevant network section and the vehicle-speeds play the number of vehicles, which are equipped with ADAS, and also the number of vehicles, which are affected by ADAS, an important role for the effects on travel time. The product between amount of travel time and time cost unit rate gives the time costs.

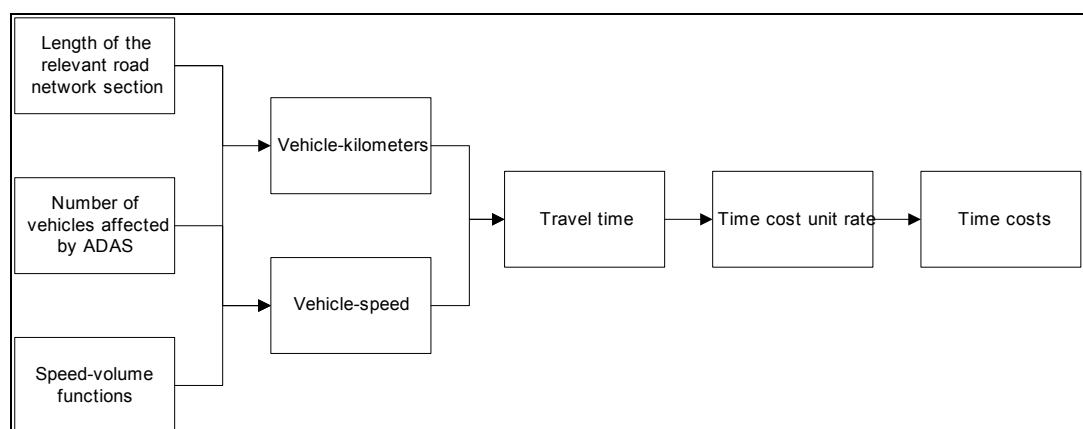


Figure 77: Proceeding of determining time costs<sup>36</sup>

Figure 78 shows the various components, which have been integrated in the calculation of the time cost rates.

<b>Freight transport</b>	Labor costs and expenses of the drivers	Labor costs
		Expenses
	Provision costs	Interest charges of the capital investment
		Depreciation of the capital investment (50% independent of vehicle-kilometers)
		Garage
	General costs	
<b>Passenger transport</b>	Time costs	Time costs for a labor-hour
		Time costs for a leisure-hour
	Provision costs	Commercially used passenger cars

Figure 78: Components of time costs<sup>37</sup>

On the basis of Figure 78 are normally cost unit rates worked out for the vehicle types. Figure 79 represent the cost unit rates for time, which are used in Germany for the Federal Transport Plan and UK for the “standard **Cost Benefit Analysis** framework for evaluating transport improvements” (=CoBA model), differentiated for average vehicle-types.

<b>Vehicle category</b>	<b>Cost unit rates in €/h</b>	
	<b>Germany</b>	<b>U.K.</b>
Average Passenger Car	11	13
Average Truck	32	14
Average Bus	66	82

Figure 79: Time cost unit rates for vehicle categories (Base Year 2000)<sup>38</sup>

Figure 79 shows that the main difference exists for the cost unit rates of trucks. The cost unit rates for trucks in the CoBA model is lower because provision costs for freight transport are not considered.

The cost unit rates for passenger cars are quite similar. Furthermore, the CoBA model allows a distinction for passenger cars between work-related traffic and leisure-related traffic. The cost-unit rate for passenger cars used for work is 32 € per hour and for passenger cars used for leisure is 9 € per hour.

37 own illustration following Kommentar EWS-97, pp. 63.

38 Planco Consulting GmbH, Numerische Aktualisierung interner und externer Beförderungskosten für die Bundesverkehrswegeplanung (BVWP) auf den Preisstand des Jahres 1998, Schlussbericht im Auftrag des Bundesministeriums für Verkehr, Bau- und Wohnungswesen, Essen 2000, pp.15; Baum, H., Höhnscheid, H., Höhnscheid, K.-J., Peters, H., Zeitbewertung im Güterverkehr, Schlussbericht im Auftrag des Bundesministeriums für Verkehr, Bau- und Wohnungswesen, Köln 2000, p. 74; Forschungsgesellschaft für Straßen- und Verkehrswesen, Empfehlungen für Wirtschaftlichkeitsuntersuchungen an Straßen (EWS-97), Köln 199, p. 13; R. Vickerman, Evaluation Methodologies for Transport Projects in the United Kingdom, in: Transport Policy, Vol. 7, No. 1, January 2000, pp. 7-12; own calculations.

Different occupancy assumptions are the main reason for the higher cost unit rate for buses in the CoBA model.

### 2.6.5 Vehicle-Operating Costs

The estimation of vehicle operating costs is based on two terms. The first term is fixed for every vehicle type and describes the basic costs for vehicle operating. This cost component is independent from the vehicle-kilometers. The second term is the product of fuel consumption and fuel price. The fuel consumption depends on vehicle-kilometers, vehicle-speed, vehicle type, and road design. Following functions are the bases for calculating fuel consumption.

$$FC_{vt} = \frac{1}{10} \cdot \Phi_{vt} \cdot FP$$

with :

$$\Phi_{vt} = c_0 + c_1 \cdot v^2 + \frac{c_2}{v}$$

$FC_{vt}$ :=	fuel consumption for various vehicle-types (vt)
vt:=	passenger cars, trucks < 3 tons, trucks > 3 tons, semi-trailer, coaches, regular bus
$\Phi_{vt}$ :=	fuel consumption factor for various vehicle-types
FP:=	fuel price
$c_i$ :=	vehicle-type specific fuel consumption parameters, i = 0 to 2
v:=	vehicle speed (km/h)

The fuel consumption factors ( $\Phi_{vt}$ ) consider following technical relations:

- Fuel consumption increase superproportionally at high speeds, because the air resistance increases with the square of the speed.
- Fuel consumption depends at very low speed on the reciprocal value of the speed (for  $V = 0$  km/h rises the specific fuel consumption approximately infinitely).

Therefore, the relation between fuel consumption and speed is u-shaped.

The fixed cost term (see Figure 80) is differentiated for four groups of vehicles (passenger car, truck, semi-trailer, bus).

Vehicle type	Fixed term in €/(100 km*vehicles)
Passenger car	9.16
Truck	14.19
Semi-trailer	24.37
Bus	45.90

Figure 80: Fixed operating costs for vehicle types<sup>39</sup>

The fuel costs are calculated as product between fuel consumption and fuel cost unit rates.

- Within the framework of the CBA the cost unit rates for fuel are net fuel prices: the fuel price, which has to be paid at the gas station, is lowered by the mineral oil tax and value-added tax and for Germany furthermore the contribution for the provision of mineral oil stocks must be taken off. This happens, because taxes and contributions are transfer payments between economic sectors and the government (disbursements for private households and industry, deposits in same amount for the government).
- In the evaluation process for private based break-even-analyses the fuel price, which has to be paid at the gas station, is the relevant price. For the transport industry this fuel price has to be lowered by the value-added tax (vat), because for transport firms the vat is a going through post. However, the vat has to be included for private households.

Figure 81 gives an overview over the net fuel costs and gross fuel costs for transport industry.

Fuel	Fuel cost unit rate in €/l	
	Net fuel costs	Gross fuel costs
Gasoline	0.185	---
Diesel	0.189	0.692

Figure 81: Fuel cost unit rates<sup>40</sup>

## 2.6.6 Emission Costs

The estimation of emission quantities is based on emission-vehicle-speed functions for carbon monoxide, carbon hydrogen, nitrogen dioxide, sulfur, soot, and other particles. The different kinds of emissions are transformed by toxical factors to a standardized unity of nitrogen x-oxide.

The air pollution contains two components with different directions of action:

39 Forschungsgesellschaft für Straßen- und Verkehrswesen, Empfehlungen für Wirtschaftlichkeitsuntersuchungen an Straßen (EWS-97), Köln 1997, p. 13; own calculations.

40 Planco Consulting GmbH, Numerische Aktualisierung..., loc. cit., p. 15f.; own calculator.

- the direct emissions, which spread spaciouly in the atmosphere and thus are independently of the distance to the source of emissions and
- the indirect and secondary emissions, for whose damaging effect the distance between the source of the pollutant output and the place of the emission is of special importance. Indirect emissions are life-cycle emissions other than point of use emissions, and secondary emissions are produced by chemical reactions in the atmosphere to form pollutants such as ozone and "smog".

The indirect and secondary emissions show the direct impairment of humans and buildings by air pollutants. In order to be able to use this approach, the following data are necessary:

- auxiliary variables for the estimation of the pollution from direct emission,
- data concerning the land development structure of the examined route networks for the estimation of the number concerned of inhabitants.

Air quality is then measured (as pollutant concentration in the air, unit [g/cm<sup>3</sup>]) or calculated with simple models or more sophisticated models such as air dispersion models, weather conditions, number and characteristics of buildings along the regarded areas.

Only those locally concentrates of arising pollutants of the traffic are determined. For large road networks, as they are subordinated with the traffic measures examined here, this method - particularly due to the necessary information about the land development – is problematic. Therefore, the method for the calculation of direct emissions is used.

In the emission costs air pollutants represent the negative impacts on vegetation. They contain the costs of diminished returns for useful plants and the costs of the forest damage.

The determination of the emitted pollutant quantities takes place similarly to the algorithm deriving the fuel consumption. As a function of the vehicle speed-emission factors are determined according to the following formula:

$$EF_{FGj} = C_0 + C_1 * V^2 + C_2 / V \quad \text{with}$$

EF ...emission factor (in g/[km • vehicles])

V ...vehicle speed (in km/h)

C<sub>0</sub>, C<sub>1</sub>, C<sub>2</sub> ...parameters depending on vehicle type and emission

FG ...index for the various vehicle types

j ...index for the emission

The EWS-97 emission factors refer to the structure of the vehicle fleet of the year 1990.

The different kinds of emissions are transformed by toxical factors to a standardized unit of nitrogen x-oxide (see Figure 82).

<b>Pollutant</b>	<b>NO<sub>x</sub></b>	<b>CO</b>	<b>HC</b>	<b>SO<sub>2</sub></b>	<b>PA</b>
<b>Toxical factor</b>	<b>1.0</b>	<b>0.003</b>	<b>1.5</b>	<b>1.0</b>	<b>0.342</b>

Figure 82: Toxical factors<sup>41</sup>

The cost unit rate for this unit is 365 € for each ton of the standardized unity of nitrogen x-oxide

### 2.6.7 CO<sub>2</sub>-Costs

Carbon dioxide (CO<sub>2</sub>) is a byproduct of combustion with the harmful effect of climate change. The green house effect is considered separately because CO<sub>2</sub> does not have direct toxic effects. The evaluation of the green house effect is based on the quantification of carbon dioxide. The cost unit rate for one ton of carbon dioxide is 205 €, which represents long-term avoidance costs according to the forthcoming German Federal Transport Investment Plan [19]. In the frame of European Commission ExternE programme the green house gas damage costs were ranged between 20 to 63 € for one ton of carbon dioxide [20].

The CO<sub>2</sub>-emission is under the assumption of a complete burn of fuel directly correlated with the fuel consumption. Therefore, following emission factors are in use:

- Petrol: 3,12 kg CO<sub>2</sub> per kg petrol,
- Diesel fuel: 3,15 kg CO<sub>2</sub> per kg diesel fuel. ´

Because of the complete-burn assumption the emission factors represent the maximum value of the CO<sub>2</sub>-emission.

41 Forschungsgesellschaft für Straßen- und Verkehrswesen, Empfehlungen für Wirtschaftlichkeitsuntersuchungen an Straßen (EWS-97), Köln 1997, p. 41.

### 3 **BREAK-EVEN ANALYSES**

#### 3.1 ***Break-Even Analysis for ADAS-User***

CBA focuses on benefits and costs from the society point of view; with that they cover economic impacts on users as well as on third parties. One has to keep in mind that benefits and costs on the society level are not necessarily identical with the sum of individual benefits and costs. Therefore, benefits and costs have to be accounted separately on a private basis because market success of ADAS depends at least on the general acceptance of the system users and their willingness-to-buy ADAS.

However, the potential user groups of ADAS will have different price sensitivities. The most price-sensitively user group are the transport firms, because they have the greatest interests to be reimbursed for the additional costs of ADAS by possible cost-savings. The lower the price, they have to pay for ADAS, the earlier they can profit from the cost-savings enabled by ADAS. A less price sensitivity can be expected for the drivers of upper class cars. First, the additional costs of ADAS play only a subordinated role with respect to the total vehicle price. Second, this group will also have a higher willingness-to-pay for safety and comfort add-ups. The drivers of medium class cars are normally in the same way interested in additional safety and comfort technologies, however, their willingness-to-pay is due to their income constraints not so high. Therefore play the additional costs of ADAS in relation to the total vehicle costs a more important role for the decision to buy ADAS.

The traditional tools for the consumer acceptance analysis (like field studies, questionnaires, analysis of willingness-to-pay, price-elasticity concepts) are afflicted with substantial uncertainties for the prognosis of the future size of the market for systems, which will be introduced on the market at a later time.

Therefore, it is proposed to apply methods of the business economies (break-even-analysis, BEA) to determine the demand for ADAS. The BEA can be defined as method to find out the recovery point in time, when expenditures for an investment are reimbursed by the benefits of the investment. Objective of the BEA is the determination of the break-even point (=profit threshold) for the individual user. On the cost-side of the BEA the investment costs, operating costs, and maintenance costs of ADAS have to be quantified. Compared to the overall costs no difference in the amount of the costs arises. Otherwise the interest rate for determining the annual costs might be different to the interest rate, which is used in the CBA.

The total investment costs of the users have to be distributed over the whole economic service life of ADAS. This can be done by the annuity factor. The annuity factor is given as:

$$a = \frac{q \cdot (1 + q)^n}{(1 + q)^n - 1} \text{ with}$$



- a: annuity factor,  
 q: interest rate divided by 100,  
 n: economic service life of ADAS.

The choices of the interest rate and the life-cycle have a decisive influence on the amount of the annual investment costs. Therefore, it has proposed that an average market interest rate and an average life-cycle are used, which can be expected as representative for the whole economic service life of ADAS.

The annual investment costs are the product between the market price of ADAS and the annuity factor.

Operating and maintenance costs are normally determined as annual costs. Therefore, the total annual costs for the user of ADAS are the sum between annualized investment costs, annual operating costs and annual maintenance costs.

The annual costs of ADAS have to be confronted with the annual benefits, which a user can reach.

The break-even point represents the situation that realized benefits are equal to the costs of the user. Figure 83 gives a schematic overview over the determination of the break-even point and the relation to the overall demand for ADAS.

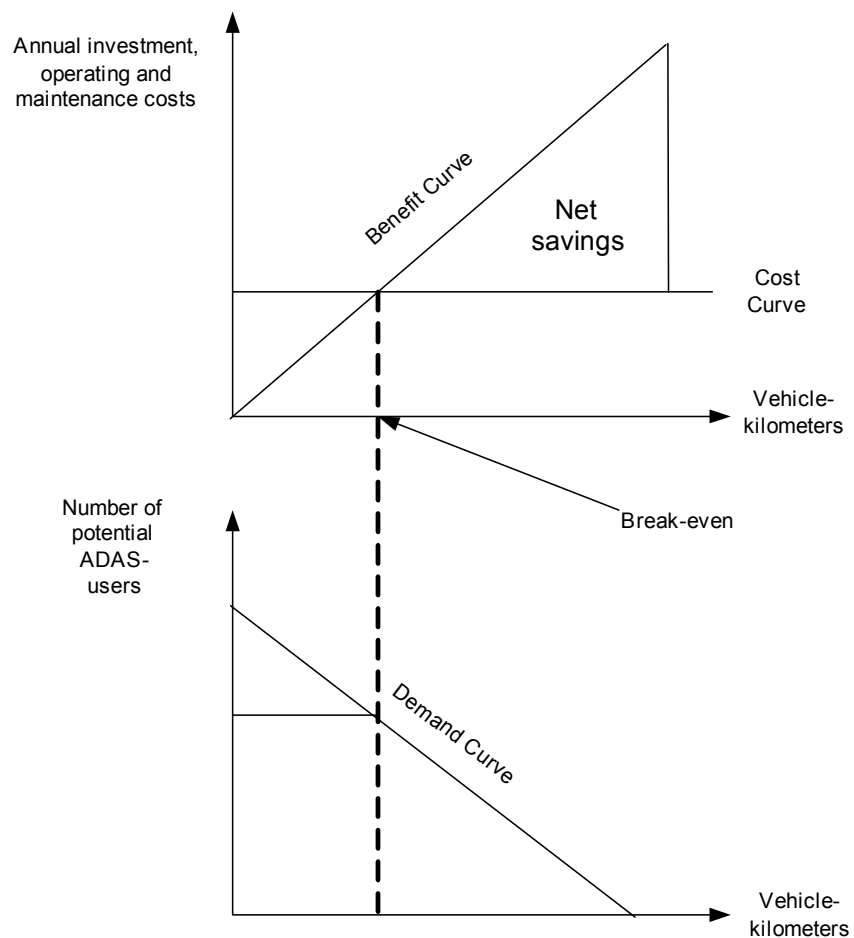


Figure 83: Break-Even Analysis<sup>42</sup>

In this figure the vehicle-kilometers are used as critical value for the determination of the break-even point. The usage of vehicle-kilometers is normally justified because safety and traffic effects depend on the amount of vehicle-kilometers, which ADAS-user will have. However, the relation of the break-even point to the vehicle-kilometers can be easily transformed to time periods. For example, if the break-even point is reached by 120,000 vehicle-kilometers a driver with an annual average of 60,000 vehicle-kilometers will reach the break-even point after 2 years; a driver with an average of 10,000 vehicle-kilometers per year will reach his break-even point after 12 years.

The break-even point is the point where costs of the ADAS-users have been recovered or reimbursed. The process of reimbursement is continuously maintained by benefits due to using the system.

The cost savings result from the following categories:

- Market costs (vehicle-operating costs: fuel, oil, tires, maintenance; ownership costs: insurance premiums, taxes);
- Non-market costs (travel time, discomfort/comfort, safety).

Benefits for the system users can come up from the possible traffic effects of ADAS, which might lead to a reduction of vehicle-operating costs, travel time and to the enhancement of traffic safety. Savings of insurance premiums depend on the overall effect of ADAS on the road accident. These benefits - as similar to the CBA - in the frame of the BEA are calculated as cost savings, which come up due to a comparison between a situation with ADAS (with-case) and a situation without ADAS (without-case). The comfort benefits present an added-value to the ADAS-users. Therefore, they have to be calculated directly.

In order to complete the BEA the attainable benefits have to be confronted with the system costs, which are paid by the system user.

The best information on possible ADAS costs can be provided by market insiders such as OEM. Therefore ADAS costs should be preferably derived in a direct way. The ADAS costs cover following positions:

- the expenditure for ADAS and
- operating and maintenance costs for ADAS-components.

Unfortunately, OEM have sometimes objections to reveal cost information to the public (e.g. transport policy, planners, research institutes, competitors). In that case cost information provided by US-DOT (ITS Unit Cost Database) can be used as reasonable proxy. Figure 84 shows exemplary estimations of average capital costs and average maintenance costs per year for several electronic vehicle-on-board-components, which could be seen as ADAS-subsystems.

<b>Vehicle-on-Board-Systems/Unit Cost Element</b>	<b>Lifetime (years)</b>	<b>Average Capital Costs (€)</b>	<b>Average Maintenance Costs (€ per year)</b>
Communication Equipment	7	300	6
In-Vehicle Display	7	75	1.5
In-Vehicle Signing System	7	280	5.6
GPS/DGPS	7	375	7.5
GIS Software	7	250	0
Route Guidance Processor	7	125	2.5
Sensors for Lateral Control	7	950	19
Electronic Toll Equipment	7	70	0
Mayday Sensor and Processor	7	400	8
Sensors for Longitudinal Control	7	400	8
Advanced Steering Control	7	550	11
Advanced Cruise Control	7	225	4.5
Intersection Collision Avoidance Processor, Software	7	415	8.3
Vision Enhancement System	7	1,700	85
Driver and Vehicle Safety Monitoring System	7	955	47.75
Pre-Crash Safety System	7	1,625	52
Software, Processor for Probe Vehicle	7	100	2
Active Tag	7	35	3.5
Passive Tag	5	7.5	0
In-Vehicle Navigation System	7	1,400	0

Figure 84: Capital and Maintenance Costs of Electronic Vehicle-Subsystems<sup>43</sup>

Possible benefits for the system users are:

- fuel-cost savings,
- time-cost savings,
- accident-cost savings,
- savings of insurance premiums,
- comfort benefits.

The reachable amount of fuel savings, time savings and accident savings depends on the system specification of ADAS. These physical effects are determined in the frame of the CBA. However, in the CBA these benefits were aggregated for all system users and include furthermore the benefits for third parties. In order to work out the individual user's benefits it is necessary to disaggregate the overall effects. Usually, BEA follows CBA, which provides the possibility of separating user benefits from third party benefits.

43

U.S Department of Transportation, IST Unit Cost Database (as of September 30, 2002), [www.benefitcost.its.dot.gov](http://www.benefitcost.its.dot.gov); own calculations.

Whereas BEA calculation procedures show significant similarities to CBA the important difference appears in the field of cost unit rates. The point of view is no longer focused on calculating resource consumptions of the society. In contrast to that BEA cost unit rates have to reflect all components that influence the asset position of the individual ADAS-user. As a consequence taxes such as fuel taxes, vat have to be included in the cost unit rates.

The effects on insurance premiums and on the comfort are not included in the CBA. Both effects therefore must be estimated additionally.

The insurance premiums might play an important role as possible savings of market costs for the system user due to the safety effects of ADAS. Normally, the lower likelihood of accidents by ADAS for a system user might be not feasible. The reason for this phenomenon, that car drivers underestimate the risk of to-be-an-accident-victim, is, that the subjective risk estimation is below the objective risk. However, the insurance premiums are until now positively correlated with the actual accident situations on roads. That means a reduction of accidents will lead to lower insurance premiums and an increase of accidents to higher insurance premiums. If ADAS reduces accidents, it can be expected that the insurance premiums will be lowered, especially for vehicles equipped with ADAS. Therefore, the insurance premiums can be seen as direct cost savings for the system user, which furthermore give him an incentive to use ADAS.

The question "Will the introduction of ADAS help to reduce insurance premiums for drivers?" is of considerable importance to drivers and the community at large. It is also, of course, significant for OEMs and suppliers in the automotive industry, for telematics contractors and experts, and for a wide range of public sector bodies. Most of all, the European Commission is rightly expecting, from insurers as well as many other parties, every possible facilitation of its ground-breaking innovations in policy, funding and research towards the halving of road deaths in Europe by 2010.

The vast majority of motor claims are for material damage to the vehicle. In this respect, therefore, improvements to even quite small aspects of vehicle design can have a major effect in reducing insurance claim payments. Thus, for example, insurers have strongly backed the move to fit high central rear brake lights, which have already saved many rear-end accidents. Location of vulnerable parts is important, as also is the beneficial trend for modular and easily replaceable elements at front and rear. Insurers have welcomed the trend to position light clusters higher up the car in design configuration so they are less likely to be damaged by contact with other vehicles, street furniture etc..

Insurance treatment of past innovations is not necessarily a clear guide to the future. Certainly, comparisons with previous individual vehicle-safety measures such as the airbag are not much help because of the complex system specifications of ADAS applications and the very different levels of technology involved.

Some examples may nonetheless be worth noting, as follows: Reversing aids are definitely helping to keep premiums down. So also have anti-theft systems. Disc brakes came in when records

were not properly chronicled so it is difficult to discern their overall effect on premiums. Seat belts greatly reduced accident deaths but this effect has to be balanced by the accidents still resulting in severe injuries, and corresponding insurance payments. Costs of replacing airbags after use made the material damage aspect of accidents more expensive. There were also initial problems with allegations of burst eardrums and unprompted deployment of them, which actually made some insurers' figures worse before the problems were solved and the benefits seen in true perspective. More stringent checks as to windscreen scratches and stone chipping introduced into some national annual vehicle tests led to more windscreen replacement claims. A car that absorbs impact by deforming may thereby save the driver's life but can cost a lot more to repair.

Introducing ADAS means adding damageable components to the vehicles. When cars become old, mechanical parts need to be replaced. But it may be much harder to determine whether an electronic component is still working correctly, especially one that only comes into its own in an accident-prevention scenario. If the vehicle in which ADAS is fitted has had an accident, even in no way involving deployment of the ADAS-linked equipment itself, it may well be necessary to check that the shock-loading or other factors have not harmed the ADAS equipment and associated electronic linkages. It may be much harder to diagnose and verify (and so reassure the driver's insurers) that such checks have been properly carried out and any necessary replacement equipment has itself been fully integrated and tested, not least because such work may well require the involvement of higher-trained, and therefore more expensive, mechanics and specialist testing agencies and their respective equipment.

Insurers may need to be convinced that more and better technology in vehicles will lead to better driving. Drivers with expensive kit increasingly drive at the edge of, or outside, the safety envelope and even to indulge in "risk compensation", the tendency for humans to need an element of risk. Drivers may use ABS to excuse maintaining high speeds in slush or heavy rain, and to overlook the fact that the system is not primarily aimed at reducing stopping distance but to prevent wheel lock-up.

Motor insurance is increasingly a commodity and renewal is so competitive that it is dominated by computer-generated tariffs, and is tabulated in the main by standard criteria such as postcode, age, sex, number of claims-free years etc.. It is possible that the introduction of ADAS and other telematic systems will have to overcome the mindset that premiums can only be reduced when telematics have been standardised in such a way that a given piece of kit can be assigned to a specific technically-defined set for which statistics demonstrate a consistent measurable advantage. Until then, it is feared, some insurers may just regard new systems as adding to the sum insured and hence translate their inclusion through the same percentage to a higher premium.

Aside from the considerations as to premium levels referred to above, it may be hoped that insurers will agree to assign any vehicle equipped with ADAS to a lower (i.e. more favourable) insurance rating group. However, The Group Rating System,

introduced in the UK in 1992, depends at present on reparability as one of its primary differentiation criteria. As this system dominates UK motor insurance tariffs, it will be important to persuade insurers to counter the reparability aspect by stressing the huge potential of ADAS to prevent accidents occurring in the first place. It will also be necessary to avoid insurers following a tendency which some have demonstrated in respect of anti-theft alarms and tracker systems, namely to require the latest upgrade of them to be fitted as a prerequisite for insurance renewal. Dialogue is needed as to the equivalent balance of criteria for reduction or levelling of premium, and as to iterative vehicle equipment stipulations, in other European national insurance markets.

Reinsurance premium is an important component of motor insurance premiums. At the level of reinsurance, there are subtle trade-offs between frequency and severity of claims. To reinsurers, personal injury is often the most important element. Medical cost inflation, at least in the UK, has been running at around 9% per year. Changes to the official discount tables in structured injury/incapacity settlements and the court awards of costs in contingency-fee/conditional fee litigation have exacerbated the position. There is a danger that structured settlements for permanent incapacity will become taxable, thereby directly increasing insurers' payments. Sadly, but logically, where a fatal injury is avoided but severe injury or long-term disability is incurred, medical costs and long-term loss of earnings compensation will increase the cost to insurers.

Insurance loss records have a direct effect on insurance premium levels. Traditionally, insurers wait until actual data develop before they adjust premium levels to reflect technology innovation. The faster and more widely that ADAS penetrate the market, the sooner beneficial loss records will develop. Meanwhile, good opportunities may already exist to use the introduction of ESP and ISA systems to demonstrate to insurers that electronic engineering can dramatically reduce accidents and their effects.

In summary, it is very much to be hoped that insurers will be prepared to reduce premiums for drivers of vehicles equipped with ADAS. In the light of market practices and considerations that have built up in recent years, it is also clear, however, that they cannot automatically be expected to do so until improved claims statistics can be shown to result from ADAS implementation.

Beneath the traffic effects ADAS-technologies facilitate routine activities of the driver, who is partly relieved by his driving tasks. The travelling comfort thereby will be improved. Whether the usage of the system creates an additional comfort benefit for the driver is essential for market acceptance and market success. The comfort benefits by ADAS for the drivers come up from the impacts on the driving situation due to the system specifications and the convenientness of operating the system.

Until now comfort benefits are not addressed in the economic evaluation of ADAS. The economic analysis concentrates on the economical advantages for the system users and/or third parties caused by the usage of ADAS. Especially for a complete BEA it is necessary to integrate comfort benefits within the economic

assessment. Therefore, the interdependency between comfort and economical benefits has to be examined:

- Comfort is a variable, which depends strongly on the feeling of the individual user. Comfort thereby has subjective character. The user satisfaction represents however a necessary condition for the market acceptance.
- The economic benefits are important for the market success, because the attainable cost savings (e.g. vehicle-operating cost savings, time-cost savings, safety gains) increase the willingness of the users to buy ADAS. These economic benefits have an objective character.

The relation between economic benefits and comfort effects and their influence on the willingness to buy or not to buy ADAS is shown in Figure 85.

		Comfort Improvements	
		Yes	No
Economic Benefits	Yes	Willingness-to-buy ADAS exists.	Willingness-to-buy ADAS is undetermined, because of missing user acceptance.
	No	Willingness-to-buy ADAS is undetermined, because economic benefits do not exist.	No willingness-to-buy ADAS.

Figure 85: Interdependencies between Economic Benefits and Comfort Improvements<sup>44</sup>

A clear order of the relations between comfort and economic benefits is not possible. Insufficient comfort of the system can hinder the market acceptance also ADAS will have significant economic benefits. On the other hand an increase of the travelling comfort might be not sufficient for market acceptance if ADAS leads to higher user costs.

Conclusion is that comfort benefits are relevant for customer decisions on ADAS. They have to be integrated in the BEA. Therefore a methodological approach has to be developed.

### 3.2 Break-Even Analysis for OEM

The BEA for OEM is normally used as an internal economic evaluation to prove, if ADAS market introduction can be justified under following objectives:

- Finding a pricing policy to achieve the rentability of ADAS,
- Increasing the market share or sale profits by adding-up the value of car due to ADAS.

Furthermore, determining the break-even point for ADAS can be seen as a starting point for the efforts of OEM to reduce ADAS-production costs. That means that the OEM due to his rentability objective are interested in lowering continuously the break-even point for ADAS.

44 Own table.

Like the BEA for the system users the OEM have to confront their benefits with the costs of ADAS. The crucial point of the BEA for the OEM is that several uncertainties due to the final values of costs and benefits exist, because the BEA of ADAS has to be undertaken before the introduction on the market takes place.

Cost components, which have to be considered in the BEA, are:

- Research and development costs of ADAS,
- Production costs for ADAS,
- Other ADAS related costs.

The research and development costs for ADAS are regularly given figures, because they are seized by the internal financial accounting system of the OEM. Due to their production experiences OEM will also be able to estimate correctly the production costs for ADAS. Uncertainties definitely exist for the position "Other ADAS related costs". This cost position covers all kind of expenditures, which are caused by ADAS. The most relevant cost types in this category are following:

- Requirements for compensation of ADAS-users because they suffered from ADAS malfunctions,
- Costs of call-back campaigns because of the technical complexity of ADAS.

Both cost positions are directly linked to the technological complexity of ADAS and the inbound risk of system malfunction. For this background the separate risk evaluation (WP 3.1) is quite an evident assessment, which can clarify to which extent malfunctioning of ADAS can be considered in the BEA.

Especially, the costs of call-back campaigns might play in Europe a more important role for the rentability of ADAS than requirements for compensation.

Figure 86 gives an overview over the development of call-back campaigns of the German automotive industry between 1992 and 2002 (KBA 2002 [21]). 127 call-back campaigns were accomplished in 2002, which means an increase of 12 percent to the year 2001. 13,4% of total call-back campaigns in 2002 were induced due to failures of electronic components, whereby software failures are included. The expectation is that in the future call-back campaigns because of failures of electronic components will more and more increase.

The reason for this development can be seen in the fact that the vehicles were above all technologically improved in the last years by implementing electronic systems. With the rising number of electronically supported functions and assistants the vehicle complexity increased at the same time. The new complexity shows thereby clearly negative effects to the vehicle reliability. The data of the number of call-back campaigns confirm this. Thus it can be concluded that the reliability in the electrical connection and electronics field becomes the large challenge for the vehicle developers in the next decade.



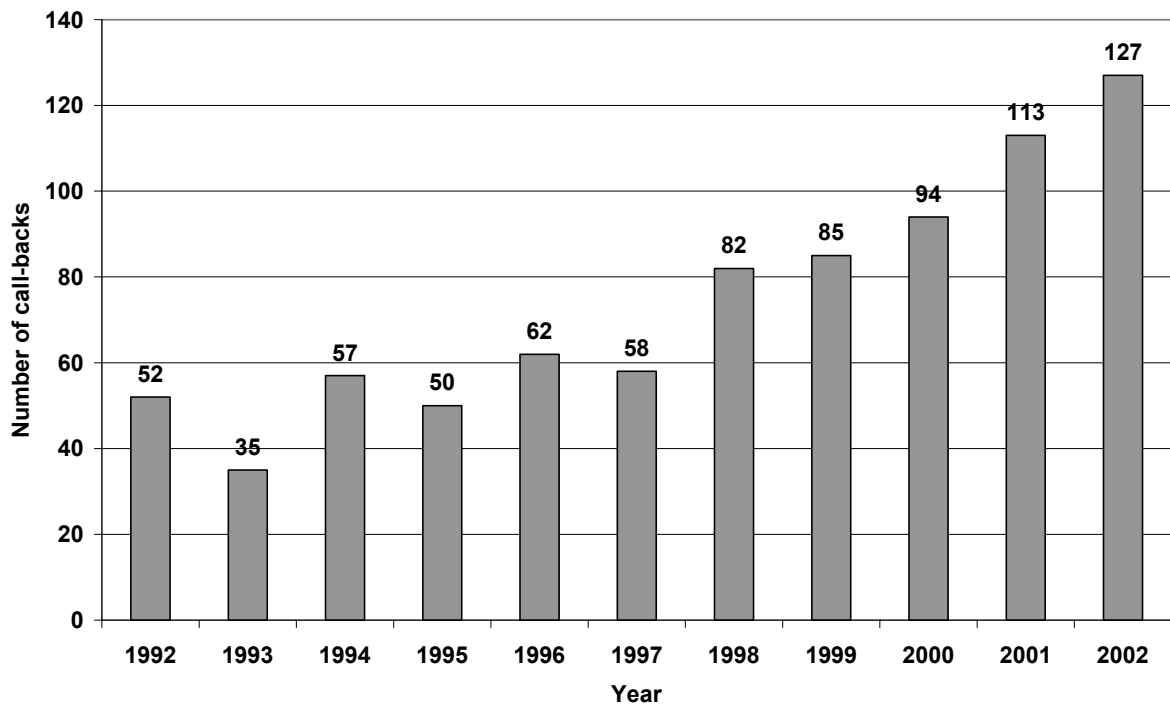


Figure 86: Number of Call-back Campaigns of German Automotive Industry<sup>45</sup>

Therefore, ADAS as a sophisticated and complex technological solution for driving bears a high potential risk for call-back campaigns due to system malfunctions. This risk of call-back campaigns can lead to enormous expenditures for the OEM. In a worst-case assumption it is estimated that one call-back campaign for one vehicle category can lead to a reduction of sales profits by 10% (Dudenhöffer 2003 [22]).

The fact that the BEA will be regularly undertaken before the market introduction of ADAS will take place leads also to uncertainties on the side of the potential benefits. The sales profits of ADAS depend on the market acceptance, which is linked to the benefit-cost-effects for ADAS-user. At this stage it is important for the OEM that they know the break-even points of potential ADAS-user groups. With the results from the break-even-analysis for the system-user, the system providers get the information about the price sensitivity of the demand depending on the costs and benefits of ADAS for the system users. This information must be enlarged by the sensitivity analysis for the system costs and the market penetration pricing strategy (market skimming, penetration pricing, and flexible pricing) of the OEM. The break-even analysis for the system users is at least an evident input for the break-even analysis of the OEM.

These interdependencies between the break-even analysis for the system users and the break-even analysis for the OEM are worked out in Figure 87.

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Krafftfahrt Bundesamt, Pressebericht 2003, Flensburg 2003.

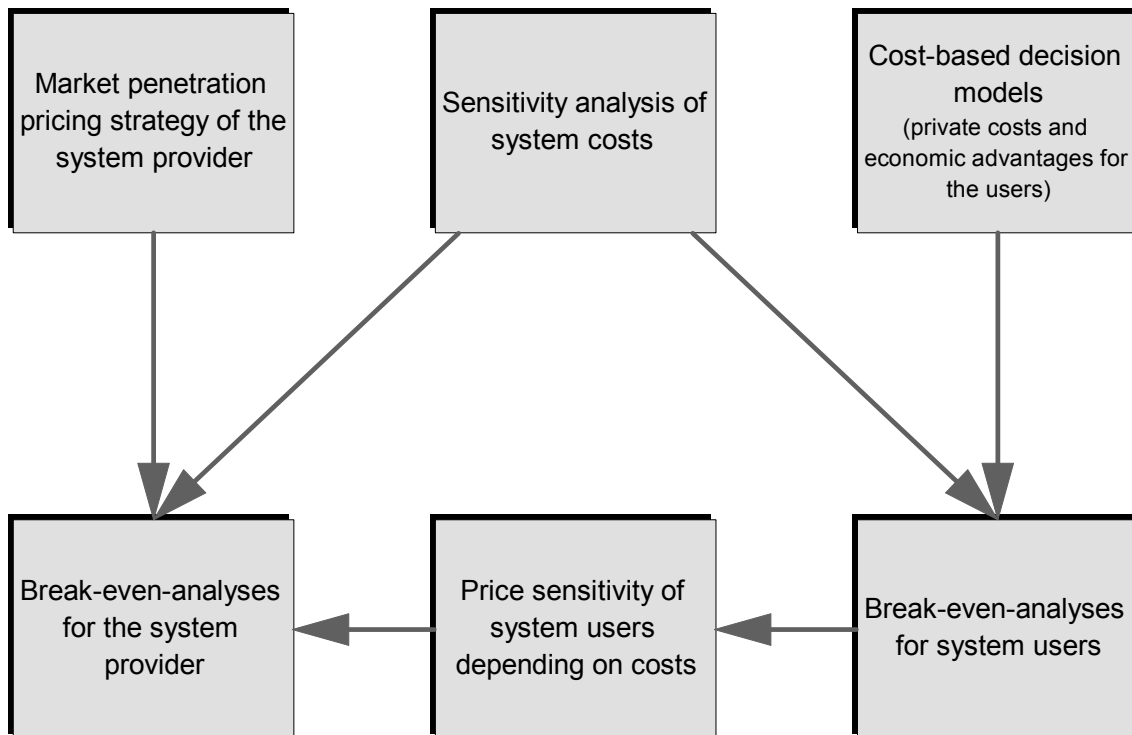


Figure 87: Interdependencies between Break-Even Analyses for System Provider and System User<sup>46</sup>

OEM have information to perform a sensitivity analysis of the ADAS-system costs. With the information on the reachable benefits the BEA for the ADAS-users can be done. The results of this assessment give an insight to the price sensitivity of ADAS-users depending on the price they have to pay for ADAS. With the defining of the price-strategy of the OEM it is possible to estimate the break-even point for ADAS.

## 4 CONCLUSION

The first conclusion, which can be drawn, is that economic evaluation of ADAS meeting the criteria of verifiability, efficiency of the evaluation procedure, trustworthiness, representative data, and transparency is possible. It was shown that economic evaluation methods are well-developed and well-defined, and cost-unit rates exist, which reflect the monetary impacts and consequences of ADAS. Furthermore, the cost unit rates are generally accepted values. With that the economic assessment of ADAS-technologies can be done on national as well as on European level; and an objective comparison of different ADAS-technologies, which enables a ranking by efficiency criteria, can be performed.

Second, with CBA and BEA two economic evaluation methods exist, which deliver information on ADAS for different stakeholders.

For the CBA the main general findings in that field can be summarized as follows:

- The CBA is an adequate approach to prove the social desirability of ADAS and with that the general acceptance of ADAS can be enforced.
- Therefore, the CBA is an important tool for those who are involved in transport policy, transport planning and traffic safety issues and concerned with ADAS.
- It is evident that CBA of ADAS can be done without the participation of OEM, because normally and as shown applicable data is publicly available.

The BEA provides information, which are relevant for the market introduction and the market success of ADAS:

- The market introduction depends at least on the readiness and willingness of OEM to place ADAS into the market. The market introduction will take place if ADAS meets the private rentability objectives of OEM. The proof of private rentability is the key objective of the OEM related BEA.
- The BEA of OEM can be only performed by third parties if OEM share their internal cost information with them. Without that participation of OEM no trustworthy OEM related break-even analyses can be accomplished.
- Within the break-even analysis of the OEM the break-even points of ADAS-users have to be known, because they determine the possible market success for ADAS-technologies. Therefore, the OEM have self-interest to determine the break-even points for the users to get information about the reachable market demand.
- Obviously, the readiness of OEM to publish BEA-results will be relatively small. It is clear that the readiness will be the more limited the more systems will move from R&D to pre-competition stage.
- The information of the break-even points of different ADAS-user groups is important for themselves, because as an outside given information the willingness-to-buy ADAS can

be strengthened. The recommendation is that results of break-even analyses for ADAS-users should be available and accessible for the public.

Furthermore, the BEA for ADAS-users is afflicted with two serious uncertainties concerning the insurance premiums and the comfort benefits:

- Until now the effect of ADAS-introduction on insurance premiums cannot be clearly determined. For some reasons it is possible that contrary to usual and normal market expectations ADAS could lead to an increase of insurance premiums. However, possible savings of insurance premiums represent an important decision factor for the ADAS-users. Clarity over the development of the insurance premiums due to ADAS-introduction - independent, whether insurance premiums decline or increase - is however necessary to get reliable figures on the market demand for ADAS.
- One major black spot until now for the break-even analysis for ADAS-users is the economic assessment of comfort effects of ADAS. It is clear that comfort aspects have a decisive impact on the willingness of drivers to buy ADAS. However, the transformation of comfort benefits into monetary values is methodologically not well-worked out. The recommendation is to put more effort on this topic, which should lead to a full integration of comfort benefits in the BEA of ADAS-users.

As third main finding the paper has made clear that in the frame of the CBA the quantification of the effects of ADAS on traffic and safety plays a crucial and sensitive role for the overall efficiency. That refers to the modeling of the with-case, which defines the situation that ADAS is introduced on the market. The trustworthiness of the safety and traffic effects depends, first of all, on the workability and reliability of ADAS itself. The question is, if the expected traffic and safety effects determined by the system specification can be realized in the real-environment use of ADAS. This problem cannot be solved by the economic evaluation methods, but by the risk-benefit analysis as wider frame, in which the technological aspects of ADAS are checked. Therefore, it is necessary that a methodological link between the technological-oriented risk-benefit analysis and the economical-oriented cost-benefit analysis has to be established and relevant data for both analysis tools are made available.

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## **6 ACRONYMS MACROPERSPECTIVE**

ADAS	Advanced Driver Assistance Systems
BCD	Benefit-Cost Difference
BCR	Benefit-Cost Ratio
BEA	Break-Even Analysis
CBA	Cost-Benefit Analysis
CoBA	Cost Benefit Analysis Model
CoP	Code of Practice
DOT	Department of Transport
EC	European Commission
HMI	Human Machine Interaction
KBA	Kraftfahrt Bundesamt
OEM	Original Equipment Manufacturers
RBA	-Risk-Benefit Analysis
WHO	World Health Organisation
WTP	Willingness-to-Pay

## ANNEX II: RESPONSE2 Deliverables List

Del. No.	Deliverable Name
D1	ADAS: market introduction scenarios and their proper realization
D2	Methods for Risk-Benefit Analysis of ADAS: Micro Perspective and Macroscopic Socio-economic Evaluation
D3	Steps towards a Code of Practice for the Development and Evaluation of ADAS
D4	RESPONSE 2 – Final Report: ADAS – from Market Introduction scenarios towards a Code of Practice for development and evaluation
D5	Final workshop Response 2: From Market Introduction scenarios towards a Code of Practice for development and evaluation
D6	Permanent updating of website containing deliverables & other relevant info
Extra Deliverable	Legal and Liability Issues regarding Inter-Vehicle-Communication - CarTALK 2000

All published deliverables are public documents. There are available on the RESPONSE2 websites

<< <http://response.adase2.net> >> and

<< <http://www.response2.org> >>

as PDF-download.

From the previous project RESPONSE1 the following deliverables are available at <<<http://docs.adase2.net/response/>>>:

- [Deliverable 2.1](#)  
System, user and legal aspects: The integrated approach for the assessment of driver assistance systems
- [Deliverable 4.2](#)  
Checklist for theoretical assessment of advanced driver assistance systems: Methods, results and assessment of applicability
- [Deliverable 7.1](#)  
Legal aspects of testing driver assistance systems in Europe
- [Deliverable 7.2](#)  
National reports on existing law concerning the market introduction of driver assistance systems
- [Final Report](#)  
Recommendations for testing and market introduction of advanced driver assistance systems