Exploratory Study on the potential socio-economic impact of the introduction of Intelligent Safety Systems in Road Vehicles

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1 Summary

Introduction

Transport is a key factor in modern economies. The European Union, with its increasing demand for transport services, needs an efficient transport system and has to tackle the problems caused by transport: congestion, harmful effects to the environment and to public health, and the heavy toll of road accidents. The costs of accidents and fatalities are estimated at 2 % of the Gross Domestic Product of the EU (eSafety 2004).

The European Commission aims to reduce the number of road fatalities by 50 % by 2010. There is convincing evidence that the use of new technologies could contribute significantly to this reduction in the number of fatalities and injuries. The eSafety initiative therefore aims to accelerate the development, deployment, and use of intelligent vehicle safety systems (IVSS). Intelligent vehicle safety systems are IT-enabled systems and smart technologies for crash avoidance, injury prevention and upgrading the road-holding and crash-worthiness capabilities of cars and commercial vehicles.

Both governments and marketing departments in the automotive industry are now facing the dilemma of deciding on new technologies or new paths of development before reliable data exists. This makes it essential to evaluate the safety impact of new technologies before they are marketed. While bearing in mind the difficulties of developing a methodology, it is, however, necessary to provide a basis for rational and convincing decisions. The eSafety initiative, as well as the European Commission, is therefore requesting a sound database and decision-supporting methodology.

The impact of intelligent vehicle safety systems goes beyond mere improvements in road safety. Other effects, such as greater reliability of arrival times, environmental benefits or increased driver convenience are also benefits of using IVSS. These effects cannot, however, be easily quantified. On the other hand, an assessment of the socio-economic impact of safety systems must also face the possibility of reverse effects, for example a reduction in traffic flow or even an increase in the number of accidents due to inappropriate human-machine interfaces.

Objectives of the Study

The EU Commission initiated this exploratory study in order to:

- provide a survey of current approaches to assess the impact of new IVSS
- develop a methodology for assessing the potential impact of IVSS in Europe
- provide factors for estimating the socio-economic benefits resulting from the introduction of Intelligent Vehicle Safety Systems. These factors, such as improved journey times, reduced congestion, lower infrastructure and operating costs, reduced environmental impacts, lower medical care costs etc., will form the basis of a qualified monetary assessment.
- identify the major indicators influencing market deployment and develop deployment scenarios for selected technologies/regions. In this, the proposed methodology will be useful in identifiying the relevant data required for the evaluation of the socio-economic benefits of intelligent vehicle safety systems.

Thereby, the proposed methodology is provides an approach for the identification of relevant data that is required for the evaluation of the socio-economic impact of intelligent vehicle safety systems.

State of the Art

Investigations of the socio-economic impact of intelligent safety systems began in the late 1980s. Since then, the benefits of IVSS and services have been assessed on the basis of more than 200 operational tests and early deployment experiences in North America, Europe, Japan, and Australia (PIARC 2000). Three broad-based categories of evaluation approach are currently being used (OECD 2003):

- empirical data from laboratory measurements and real-world tests
- simulation
- statistical analysis

Several projects funded by EU member states or the European Commission as well as studies carried out by the automotive industry and equipment suppliers have already provided some data on IVSS impact. A large number of projects deal with technological research and development and provide a good basis for further progress. These projects include AIDE, ARCOS, CarTALK 2000, CHAMELEON, EDEL, E-Merge, GST, HUMANIST, INVENT, PReVENT, PROTECTOR, RADARNET and SAFE-U. Several projects (such as ADASE II, GST, HUMANIST) are focused on accompanying measures to develop the sectoral innovation system and strengthen networks and co-operation. Some projects (such as ADVISORS and RESPONSE) deal with the implementation of safety systems and measures to support the application of new technologies. Finally, a number of projects discuss the costs and benefits of the technologies that were investigated. These include ADVISORS, CHAUFFEUR, DIATS, E-Merge, STARDUST, and the TRL Report. There is, as yet, no systematic assessment and coherent analysis of the socio-economic impact of Intelligent Vehicle Safety Systems. In addition, the compilation of such an analysis is further complicated by the fact that many systems have not yet been widely deployed.

Approach of the Study

VDI/VDE Innovation + Technik GmbH (VDI/VDE-IT) and the Institute for Transport Economics at the University of Cologne (IfV) have teamed up to investigate a comprehensive IVSS assessment methodology. The exploratory study, called SEiSS (**S**ocio-**E**conomic **i**mpact of **i**ntelligent **S**afety **S**ystems) was given a time frame of 6 months.

In order to assess the socio-economic impact of intelligent vehicle safety systems, it is necessary to define the safety technologies taken into consideration and to discuss their market deployment. This enables us to consider the traffic effects which provide the basis for the socio-economic benefits of intelligent vehicle safety systems. Figure 1 provides an overview of the general workflow of the study, including

- the Technology and Market investigations led by VDI/VDE-IT,
- the Traffic and Impact methodology led by IfV Köln,
- the exemplary calculations for model evaluation led by IfV Köln.

Figure 1: SEiSS workflow (author's figure)

The **Technology** work package provides a brief description of intelligent vehicle safety systems and discusses their potential impact on road safety. Safety function interdependencies and their combined potential influence on road safety are considered. At this point, it is also possible to account for drawbacks. New technologies can, for example, contribute to an increase in accidents due to driver distraction, or reduce the traffic flow. The **Market** work package outlines different methods of market penetration. The target figure is the rate of equipment with intelligent vehicle safety systems on a given date. Obtaining this figure involves taking into account the factors which influence market potential and potential user acceptance. The project also analyses **Traffic** effects resulting from the market introduction of IVSS. This work package requires data from the latest traffic forecasts (e.g. traffic development and number of accidents) for the member states of the European Union. The main outcome of the project is a methodology for assessing the socio-economic **Impact** of intelligent vehicle safety systems. A key element of the methodology is the benefit-cost analysis, which allows us to determine the extent to which a society would profit from the introduction of an IVSS to the market. Although benefit-cost analysis represents the key element, the methodological framework is also designed to be able to satisfy the information needs of different stakeholders. This would require the scope of the analytical tools to be extended, e.g. integration of break-even analyses for individual users and OEMs as well as macroeconomic impact considerations.

In accordance with its objectives, the SEiSS project developed three major results:

- A comprehensive methodology for the assessment of the potential impact of the introduction of intelligent vehicle safety systems.
- A proposal for a generic approach to the assessment of IVSS interaction, of the ability of IVSS to affect collision probability and of the ability of IVSS to affect accident severity.
- Conclusions from the study to further support eSafety initiatives.

(1) IVSS Assessment Methodology

Looking through related reports and studies shows that there are several fixed elements in dealing with IVSS assessment. These are a clear definition of the system(s) to be evaluated, a prediction for the effect the IVSS will have on collision probability and severity, predictions for market penetration and number of accidents and the use of cost-unit rates as well as the calculation of investment costs. The suggested methodology is based on these fix points and consists of 14 major steps (see Figure 2). The methodology therefore includes knowledge from automotive and traffic engineering, market research and economics. It allows for an assessment of the socio-economic impact at EU-25 level, but it also delivers the opportunity to differentiate results at member state level.

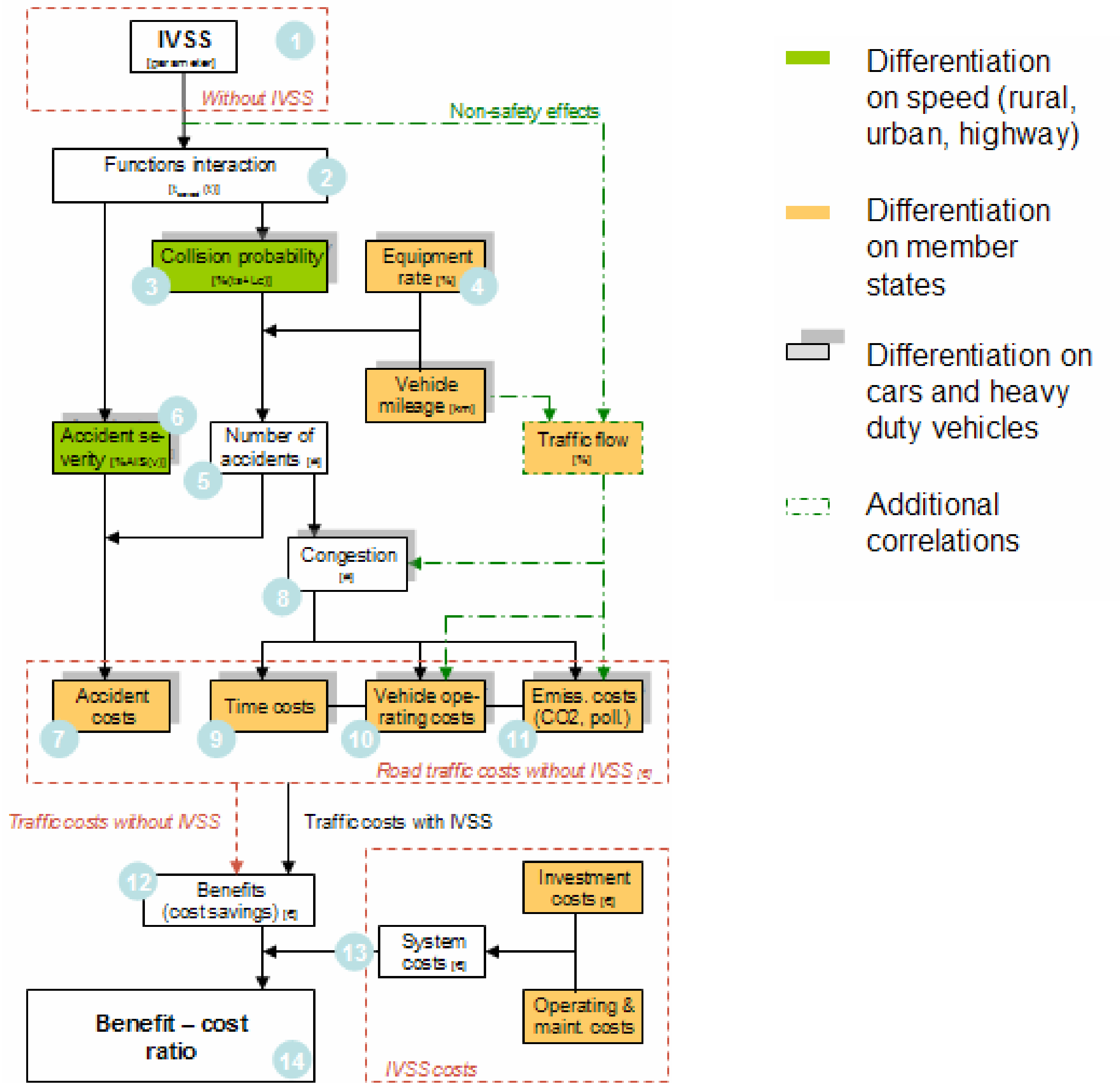

Figure 2: Relevant Steps for SEiSS Methodology

Technology is a prerequisite for any automotive function. Intelligent vehicle safety systems in road vehicles are known under several terms including ITS (Intelligent Transport Systems), ADAS (Advanced Driver Assistance Systems), and active or predictive safety systems. Relevant functions have been identified based on European project lists and expert interviews:

ABS – Anti-lock Braking System

- ACC – Adaptive Cruise control
- Adaptive light – curve illumination
- Airbag system – multistage/fire scenarios
- Automatic light – light on/off
- Crash avoidance
- Crash detection/warning
- Driver monitoring – driver drowsiness
- EBS – Emergency Braking System
- eCall – in-vehicle emergency calls
- ESP – Electronic Stability Programme
- LCA - Lane Change Assistance
- LDW - Lane Departure Warning
- Night vision
- Passenger classification – weight, size, incorrect position
- Pedestrian protection
- Pre-crash – preparation of the car for a crash
- Safe following – adaptive cruise control/ACC in future versions
- Safe speed – adaptive maximum speed of the car

On the basis of new technologies, new safety functions could be introduced. However, we face the problem of system interaction (step 2) between different safety functions. Simply evaluating individual functions does not provide a reliable assessment of the overall system (driver and vehicle) behaviour. It is therefore necessary to define the areas of interaction. The common approach for the assessment of a system's ability to avoid accidents is an in-depth analysis (a combination of the aforementioned statistical analysis, empirical data and simulation approaches) of a specific vehicle setup leading to a quantification of the IVSS-related collision probability (step 3). A similar analysis is used in calculating accident severity (relevant for step 6).

In order to evaluate the effects of the introduction of IVSS, their use in vehicles must be predicted. Therefore, integrating the market perspective into the proposed model helps in predicting the diffusion of intelligent vehicle safety systems (IVSS) within the vehicle fleet; or in other words, in calculating the equipment rate (step 4). The IVSS market deployment influences its socio-economic impact, for two reasons. The first is that vehicles which are equipped with IVSS and vehicles or other road users involved in crashes with those vehicles profit from the advantages of the accident-avoiding or accident-mitigating effects of IVSS. Only the equipped vehicles therefore influence the overall socio-economic impact. The second reason is that some IVSS may need a certain equipment rate to fully exploit their potential benefits. Car-to-car-communication systems, in particular, need a minimum of equipped cars for the technology to function properly and for the potential benefits to be exploited. To forecast market deployment, i.e. to calculate an equipment rate at a given point in time, the time of market introduction must be assessed, and a probable market diffusion method must be decided upon.

Considering the methodological framework, a widespread approach for assessing the potential socio-economic impact is the welfare-economics-based benefit-cost analysis. The benefit to society of intelligent vehicle safety systems can be illustrated by comparing the socio-economic benefits with the system costs (investment, operating and maintenance costs). Benefit-cost ratios of more than 1 indicate that the deployment of the IVSS would be in the public's interests.

After defining the assessment framework and the relevant alternatives tol be compared ("without" case: IVSS is not used; "with" case; IVSS is used) the benefit-cost-analysis consists of the following calculation procedure.

- Analyse the impacts of each case by traffic and safety indicators such as traffic flow, vehicle speed, time gaps and headways
- Calculate the physical dimensions of the traffic effects, such as total transport time, fuel consumption, level of pollution and number of accidents for both the "with" and "without" cases. Calculate the benefits (=resource savings) by assigning values to these physical effects using cost-unit rates (steps 7 to 11)
- Aggregate the benefits, determine the system costs (investment costs, maintenance costs, operating costs), and work out the benefit-cost ratios (steps 12 to 14).

The proposed methodology allows for the impact calculation of three different speed patterns covering urban, rural and highway traffic. The approach described has to be calculated for cars and heavy-duty vehicles separately because impacts are not assignable from one mode to the other. In addition, different market deployment, vehicle mileage, safety systems relevance, accident path, and cost figures call for separate calculation. The sub-calculations (cars and heavy-duty vehicles for urban, rural and highway traffic) combined determine the overall benefit-cost ratio for a specific IVSS set-up. The calculations can be made for both a worst-case scenario and a best-case scenario to provide a range for the benefit-cost ratio.

Exemplary Calculations

This report refers to case studies in order to demonstrate the workability of the general approach. The selected case studies represent systems which address different accident situations. The eCall case study deals with an emergency call system which is generated either manually or automatically when a vehicle is involved in an accident. The accurate vehicle location and additional safety-related information can be passed to a Public Service Answering Point. The efficiency of the rescue chain is thus improved. Impacts of systems which offer longitudinal control are demonstrated using Adaptive Cruise Control which automatically maintains vehicle distance and optimises driving speed accordingly. Lateral control systems will warn the driver if his or her vehicle leaves its lane unintentionally (lane departure warning) whereas a lane change assistant will check for obstacles in a vehicle's course when the driver intends to change lanes. This type of combined system forms the object of the third case study.

Scope of the Proposed Methodology

A comprehensive approach like the one proposed must be built on several assumptions and simplifications. Some examples are the differentiation between just two vehicle classes (cars and heavy duty vehicles) the differentiation between just three speed patterns (representing urban, rural and highway traffic), the proposed definition of average parameters for the IVSS, the differentiation according to accident types rather than to accident causes, the differentiation of accident severity into only two categories (slight and heavy injuries) as well as fatalities, the calculation using European cost-unit-rates and the referencing of reported accidents only. Adding unavoidable inaccuracies, a rather broad bandwidth can be expected. It is therefore proposed that the calculations be performed for different scenarios, including the worst and best case.

Within the socio-economic impact assessment it is shown that at the current stage evaluation methods exist, which fulfill the criteria of verifiability, efficiency of the evaluation procedure, trustworthiness, representative data, and transparency.

The current status on methods for the economic of relevant cost categories assessment (e.g. subjective methods like willingness-to-pay-approach, objective methods like cost of damage or cost of avoidance approach) in the EU were presented in a comprehensive manner. On this basis appropriate evaluation methods and cost-unit rates, which allow an economic assessment of IVSS on the EU-level, were proposed. With that, the comparability of the results of IVSS assessment between the member states is made possible.

It was worked out that the benefit-cost-analysis should be used as core method because only with the benefit-cost analysis the welfare proof of IVSS can be performed. However, the decision on the introduction of IVSS has to be based on broader information, those information can be given by additional assessment tools like financial analysis, break-even analysis for the system user, and break-even analysis for the OEM. Furthermore, it was outlined that all kind of assessment tools can be integrated in a multi-criteria analysis, which can be used as an umbrella-approach for a full assessment of IVSS.

(2) Generic Approach for the Evaluation of System Interaction and the Prediction of Collision Probability and Accident Severity

In contrast to common assessment approaches which rely on a defined IVSS setup for the entire cost benefit calculation, this project proposes a generic assessment approach. Relying on a defined IVSS setup means that the introduction of a completely new IVSS system would require new calculations, including all IVSS combinations. The generic approach simply requires the definition of system-specific parameters; the parameters of IVSS which have already been introduced do not need to be adjusted.

Following the principle of time correlation in accident mitigation, it is proposed to use time as a basic value in calculating system interaction, collision probability and accident severity. IVSS are correlated to a time pattern, i.e. the effect of a function is assessed with regard to its time slot in accident mitigation (accident phase) and its effectiveness. A specific IVSS setup translates into specific time patterns for the different accident types, meaning overall time gains or losses. These time patterns correlate to collision probability; we know that a time gain or loss will lead to a change in the probability (step 3). According to publications by Enke (Enke 1979), such curves (differentiated according to accident type and speed) can be derived using statistical investigations and calculations. The severity of an accident depends on the impact energy, which corresponds directly to impact speed. Depending on time gains and losses and an assumed speed (urban, rural or highway) a new impact speed, based on the effectiveness of an IVSS setup, can be derived. Passive safety systems add absorption potential to the vehicle or the human. This absorption potential can also be translated into a time gain (leading to a change in impact speed) for a specific accident type.

The majority of accident types and IVSS can be correlated to time patterns. Exceptions are systems like ABS and ESP which include time-independent principles. These could be summarised as “loss of control” scenarios. However, this approach might deliver a transparent and generic methodology for the evaluation of system interaction and the prediction of changing collision probability and accident severity based on the use of IVSS. The challenge hereby would be to define IVSS parameters for time gains or losses and to provide standardised curves for (on the one hand) collision probability depending on time gain or loss and (on the other) accident severity probability depending on impact speed. The proposed curves should be generated for all accident types.

The proposed generic approach has been introduced to some experts but could not be verified in the short project duration. Further research is needed in order to qualify this approach or to develop alternatives that assess changes in the collision probability and the severity of an accident. It also remains important that the generic approach (as briefly introduced) will also deliver the needed information.

(3) Conclusions from the Study

Reflecting the reviewing of projects and publications as well as several discussions with experts brought us in the position to come up with statements which might be helpful to further encourage safety initiatives as well as accident research.

Harmonisation of IVSS definitions and input parameters is needed

The assessment of the socio-economic impact of IVSS relies on assumptions regarding the costs, the safety impact, the deployment, the development of the transportation system as well as accident forecasts. These assumptions are based on available data and, if necessary, on expert assessment. It is proposed to develop a common understanding of Intelligent Vehicle Safety Systems, including definitions and parameters. The technical abilities of these systems might differ between vehicles and over time, but for calculatory and dissemination purposes they should be assumed to be static. The same remains valid for cost-unit rates at member-state level, which can be seen from different perspectives. For transparent calculations, this data must be publicly defined at the appropriate level. Further discussion are therefore needed in order to harmonise the necessary assumptions.

Dissemination and outreach on common understanding

Market penetration for IVSS seems to be rather slow when standard market introduction patterns are followed. Implementing these mostly complex systems therefore requires a better understanding and acceptance of the consumer. To improve the needed communication, messages should be compatible, which once more calls for harmonisation. Providing common information sources will further improve the comparability of related R&D. A comprehensive approach to impact assessment has the potential to enhance the basis for decision-making regarding innovation and transport policy as well as company strategies. Sound information on the socio-economic impact of IVSS would complement measures to support the introduction of IVSS into the markets and contribute to sustaining consumer awareness.

Information exchange on current research

There is a large amount of research which deals with specific aspects of the socio-economic impact of IVSS. This exploratory study proposes an integrative approach which brings together investigations from fields such as technological development, accidentology, statistics, marketing, traffic research and economics. The quality of future studies as well as safety initiatives will improve if new results from each of these proximate fields of research can be taken into consideration. Bringing together experts, not just from a specific R&D field but also from different backgrounds widens the possibility for solutions and improves the interfaces required.

R&D for accident causation, interface to economic assessment

A crucial input factor for the evaluation of intelligent vehicle safety systems is accident causation data. Accident causation considers the effectiveness of possible countermeasures. In this context, it is necessary to have an in-depth knowledge of vehicle parameters (even for upcoming vehicles), very good access to all kinds of statistical information (macroscopic and microscopic) on normal driving as well as accidents and to have the methodological framework to connect this information. The study recommends close co-operation between accident causation analysis and the evaluation of socio-economic impacts related to safety systems.

Further improvement of databases (EU-25, standardisation)

To be effective, all methods for the assessment of the socio-economic impact of safety systems must be based on reliable data. The exploratory study has identified the following major input factors: the impact of safety technologies and systems on the number and severity of accidents, vehicle stock and IVSS sales forecasts for Europe (EU-25) and the EU member states, and forecasts of traffic flow and safety performance in Europe and in the member states. For a better compatibility of results of different investigations it is suggested to rely on common data, for example on commercial forecasts. For specific areas, such as figures for the definition of accident probability and accident mitigation as well as accident severity, additional research must be carried out and results published on a regularly basis. Anyone looking for impact analysis needs this kind of information and faces the lack of relevant data.

Awareness of different stakeholder interests

The assessment of the socio-economic impact of the introduction of intelligent vehicle safety systems might be interesting for several different parties. Examples are the EC, the member states (with different ministries), OEMs, suppliers, and insurance companies. All of these will have different specific objectives and will therefore work with different assumptions. For comparability it is very important to look closely at the differences in calculation and the specific objective of a study, which may lead to the conclusion that results cannot be easily applied to similar areas. The SEiSS methodology can be expanded for increased accuracy and to allow the inclusion of modules to permit scenario calculations based on additional input variations.

This study explores the potential socio-economic impact of intelligent vehicle safety systems. This methodology provides a basis for rational decisions about research and development priorities and about the selection and use of vehicle-based safety systems. The study proposes a comprehensive approach for the assessment of IVSS which integrates current research on emerging safety technologies and market deployment scenarios, traffic impacts and a benefit-cost analysis. Following this exploratory study, further research is needed to qualify and expand the proposed methodology. Other procedures for the analysis and evaluation of IVSS should be further investigated and integrated in such a comprehensive approach for socio-economic evaluations. A large number of systems will be introduced onto the market in the next few years. Although their diffusion rate is comparatively low, these systems can contribute significantly to the European Commission’s aim to reduce the number of road accidents and fatalities.

2 Introduction

The following chapter provides a brief overview of the reasons behind and the organisation of this project.

2.1 The Safety Situation in Europe

Road safety is essential if we are to take advantage of mobility's benefits. Mobility is an expression of individual freedom and quality of life. In addition, road traffic is a key economic factor. Increasing needs for mobility and transport in Europe require action to improve road safety. Accidents further amplify the problem of congestion, which is increasingly affecting the entire road network. There is still an unacceptable number of injuries and fatalities;. 1.3 million accidents occur per year in Europe, about 50,000 people lose their lives, and 1.7 million are injured. The economic damage is calculated to be 160 billion euros, which amounts to approximately 2 % of the gross domestic product (GDP) in Europe (eSafety 2002). For EU 15, the number of fatalities is continuing to decrease, the trend aimed at by the eSafety initiative. For EU 25, which includes the 10 new member states, the situation is different. Road conditions for the new member states, are much poorer than those in EU 15. Due to the open borders and increasing income, traffic in these countries is increasing. Increasing numbers of older vehicles on an underdeveloped infrastructure (compared to EU 15) does have a negative effect on traffic safety. This situation makes it very important to ensure that the available resources are allocated as effectively as possible. There is convincing evidence that the use of new technologies has contributed significantly to the reduction in the number of fatalities and injuries in EU 15. Since the late 1980's, a large number of studies have dealt with the impact of intelligent traffic systems on road safety. The development of advanced driver assistance systems and other intelligent road safety systems has raised the issue of their potential impact.

Both governments and marketing departments in the automotive industry are now facing the dilemma of deciding on new technologies or new paths of development before reliable data exists. This makes it essential to evaluate the safety impact of new technologies before they are marketed. While bearing in mind the difficulties of developing a methodology, it is, however, necessary to provide a basis for rational and convincing decisions. The eSafety initiative, as well as the European Commission, is therefore requesting a sound database and decision-supporting methodology.

The European Commission is aiming for a 50 % reduction in road fatalities by 2010, to which the use of new technologies can make an important contribution. **Road safety** is concerned with reducing both the number and the consequences of vehicle crashes. It can also be described as the probability of reaching a destination without facing hazardous road conditions en route. There are a number of ways in which road safety can be improved, including:

- improving traffic infrastructure
- reducing traffic density and speed
- improving the education of all road users
- supporting vulnerable road users
- supporting or limiting potentially dangerous road users
- supporting collision prevention
- improving predictive and active safety systems
- improving passive safety systems

Accidents are caused by a set of influencing factors rather than a single reason. Figure 3 lists the main causes of collisions:

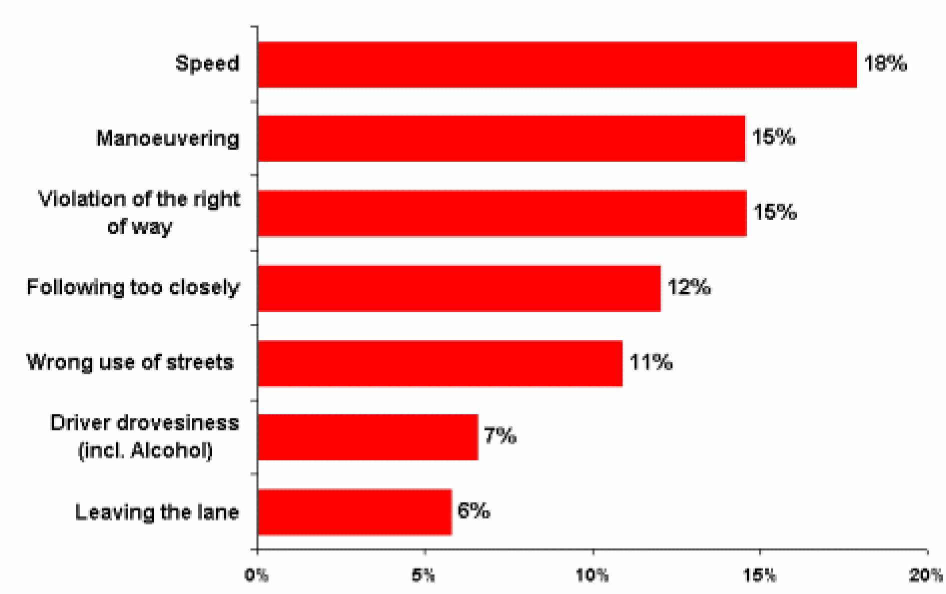

Figure 3: Causes of vehicle accidents with injuries in Germany 2002 (Statistisches Bundesamt 2002)

Besides high speed and following to closely false manoevering and wrong interpretation of the right of way are the main causes for collisions. Research (for example eSafety 2002) has shown that more than 90 % of road accidents are partly caused by human error. A behavioural study is required to identify relevant errors. Literature shows that the probability of human error depends on certain error-shaping conditions:

- external conditions, such as limited vision due to obstruction or blinding
- errors caused by distraction (e.g. phone, conversation)
- overload
- underload, caused by extended absence of sufficient stimuli (highway hypnosis)
- the driver's physical condition: fatigue, alcohol and drug abuse.
- insufficient reactiontime (high speed differences)
- unfamiliarity with location and/or local driving behaviour
- ignorance
- lack of adequate skills or training

Another important general error-shaping factor is the available time (hurry). Aside from this list, errors in judging one's own capabilities, vehicle capabilities and in assessing the environmental conditions are also of importance. It is therefore obvious that active safety systems and applications which support the driver's perception could help the driver to perform the complex task of driving if the human-machine interaction principles are designed appropriately.

The following figure shows the correlation of safety systems to accident clusters. More and more appropriate safety and supporting functions are being launched the market. On the downside, however, legal issues, poor cost/benefit ratios, inappropriate human/machine interfaces, lack of user acceptance or goodwill of political or industrial stakeholders inhibit the maximum possible outcome of the use of intelligent vehicle safety systems (IVSS).

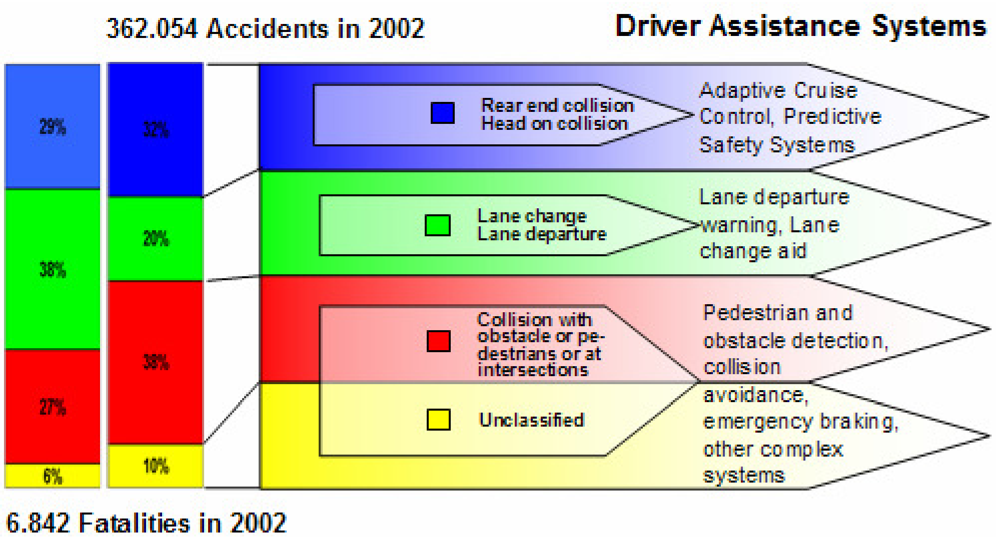

Figure 4: Clustering of German accidents and fatalities (2002) with corresponding potential safety systems (Statistisches Bundesamt 2002)

Lateral and longitudinal faults count for the majority of all accidents. Depending on the problem specific IVSS support such situations toward safer driving.There is a close correlation between the number of accidents and their severity and the time available to react to a potential problem. Systems like vision enhancement, better brakes and stability programmes or car-to-car communication have the potential to provide additional reaction time. Cascading interference approaches (being the reaction of the car in the accident mitigation phases), mean that driving becomes, at least for dangerous situations, more and more of a cooperative approach between driver and vehicle.

2.2 Objective of the Study

The objective of this study is to provide a proposed methodology for a systematic assessment of the potential impact of intelligent road safety systems. The state of the art for intelligent vehicle safety technologies was investigated and a synoptic overview of up-to-date impact estimates compiled. In the course of the proposed study, important indicators influencing market deployment were identified and deployment scenarios for selected technologies/regions developed. The potential impact on traffic was discussed and estimated and a methodology for predicting the socio-economic impact of intelligent traffic systems was derived. The timeframe is 2004-2020, with particular emphasis on the years 2010 and 2020. The starting point for our investigations is the related RTD, which was analysed for helpful elements for the assessment of intelligent vehicle safety systems.

2.3 Organisation of Work

Two institutions, VDI/VDE Innovation + Technik GmbH (VDI/VDE-IT) – a consultancy company – and the Institute for Transport Economics at the University of Cologne (IfV) have been working on the SEiSS project. The team comprises a multidisciplinary mix of experts in the field of engineering, economics, and social sciences, allowing us to draw on a excellent combination of skills and experience, both in technology-related and socio-economic fields. The workpackages covered by the institutions are:

- the Technology and Market investigations led by VDI/VDE-IT,
- the Traffic and Impact methodology led by IfV Köln,
- the exemplary calculations for model evaluation led by IfV Köln.

Project management was performed by VDI/VDE-IT.

Expert discussions, interviews and workshops accompanied the research. These included meetings with TU Berlin (Institut für Land- und Seeverkehr), Hella, Bosch, DaimlerChrysler, the German Insurers’ Association (GDV), Bundesanstalt für Straßenwesen (BASt), BMW, Renault, INVENT and ARCOS (refer to the list of reference projects in the appendix) as well as with representatives of the eSafety Working Groups Road Mapping and Accident Causation. In order to meet the high expectations of technology foresight and the technology studies on intelligent vehicle safety systems, a mix of methodologies, consisting of desk research, expert opinion, and quantitative and qualitative data have been applied:

- The *bibliographic analysis* covers the most relevant citation indices (i.e. Science Citation Index) providing information on basic research conducted in the specified and selected technology areas.
- Scanning *existing literature* and other available information (e.g. on the web) on relevant technologies provided further qualitative information. Comparison with the other sources will separate common and general features from spectacular prospects, allowing the most dominant trends to be identified and evaluated.
- A series of *expert interviews* provided comments and suggestions for the improvement of the study, the main emphasis being on the technical details and economic outlook. Wherever necessary, additional desk research and telephone interviews were held to update the intermediate results.
- *Workshops* with representatives of the automotive industry, aimed at cumulating the knowledge acquired by the industry, were a key methodological tool.

The project started on the 15th July 2004 and was completed on the 15th January 2005. A kick-off meeting was held on the 16th July in Brussels. The inception report was delivered on the 15th September. On the 27th September, the initial results of the exemplary calculation eCall were presented at the eSafety Forum in Brussels. The interim report was handed to the EC on the 15th November.

The project has been divided into four major sections – technology, market, traffic and impact. A comprehensive methodology was introduced and all milestones were reached:

	Milestones	Title
Technology	1A	Roadmap of relevant technologies-
	1B	Roadmap for advanced driver assistance systems
	1C	Systems networks related to accident clusters
	1D	Systems potential for accident prevention
Market	2A	Market characterisation and forecast for Europe
	2B	Systems deployment roadmap and model
	2C	Exemplary assessment for a region to be defined
Traffic	3A	Identification of key variables and impact relations
	3B	Traffic forecasts for 2010 and 2020
	3C	Accident analysis
	3D	Assessment of traffic impact of IVSS
Impact	4A	Evaluation methods for IVSS
	4B	Benefit-cost analysis of IVSS
	4C	Break-even analysis and social dimension of IVSS
	4D	Report on the workshop for a roadmap for a common economic assessment of intelligent safety systems

Table 1: Project milestones (author`s table)

3 State of the Art

3.1 Approaches for the Assessment of the Socio-Economic Impact of IVSS

Investigations of the socio-economic impact of intelligent vehicle safety systems began in the late 1980s. Since then, the benefits of ITS technologies and services have been assessed on the basis of more than 200 operational tests and early deployment experience in North America, Europe, Japan, and Australia (PIARC 2000).

There is considerable variance in the complexity of the evaluation of intelligent safety systems, depending on the objectives and the end use of the evaluation results. In addition, it is necessary to find a balance between the complexity of the evaluation methodology and the availability of (or the cost and effort involved in collecting) the relevant evaluation data. Achieving a reliable analysis of the economic socio-economic benefits of specific Intelligent Safety Systems requires the development of a complex and sophisticated methodology. Procuring the evaluation data required is then a challenging and cost-intensive task. On the other hand, a less complex approach might be a more appropriate choice for assessing and comparing the impact of a wide range of safety systems. The results of a coherent methodology can then be used to support decision-making about research and development priorities and further innovation policies. An estimation of the socio-economic benefits and tradeoffs of intelligent vehicle safety systems will support their selection and deployment (Peng/Beimborn/Neluheni 2000: 2-3). Finally, the appropriate approach for the assessment of the socio-economic impact of safety technologies depends on the level of decision-making. It makes a difference whether project selection and identification is due on a local, national or international level.

Three broad-based categories of evaluation approaches are currently being used (OECD 2003)

- empirical data from laboratory measurements and real-world tests
- simulation
- statistical analysis

The specific indicators for measuring road safety differ from study to study. The most basic indicator is the impact of intelligent vehicle safety systems on injuries or fatalities (or on crashes in general). Accidents can be differentiated according to type and cause. Although accident causes are closely related to the safety impact of technologies, there is a lack of reliable statistical data for a thorough impact assessment. Data on accident type is of a much higher quality. Apart from that, the number of crashes is a measure with comparatively low reliability because crashes are statistically rare events. For this reason, empirically sound data on the safety impact of technologies can only exist if these technologies have been applied for a comparatively long time with a wide dissemination. On the other hand, there are a number of indicators that have a known correlation with direct road safety measures, like exposure, speed or the wearing of personal protection. However, these indicators have a low or unknown validity since they are not directly measuring crashes (OECD 2003). It remains an important task to organise follow-up studies after initial deployment in order to get an empirical basis for the impact of new technologies on safety. The results of further research in the field of accident causation analysis are important input factors for the evaluation of intelligent vehicle safety systems. These investigations can also consider detailed information on accident history which has become available (e.g. German-In-Depth-Accident-Study).

According to the European Transport Safety Council, intelligent vehicle safety systems can affect three main variables which influence the level of road safety (OECD 2003; ETSC 1999):

- the exposure in traffic
- the risk of crash at a given exposure
- the consequences of a crash.

These variables can be a starting point for a categorisation of safety functions and the evaluation of their safety impacts.

There are a number of methodological problems related to the evaluation of safety technologies. Road safety depends on the complex interaction of a large number of influencing factors. The task of identifying the relevant factors that have to be taken into consideration is therefore a challenging one. Previous studies have put much effort on the discussion and selection of the most relevant factors (IfMO 2002).

Another problem is the interaction between different safety technologies. Different technologies might affect each other and system behaviour cannot be assessed by evaluating the performance of a single technology. A look at the traffic system does make things even more complex. System-wide factors might affect a particular occurrence of technology deployment. It is plausible to assume that national and regional factors do heavily influence the deployment. However, it remains difficult to predict the effects of system deployment on the basis of evaluation data related to a specific technology.

Driver behaviour also changes over time. The task of measuring and predicting driver behaviour and acceptance is a delicate one, as drivers adapt to new systems and technologies. This may make initial data and observations irrelevant in the longer term.

Finally, it remains extremely difficult to assess the impact of future technologies with little or no application history. The study will have to take into account the methodological problem of all foresight activities and make assumptions on the continuation of existing trends. The study will be based on information and data available today, but the results of the study may not necessarily represent the true situation in the years 2010 or 2020, or when the safety systems are fully deployed.

All assessments of the impact of future IVSS have to rely on roadmaps of technologies and safety functions. A large number of expert groups, such as the marketing departments of automotive companies or consulting companies developing and selling surveys, deals with these kinds of forecast. Roadmaps discuss the time of the technological availability of safety functions, when a supplier offers a new safety system, the timing of the launch on the global market or the time when a safety system has reached a minimum deployment rate. In most cases, roadmaps refer to the time when an OEM begins series production of a safety system in the market of interest. Roadmaps are part of the regular planning process for the research, development, production and marketing of safety systems. It is, therefore, commonly understood that the collection and aggregation of such information is feasible. This information, however, touches upon the manufactuers' core interests and is not always publicly available.

Economic analysis provides techniques for assessing and quantifying the specific monetary value of the socio-economic impact of intelligent vehicle safety systems. Such an evaluation should encompass more than the benefits of immediate relevance to road safety. Instead, it should also consider the impact on the transportation system, on regional or national economies, and on the environment. The assessment of the impact of IVSS therefore, looks not just at the effects on traffic safety, but also at the indirect benefits for the transportation system, for the environment and for the economy. Benefit-cost analysis is a challenging endeavour because it is difficult to assign monetary values to many of the benefits. For this reason, a qualitative investigation of non-quantified factors should be part of any impact evaluation. A number of indicators have been developed for identifying measures for the assessment of the socio-economic impact of intelligent vehicle safety systems (Peng/Beimborn/Neluheni 2000; Maccubbin et al. 2003):

- Safety: Typical measures used to quantify safety performance include the overall crash rate, the fatality crash rate, and the injury crash rate. A related indicator is health costs.
- Mobility: Improving journey times by reducing delays is a significant effect of improved road safety. Delay of a system is typically measured in seconds or minutes of delay per vehicle. The delay for users of the system may be measured in person-hours.
- Efficiency: The throughput is defined as the number of people, goods, or vehicles traversing a road section per unit of time. Other measures are the capacity or the effective capacity.
- Energy and Environment: Assessing the impact of improved road safety on the environment is a difficult task, since regional environmental effects depend on a large number of exogenous variables like weather, ozone pollution, etc. However, decreasing levels of CO, NO_x or HC pollution, reduced fuel use or an increase of fuel economy are established measures for showing improvements in environmental protection.
- Productivity: Intelligent safety systems have the potential to enhance productivity by reducing fleet operating costs through reductions in journey times and through improving the planning and management of the transportation system. It is difficult to measure these macroeconomic impacts because they may not be evident for many years.

- Customer Satisfaction: Methods of qualitative social research provide approaches to analyse the extent to which the consumers feel satisfied by a safety system. The number of users of a system can serve as an indicator for the quality of a service.

In spite of the valuable research that has been undertaken so far, it is necessary to provide a systematic assessment of the potential socio-economic impact of intelligent vehicle safety systems. Based on short project summaries, the project will collate the existing results and provide a synoptic overview of the available research.

3.2 European Research on Intelligent Vehicle Safety Systems

There are a large number of EU projects targeting specific aspects of IVSS. The projects which cover aspects that might be relevant for the model development task of SEiSS have been reviewed. The relevant aspects are new technologies and functions in the area of intelligent vehicle safety systems, market deployment models or analysis of market deployment for single technologies/functions, traffic development, and the assessment of socio-economic impact.

No.	Acronym	Project start/end
1	ADASE I+II Advanced Driver Assistance Systems in Europe	II: 2001-2004
2	ADVISORS Action for advanced Driver assistance and Vehicle control systems Implementation, Standardisation, Optimum use of the Road network and Safety	2000-2002
3	AIDE Adaptive Integrated Driver-Vehicle Interface	2004-2007
4	ARCOS Action de recherche pour une conduite sécurisée	2001-2004
5	CarTALK 2000 Safe and comfortable driving based upon inter-vehicle communication	2001-2004
6	CHAMELEON Pre-crash application all around the vehicle	2000-2003
7	Chauffeur I+II EU freight traffic control/ Promote Chauffeur II	1996-2003
8	COMUNICAR Communication multimedia unit inside car	2000-2002
9	DIATS Deployment of interurban ATT (Advanced Transport Telematics) test scenarios	1996-1999
10	E-Merge Pan-European Harmonisation of Vehicle Emergency Call Service Chain	2002-2004
11	EDEL Enhanced driver perception in poor visibility	2002-2005
12	GST A Global System for Telematics enabling on-line safety services	2004-2007
13	HUMANIST Human-Centred Design for Information Society Technology	2004-2008
14	INVENT Intelligent Traffic and User-Oriented Technology	2001-2005
15	PREVENT Preventive and active safety applications	2004-2008

No.	Acronym	Project start/end
16	PROMETHEUS Program for a European Traffic and High Efficiency and Unprecedented Safety	1987-1995
17	PROTECTOR Preventive safety for unprotected road users	2000-2002
18	RADARNET Multifunctional automotive radar network	2000-2004
19	RESPONSE Vehicle Automation – Driver Responsibility – Provider Liability: Legal and Institutional Consequences	1998-2000
20	RESPONSE 2 Advanced driver assistance systems: from introduction scenarios towards a code of practice for development and testing	2002-2004
21	SAVE-U Sensors and system architecture for the protection of vulnerable road users	2002-2005
22	STARDUST Towards Sustainable Town development: A Research on the Deployment of Urban Sustainable Transport systems	2001-2004
23	TRL Report 220 Review of the potential benefits of road transport telematics	Report published 1996

Table 2: Selection of current research on intelligent vehicle safety systems and their socio-economic impact

The appendix summarises basic facts about each of the projects. In addition to organisational information (project name, project duration, partners and coordinator, funding and web site) for each project, the final report and additional available documentation, such as presentations or articles in professional journals, were analysed in order to sum up the main objectives of the project, important work packages, the specific work done, or the results produced in the areas of technology, market, traffic and socio-economic impact.

3.3 Résumé of IVSS Impact Assessments of European Research Projects

European research on intelligent vehicle safety systems covers a wide range of aspects. A large number of projects (e.g. AIDE, ARCOS, CarTALK, CHAMELEON, EDEL, E-Merge, GST, HUMANIST, INVENT, PReVENT, PROTECTOR, RADARNET, SAVE-U) deal with technological research and development and provide a basis for further progress in this field. The research encompasses the development of technologies like collision avoidance, lane departure warning, collision warning, inter-vehicle communication, adaptive cruise control, HMI concepts and vision enhancement. Several projects (e.g. ADASE II, GST, HUMANIST) are focused on accompanying measures for developing the sectoral innovation system and strengthening networks, standardisation and co-operation. It is necessary to strengthen the communication between experts in the field, public authorities and the consumers. Further measures aim at integrating international, national and regional activities. Some projects (ADVISORS; RESPONSE) examine the implementation of safety systems and measures to support the application of new technologies . Of particular interest are stakeholder analyses which consider political or investor interests, user acceptance, public regulation and possible implementation scenarios. Finally, a number of projects (such as ADVISORS, ARCOS, CHAUFFEUR, DIATS, E-Merge, STARDUST, TRL-report [Perrett 1996]) discuss the costs and benefits of the technologies investigated. The ARCOS project, for example, estimates the overall annual safety benefits for France at between 1.4 billion and 2.6 billion euros.

All these studies provide useful input for the assessment of the socio-economic impact of IVSS. It is essential that the evaluation of safety technologies is based on sound research which provides reliable data about the effects of safety technologies. Deepening our understanding of the relevant factors influencing the socio-economic impact of IVSS will be an ongoing task, and will provide the basis for identifying a number of indicators for the evaluation of safety systems. It is also necessary to supply statistical data on the European car market, as well as traffic and accident forecasts. There are also research projects which deal with the assessment of the socio-economic impact of safety-related technologies. These include the TRL report 220, ADVISORS and CHAUFFEUR.

To assess the socio-economic effects of IVSS, it is necessary to distinguish different levels of impact. Based on earlier findings, the TRL report 220 distinguished between operational analysis dealing with the technical assessment of operational effectiveness, socio-economic evaluation and strategic assessment (Perrett 1996: 16). The differences between these various evaluation categories are summarized in the following table:

Features	Categories		
	Operational Analysis	Socio-Economic Evaluation	Strategy Assessment
Kind of evaluation	Technical assessment of operational effectiveness	Economic evaluation of social impacts	Long-term strategic assessment on a political level
Purpose	Determination of technically-superior solution	Indication of social worth	Estimation of fundamental potentials and long-term risks
Alternatives to be evaluated	Individual technical options	Concrete, public investment projects	Entire technologies
Perspectives	Control and optimise a technical solution	Optimal allocation of scarce resources	Provision of a basis for comprehensive progress
Result	Statements on technique-specific operational performance	Identification of concrete social gains and losses	Appraisal of far-reaching consequences

Table 3: Evaluation Categories (Perrett, 1996: 16)

The TRL report was concerned with the potential benefits of road transport telematics. Although its main topic differed from the focus of this study, i.e. intelligent vehicle safety systems, the TRL report established clear categories for the impact assessment of intelligent transport technologies and proposed a methodology for benefit-cost analysis. The authors placed emphasis on the consistency and transparency of the method. They also aimed to include all the factors affecting decisions relating to transport telematics in the assessment. The report had a substantial impact on following research. It provides a useful starting point for the tasks of this study on IVSS.

The main categories of this study are similar to the evaluation categories developed in the TRL report. The TRL report merely puts an emphasis on a combination of socio-economic evaluation and strategy assessment because the report was aimed at developing policy recommendations which could be implemented to strengthen the transport telematics industry. The question of developing adequate policy measures, however, requires a convincing and comprehensible assessment of the socio-economic impacts.

This study argues that such an impact assessment must combine the different evaluation approaches quoted in the TRL report. In particular, the technical assessment must be linked with the socio-economic impact assessment. An evaluation of the operational effectiveness of technical systems is a crucial input factor for the appraisal of the social and economic impact. Additional influencing factors, such as market penetration and the traffic situation, must also be taken into consideration.

The TRL report provided a technology assessment for 36 transport telematics applications. The methodology used was based on ERTICO guidelines, with some modifications to generalise the approach across several systems. The main assessment stages were as follows (Perrett 1996: 387):

- Define assessment objectives (intended effects of transport telematics, efficiency, safety, environment, timescale)
- Describe system characteristics (technology components; performance; market penetration)
- Define assumptions concerning the policy and technological contexts
- Identify impacts (expected in principle; included in the assessment)
- Select appropriate indicators
- Apply “standard” values
- Analysis and results

The ADVISORS project took a different approach, developing a methodology from a problem-focused perspective instead of using a technology-driven approach. A crucial part of the methodology is the actor (stakeholder) analysis, which provided a sound understanding of the needs and requirements of the different stakeholders involved in the deployment of advanced driver assistant and vehicle control systems (ADAS). The methodology began by defining ADAS, including their technical capabilities and scope, as well as scenarios where they will be used. Next, a risk analysis assessed the risks involved in the implementation of ADAS. Following the stakeholder analysis, the study reflected on the costs and benefits that such a system might involve for the various stakeholder groups. Because the costs and benefits differ considerably between stakeholders, assessment criteria were developed an a weighting system defined to quantify the differential costs and benefits. Indicators were then generated and applied to empirical studies on ADAS impacts. The ADVISORS project developed a comprehensive framework for assessing and predicting the implications of ADAS, as well as for developing implementation strategies for ADAS expected to have a large positive impact. In particular, the specific focus on users and stakeholders enabled the authors to consider the issue of the societal acceptance of ADAS and to recommend potential implementation strategies. The project carused multi-criteria analysis to carry out a system impact assessment, and identified driver safety, third-party safety, environmental impacts and travel time reductions as the most important factors for successful implementation strategies.

The most striking difference between the TRL approach and ADVISORS is their politically- and stakeholder-orientated perspective. The TRL report aimed to provide a basis for strategic decisions about the direction UK Department of Transport policy should take. In order to prompt a debate on the relative benefits across the complete spectrum of applications, the report provided a broadly similar treatment of costs and benefits. In contrast, ADVISORS aimed to identify appropriate implementation strategies for various ADAS. The project therefore considered the specific interests of different stakeholders and discussed corresponding implementation scenarios. The underlying problem is that, while an application might be considered highly beneficial in cost/benefit terms, its implementation might prove difficult, due to requirements for commercial and public investment, for example. On the other hand, applications with poor cost/benefit ratios may find a highly profitable niche market among a particular group of users who are willing to pay a premium price (Parrett 1996: 17). ADVISORS took the stakeholders’ different objectives into account. Users, for example, are primarily interested in the full user cost, driver comfort, driver safety and journey time, while political actors are concerned with the public expenditure associated with ADAS introduction, the environmental effects, the health costs or the network efficiency. Manufacturers are interested in the technical feasibility and the acceptance risk (ADVISORS 2003: 73). The aim of this study is to develop a methodology for the assessment of the socio-economic impact of safety technologies. The reference to the ADVISORS project shows that this can be the starting point for further investigation, which will, in turn, lead to specific implementation strategies.

Intelligent vehicle safety systems can have a considerable impact for system users, road traffic and the general public. For this reason, the CHAUFFEUR project included a socio-economic evaluation at an early stage of system development in order to identify impediments to market success and to develop adequate solutions. The assessment of the socio-economic impact of IVSS can contribute to the IVSS being accepted by potential users and public decision makers. A benefit-cost analysis is a widely-accepted measure for economic welfare, because it can show that the system implementation is profitable for the whole society. The CHAUFFEUR project has formulated four steps leading to a benefit-cost analysis (CHAUFFEUR 2003: 3; see Appendix).

In order to create a reliable benefit-cost analysis, it is necessary to develop a market penetration model and to discuss the traffic impacts. A traffic simulation model is used in the financial evaluation. This model converts physical changes of traffic parameters, such as speed, average daily traffic volume and heavy duty vehicles shares. into monetary values (CHAUFFEUR 2003: 7). These three projects described above show the principle factors involved in creating a coherent socio-economic impact assessment of intelligent vehicle safety systems:

- Propose a sound evaluation methodology as basis for reliable results
- Assess the socio-economic impact in terms of benefits and costs by “simulating” the operation of the system under real-life road traffic conditions
- Address stakeholders’ interests in order to overcome potential market barriers and propose appropriate introduction strategies

Beyond the methodological level, the large number of European research projects provides indispensable input for an impact assessment of this type. These studies enable functional specifications of systems, socio-economic impact channels and the results of field tests or traffic simulations to be adopted. It is of crucial importance to integrate the results of current accident causation analyses which provide further information about the potential of emerging technologies to reduce the number and severity of accidents. A specific problem is the consideration of the interaction of safety functions. Up until now, the emphasis of research has been on the evaluation of single safety functions. Representing real deployment scenarios, however, requires – because of system interaction – the deployment of numerous IVSS to be taken into consideration at once. Another consideration is the fact that the research fields of market and traffic are not yet well-covered. There is a considerable lack of knowledge about how the systems fit into real-world market and traffic conditions. It is therefore possible to ensure that the socio-economic benefits of IVSS are assessed far more comprehensively way in previous studies. We need further information, not only about the readiness to market and system costs, but also about consumer interest and consumers’ willingness to pay.

The results of the project must be fitted into a coherent evaluation scheme. This study proposes a simple and comprehensible method for assessing the costs and benefits of intelligent vehicle safety systems. The main task was to agree methods for estimating the socio-economic impacts, without recourse to using complex and expensive models to support decision-making.

4 IVSS Assessment Methodology

Intelligent vehicle safety systems (active safety systems), were introduced in the 80s with the launch of Anti-lock Braking Systems (ABS). Since then, the automotive industry, insurance companies and public authorities have been modelling the effects of the introduction of IVSS from a safety and economic point of view. At the same time as accident data became much widely-available, IVSS systems were introduced, leading to a much more complex safety causation situation. So far, even for correlations in the past, a direct link between IVSS and accident statistics has not been proven.

Taking this situation into consideration, a standardised methodology is suggested, in which commonly-supported assumptions are made to cover gaps in in-depth data or clear correlations. Supplementing existing approaches, SEiSS addresses IVSS interaction and the influence of market deployment and traffic development on the socio-economic impact of intelligent vehicle safety systems. This project also discusses the possibility of a coherent impact assessment for all EU member states and provides a corresponding methodological outline.

In order to assess the socio-economic impact of intelligent vehicle safety systems, the safety technologies to be taken into consideration must be defined and their market deployment discussed. It is then possible to consider their effects on traffic, which form the basis of the socio-economic benefits of such systems.

Figure 5: SEiSS workflow (author's figure)

The technology section provides a brief description of intelligent vehicle safety systems and discusses their potential impact on road safety. The model proposed by the market section describes the diffusion of intelligent vehicle safety systems. The target figure is the number of vehicles fitted with intelligent vehicle safety systems at a given date. A number of external factors which could influence market deployment (e.g. regulation) are also taken into consideration. However, it is not the task of the study to discuss policy measures designed to influence road safety, and these factors will not, therefore, be taken into account. The project considers additional traffic effects (besides safety) resulting from the market introduction of intelligent vehicle safety systems.

There are several problems associated with collecting data for assessing the impact of intelligent vehicle safety technologies. Evaluation data may not be available, or data collection methods may be incomplete. The study proposes to use accident causation, market deployment scenarios, traffic development data and European cost unit rates to provide a benefit-cost analysis methodology for the assessment of intelligent vehicle safety systems.

The SEiSS project, running for just 6 months, focused on the formulation of a comprehensive assessment methodology to reflect the latest research and data availability for EU 25. The quantification of parameters and correlations should form part of subsequent projects. Some exemplary quantifications are used to demonstrate the overall data availability or (in the case of the exemplary calculations) to explain the logic of the proposed methodology and the calculation process. However, the study refers to further research requirements which might lead to an improved access to data dealing with the assessment of the socio-economic impact of safety technologies. Further investigations are required to decide on policy measures to support market deployment and penetration.

The study is based on available data taken from official statistics, traffic analyses, available market reports, and other sources which are referenced as appropriate. The study did not collect empirical data or perform simulations. It did, however,analyse the results of important studies and take these into consideration. In addition, workshops and expert discussions helped to consolidate the model and provided limited access to empirical data and studies undertaken on behalf of the industry.

4.1 Scope of the Model

The proposed methodology relies on three input dimensions (see graphic below):

- Parameters for IVSS definition
- Data
- External parameters.

All intelligent vehicle safety systems to be considered in this study must be defined in a way that makes their (technological) functions clear. They must also be described in terms of quantitative values to allow calculations in accordance with the proposed methodology to be performed (a). Data (b) is understood as input for statistical information or prediction. These values will remain constant in all calculations performed according to the model. External parameters (c) are considered to be values which could be used in scenarios, but which are not directly related to the intelligent vehicle safety systems.

If data is missing, predictions or assumptions can be made where comparable data is available. The available data is sufficient to allow a calculation to be performed according to the proposed methodology. Suggested sources are listed in brackets.

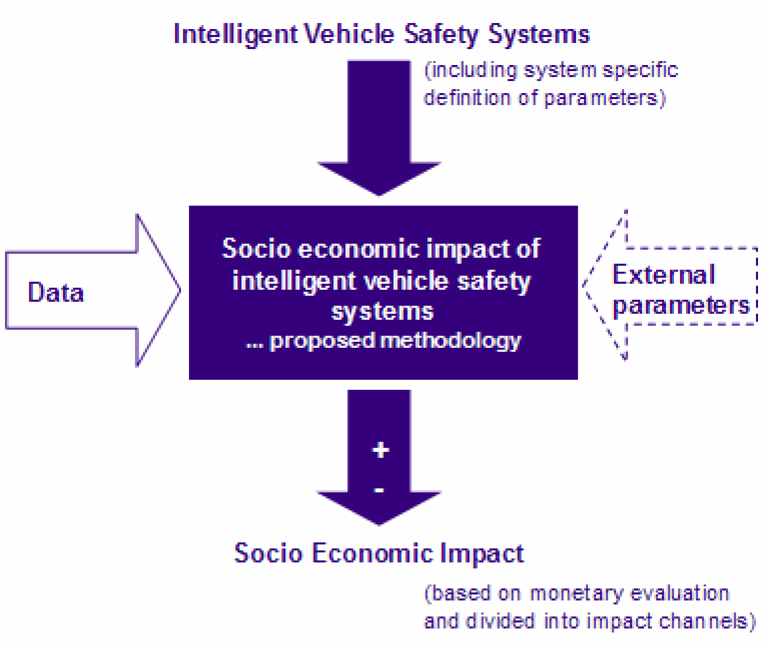

Figure 6: SEiSS system approach (author's figure)

Figure 6 reflects the proposed methodology (centre), viewed as a closed system. All calculations are made as part of the proposed methodology. The SEiSS project proposes a model to link Intelligent Vehicle Safety Systems (IVSS) with their socio-economic impact. The vertical axis therefore represents the underlying philosophy (design approach) for the suggested methodology, while the input parameters for IVSS (a) define the IVSS on a standardised level. The socio-economic impact is the outcome of the proposed methodology and therefore the result of all calculations.

In order to properly assess the effect of the introduction of IVSS, additional parameters (input dimensions) must be taken into consideration. This information (which is not directly linked to IVSS) is shown on the horizontal axis of Figure 6. A further distinction between Data (b) and External Parameters (c) is proposed. Data (b) is mostly statistical information for reference purposes, or information which will not change. In contrast, External Parameters (c) can be seen as input information which might change. Following this approach, examples for Data would be statistics on vehicle fleets, accidents or driven mileage for EU member states, while examples of External Parameters would include national cost-unit rates, fuel prices, taxation, and market predictions.

The following overview lists the input parameters for the proposed methodology:

a) Parameters for IVSS

- Definition and description of IVSS systems, including their correlations to other technologies and functions (e.g. Strategy Analytics)
- Availability of IVSS (e.g. Strategy Analytics)
- Time factors for system interaction and safety potential (accident causation research provider-t.b.a.)
- Time and price for market introduction (e.g. Frost & Sullivan)
- Diffusion pattern and price development (e.g. Frost & Sullivan)
- Rates of equipment at member state level (e.g. Frost & Sullivan)
- Operating and maintenance costs (OEM)
- Measurement of non-safety effects of IVSS and their correlation to traffic flow

b) Data

- Collision probability based on time savings (accident causation as per DaimlerChrysler, Enke 1979)
- Change of impact severity based on time savings (accident causation)
- Forecast of total number of vehicles stock at member state level (e.g. ProgTrans)
- Forecast of newly-registered vehicles per segment at member state level (e.g. J.D. Power – LMC Automotive Forecasting Services)
- Traffic development, traffic flow and vehicle mileage at member state level (e.g. ProgTrans)
- Vehicle mileage, by road type
- Speed patterns (average speeds on different road types for EU member states)
- Accident prediction data

c) External Parameters

- Cost unit rates at member state level
- Fuel price forecast

4.2 Proposed Methodology

The proposed methodology consists of 14 major steps. It takes technology, function, market and traffic input into consideration and delivers the ability to differentiate between EU member states. This process must be performed separately for cars and heavy goods vehicles.

4.2.1 Basic Approach

The starting point for the assessment is a clear and common definition of the IVSS of interest. This definition is assumed to be static over time, apart from the reduction of investment costs. The next major point is to determine a system's safety potential, including its interaction with other systems. This should done on the basis of accident types (as opposed to accident causes) and for 3 representative speeds to represent urban, rural and highway traffic. Accident causation methodologies must be combined with statistical data, and these findings must then be combined with equipment rates and vehicle mileage to represent real-world IVSS use. This information should then be used to predict the change in the number of accidents as well as any change in their severity. Accident severity should be calculated on the basis of impact speed and differentiated according to the AIS scale (no injuries, slight injuries, heavy injuries, fatalities). The predicted difference in the number of accidents is then used to assume the congestion situation. We can use European cost unit rates to calculate the direct accident costs as well as the indirect accident costs (time costs, vehicle operation costs and emission costs) for specific IVSS setups. The difference between IVSS being used and not being used is the benefit cost. The benefit must be correlated to the system costs (investment, operating and maintenance costs) to provide the benefit-cost ratio we want.

4.2.2 IVSS Assessment Methodology

The detail model is outlined in the following figure:

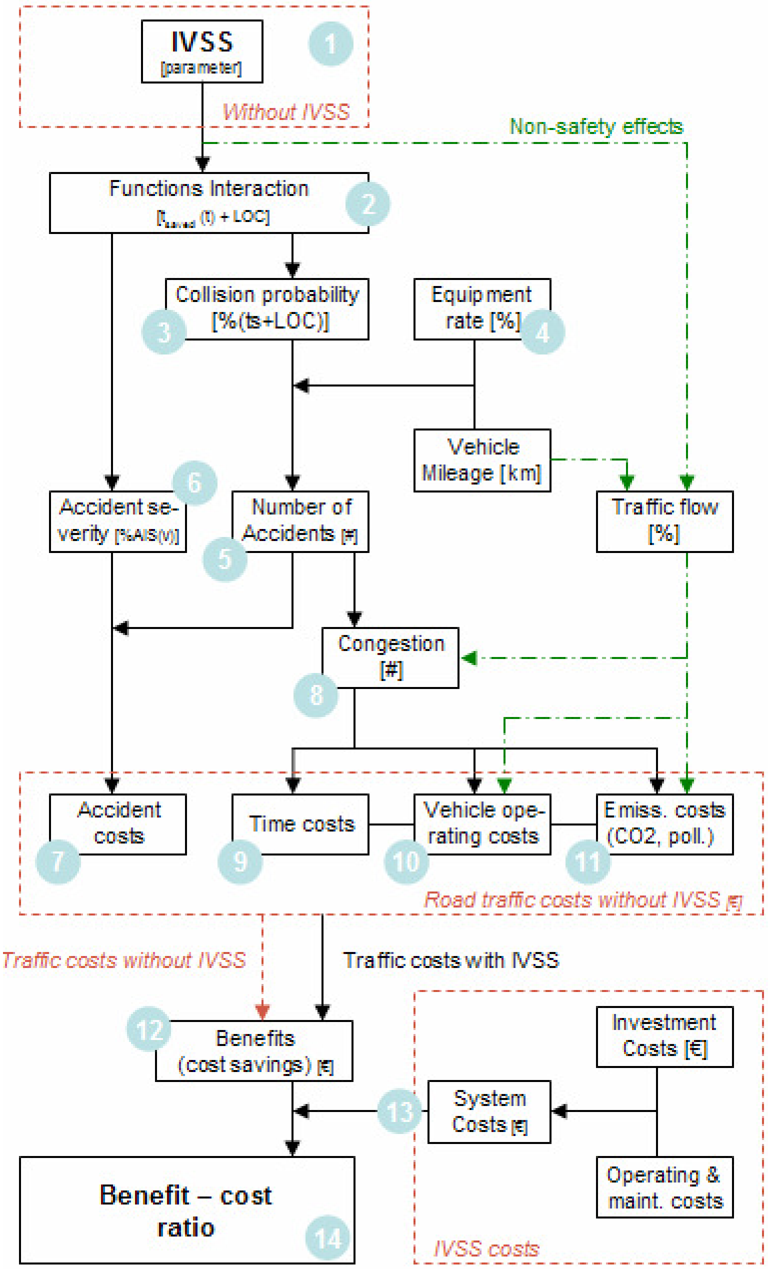

Figure 7: SEiSS methodology (author's figure)

The relevant steps for SEiSS methodology are:

1 Technology and functions interaction matrix (IVSS)
2 Assessment of function interaction
3 Collision probability for IVSS differentiated according to accident type
4 Equipment rate for IVSS systems according to specific market deployment scenarios
5 Prediction for number of accidents for specific IVSS set-ups
6 Prediction for accident severity for specific IVSS set-ups
7 Calculation of accident costs
8 Prediction for congestions
9 Calculation of time costs based on congestion
10 Calculation of vehicle operating costs
11 Calculation of emission costs differentiated into CO2 and pollution
12 Difference in costs with and without IVSS
13 IVSS-specific cost
14 Calculation of benefit-cost ratio

Technology is a prerequisite for an automotive function. As new technologies become available, new functions may be introduced. Functions (IVSS) can also depend on each other. We can therefore use this information to predict IVSS availability. Different functions may influence the same problem (step 2), making it necessary to define the areas of interaction. We propose correlating functions to time. This means that the effect of a function is assessed with regard to its time slot in accident mitigation and its effectiveness. A specific IVSS set-up translates into specific time patterns for different accident types. Based on the physics of an accident, this time pattern correlates to collision probability (step 3). As well as time-correlated dependencies, the loss of control (LOC) scenario has to be taken into account. It must be applied for the evaluation of systems interaction and for the prediction of collision probability and would be the second mode of systems functioning, besides the time-related mode. The compound evaluation of the time-related and LOC modes gives us the collision probability. If we then take into account the IVSS market penetration (step 4), the vehicles' driven mileages and the collision probability, we can predict the number of accidents (step 5). The time-related pattern used for step 3 can also be used to calculate the accident severity (step 6). The severity of an accident depends on the impact energy, which corresponds directly to the impact speed and the absorption potential of the passive safety system. The latter can be translated into additional time for the specific accident type. Bringing together the predicted number of accidents and their severity enables us to calculate the direct costs of an accident (step 7). Standardised European cost unit rates are applied. To calculate the indirect costs of an accident (steps 9 – 11), we suggest using the correlating congestion forecast (step 8). Summing up the results from steps 7,9,10 and 11 defines the “negative” traffic costs for a specific IVSS set-up..

The benefit-cost ratio of a specific IVSS set-up is calculated based on the definition of this IVSS set-up. This calculation must be performed twice; once including this specific IVSS set-up and then again with the reference configuration excluding this specific system set-up. The remaining difference translates as the benefit of using this specific IVSS set-up (step 12).

To finalise the calculation, the specific IVSS set-up costs must be defined. This calculation includes investment, operating and maintenance costs (13). Finally the benefit-cost ratio can be calculated (14).

The proposed methodology requires the calculation to be performed for three different speed patterns covering urban, rural and highway traffic. The approach described thus far must be performed separately for cars and heavy goods vehicles, as different market deployment, vehicle mileage, safety systems relevance, accident path and cost figures call for separate calculations. The resulting benefit-cost ratios for cars and heavy goods vehicles for urban, rural and highway traffic combined provides the overall benefit-cost ratio for a specific IVSS set-up. The calculations can be performed for both best- and worst-case scenarios to give a benefit-cost range.

The proposed methodology allows for a competitive assessment of the introduction of different IVSS and provides an absolute estimate of the associated costs and benefits. It must, however, be mentioned, that for e.g. investment decisions, the differentiation must be much higher and more specific analysis is required.

Step 1: Technology and Functions Interaction Matrix (IVSS)

Technologies are the prerequisites for vehicle functions. Different, often competing, technologies serve specific automotive functions. An IVSS, such as car-to-car communication, for example, could be understood as a technology, but in fact should be interpreted as a function, as it has a direct influence on safety. Technologies add to functions and both can be predicted on a time line.

The availability of technologies and functions enables to predict market launch from a technical point of view. Functions have to be described in parameters to define their effectiveness. Because the ability of a function to perform might differ between different OEM or supplier systems, for overal benefit-cost estimations it is suggested to relay on average parameters. In addition it is assumed that a function decreases in price but not evolve in its effectiveness.

A technology and functions dependance matrix is introduced in chapter 4.3.

Step 2: Assessment of functions interaction

The following figure shows that different IVSS can modify the vehicle's or the driver's reaction to a given accident type. It is therefore necessary to find a methodology to combine the different potential safety features of the vehicle functions to reflect this.

	Rear end collision	Side collision	Left roadway accident	Head on collision	Merging and intersection collision	Vehicle – pedestrian collision	Collision with obstacle	Other
ABS – antilock braking system	■	■	■		■	■	■	?
ACC – adaptive cruise control	■							?
Adaptive light – curve illumination	■		■	■	■	■	■	?
Airbag system – multistage/fire scenarios	■	■	■	■	■	■	■	■
Automatic light – light on/off	■		■	■	■	■	■	?
Crash Avoidance	■	■	■	■	■	■	■	?
Crash detection/warning	■	■		■	■	■	■	?
Driver monitoring – driver drowsiness	■	■	■	■			■	?
EBS – emergency braking system	■		■	■	■	■	■	?
eCall – in vehicle emergency calls								
ESP – electronic stability programme			■	■		■	■	?
LCA - lane change assistance		■						?
LDA - lane departure warning		■	■	■				?
Night vision	■			■	■	■	■	?
Passenger classification – weight, size, out of position	■	■	■	■	■	■	■	■
Pedestrian protection						■		?
Pre-crash – preparation of the car for a crash	■	■	■	■	■	■	■	■
Safe following – ACC in future versions	■							?
Safe speed – adaptive maximum speed of the car	■		■	■	■	■		?

Figure 8: IVSS correlation to accident types (author's figure)

The time correlation approach allows to see an accident in reverse and to match it with windows of time. Each phase of an accident can be correlated to a time scheme. The phases are:

- Prior to driving (planning and preparation of a trip)
- Driving (support of the driver by the vehicle for normal operation)
- Warning (a dangerous situation is expected through the vehicle, the driver gets informed)
- Assistance (support of the driver by vehicle systems)
- Pre-crash (time directly before an unavoidable crash)
- Crash (with passive safety systems in operation)
- Post crash (after the crash)

The mentioned phases emphatise different level of danger and support of the vehicle. The following figure draws such a time line.

IVSS perform in the different phases to support the driver. The systems performance should lead to an earlier information, better car stability, faster breaking or fewer driving faults. These systems can therefore be represented by time gains or contrary, time losses. Depending on the systems (interaction), the time gained or lost can be added or subtracted. The effort cannot exceed the time slot. The following figure indicates this IVSS/time correlation. The time factors are speed-dependent.

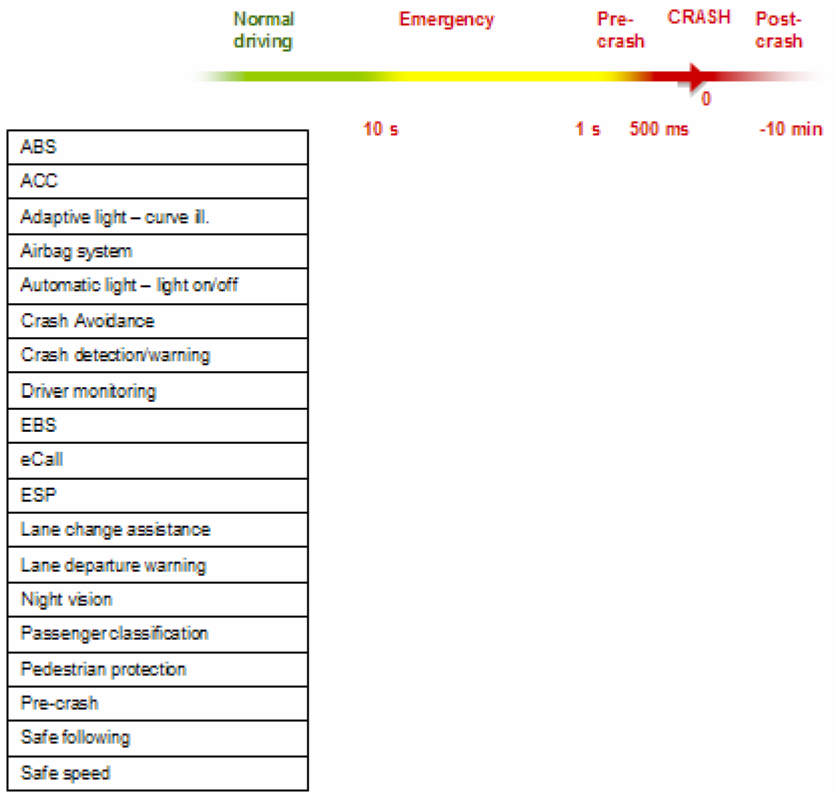

Figure 9: IVSS correlation to accident mitigation (author's figure)

It is difficult to correlate some IVSS to time. This remains the case for ABS (ensuring steerability while braking), ESP (preventing loss of traction through braking of specific wheels) and Safe (Adaptive) Speed (which limits the maximum speed to the physical limits of the vehicle combined with the specific road conditions). The mechanism for these functions is a so-called Loss Of Control scenario. Because of its high relevance in accident causes the Loss Of Control scenario (LOC) must be considered in the model and modelled separately due to its time independance.

Step 3: Collision Probability for IVSS, Differentiated According to Accident Type

IVSS can be related to known accident types. For different speeds and accident types IVSS can be translated into time savings or losses, which can be matched to each other. Taking the physics of accidents into account, these the overal changed timing will lead to a change in the number and severity of accidents. Correlation tables can be determined for different accident types and speeds. These tables can be used to calculate the accident probability for a specific IVSS set, but are independent from the technology. Such correlations should become the result of accident causation analyses providing a standardised basis for further calculation (refer to chapter 4.3). Separate curves are needed for different speeds and accident types.

Time gains will lead to a reduction in collision probability. No time gain translates into normal accident patterns or accidents occurring without the use of the specified IVSS. Additional reaction time for the car or the driver adds to the time gain and reduces the probability of a collision.

Step 4: Equipment Rate for IVSS Systems For Specific Market Deployment Scenarios

The main goal of integrating the market perspective into the proposed model is to find a way of forecasting the distribution of intelligent vehicle safety systems (IVSS) within the vehicle fleet of the countries considered, or in other words, the market deployment. The target figure for capturing the market perspective is the rate of equipment with intelligent vehicle safety systems. This figure has an influence on the socio-economic impact of IVSS. There are two reasons for this. The first is that both vehicles which are equipped with IVSS and vehicles or other road users which are involved in crashes with those vehicles benefit from the advantages of the crash avoidance or crash mitigation effects of the IVSS. Only those vehicles which are equipped with IVSS therefore influence the overall socio-economic impact. Secondly, some IVSS may need a certain equipment rate to fully exploit their potential benefits. Car-to-car-communicating systems, in particular, need a minimum number of equipped cars for the technology to function correctly.

Market penetration rates can be obtained from research institutes which specialise in forecasting market developments in the automotive industry. They have figures available for equipment rates of intelligent vehicle safety systems. Not all of the intelligent vehicle safety systems are covered by these analyses, however. Additionally, most of the research carried out by professional research institutes does not cover the time span to be reflected in this study. It is therefore necessary to develop our own approach to forecasting market development to fill the emerging gaps. Two steps must be taken to forecast market deployment, i.e. to calculate an equipment rate at a given point in time. Firstly, the time of market introduction must be assessed. Secondly, a market penetration channel must be decided upon. Based on the renewal rate of the existing vehicle stock, the following three scenarios for market diffusion have been developed within the proposed model:

- Introduction for all newly-registered vehicles and upgrades to vehicle stock
- Introduction for all newly-registered vehicles
- Cascade of innovation

With no regulations or clear cost effect for the OEM the “cascade of innovation” scenario is the most feasible one. A new function will be introduced initially in higher-class models and will emerge in smaller classes later, cascading down from higher to lower segments. The average life span of a car is about 10 years. Full penetration is reached when the vehicle fleet is completely renewed. Obviously, this is a process which will take more than one decade. In most cases, full market penetration cannot be reached, as some vehicles, such as classic cars, will never be upgraded. As we are looking at upgrade solutions, we have to take interface problems into account. It is very costly to add a complex function like an IVSS to a car which lacks the necessary subsystems or interfaces. This pattern may therefore only be valid for standalone solutions. Potential examples are eCall, traffic jam alert or toll collection.

Step 5: Prediction of the Number of Accidents for Specific IVSS Set-ups

Using the collision probability of an IVSS and its penetration rate, and taking into account the overall vehicle mileage, we can predict the corresponding number of accidents. The correlation to statistical data is performed using the underlying collision probability tables of step 3.

The following methodical procedures exist for predicting the number of accidents:

- Near misses-approach (retrospective approach);
- Field trials;
- Accident reduction determined on the basis of system specification (static approach);
- Microscopic traffic simulation of accident occurrence (dynamic approach).

The near misses-approach presumes that crashes are related to driver error. However, these results have no legal basis and cannot be applied without further information and adaptation to traffic conditions in other countries. Unfortunately, no actual analytical relationship exists at this point.

Conducting field trials could be another approach which could be used in determining the safety impacts of IVSS. However, field trials hold unknown risks, both for the drivers of the "field vehicles" and for other road users, due to unexpected system behavior. In order to achieve representative results, a large number of vehicles would have to be equipped, making the costs of field trials relatively high. Even with a representative number of equipped vehicles, the results of such field trials may not be reliable, due to the fact that the driving behaviour of the trained test drivers does not correspond to the driving behavior of normal drivers. Generally, therefore, field trials might be useful to prove the workability of IVSS in a real driving environment. They are useful in the prediction of traffic safety effects, but they will be too expensive in practise.

A more traditional approach is the **determination of accident reduction** using system specification (static approach). The static approach presupposes that the system specification of IVSS is reliable, which means that the effects on the driving situations of the system characteristics are well-determined, and take into account the possibility of system failures and unexpected system behaviour. It is possible to combine the information on how the system will affect a given driving situation with historical static data for traffic effects to predict the accident reduction potential and the impacts on accident severity for a base year. This approach is a practicable one for determining the effects of IVSS-applications on accidents. The only objection which can be made to this approach is that it is too theoretical; it does not take the dynamics of real driving situations into account.

The **microscopic traffic simulation** of accident occurrence (dynamic approach) focuses on real-life driving situations (see, for example, van Arem 1996, Widodo/Hasegawa 1998). Like the static approach, this approach considers the impacts of the system specifications, but it also applies them to the traffic situation. Typical indicators of this procedure are time-to-collision and number of shockwaves. The traffic safety impacts determined using this approach are therefore more realistic. The disadvantage is that the simulation can be performed only for representative network sections, as considering the total road network would require an exceedingly high number of simulation runs and an exhaustive calibration of traffic data. Such simulations are therefore usually 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 IVSS-case, which can then be used in the CBA evaluation process.

Step 6: Prediction of Accident Severity for Specific IVSS Set-ups

Accident severity is largely influenced by IVSS. The model differentiates between fatalities and accidents with severely, slightly and uninjured people (AIS scale). The more time for driver or car reaction the IVSS provides, the lower the impact severity will be. Passive safety systems will add on the energy absorption potential of the vehicle, which can be translated into additional time gains.

Analogous to the prediction of the collision probability, collision severity figures can be determined by accident causation analysis. These can be used to predict the corresponding accident severity for a specific IVSS set-up.

Step 7: Calculation of Accident Costs

The calculation of accident costs combines two impact dimensions: the IVSS impact on the number of accidents (step 5) and the IVSS impact on accident severity for the remaining accidents (step 6). Both impacts reduce casualties and – when translated into monetary units – accident costs. Obviously, both parameters – impacts and accident cost savings – are positively correlated.

Accident costs must be calculated twice to reflect both the accident situation without using IVSS (without-case) and the situation when a specific IVSS is used in road traffic (with-case). The IVSS safety impact will reduce the damage (to both people and property) caused by an accident.. The economic consequences of this damage are expressed as accident costs. When an accident occurs, economic resources have to be expended to make good this damage. Improving road safety reduces this damage and enables these resources to be used elsewhere in the economy.

The “cost-of-damage-approach” enables the objective evaluation of the resource losses caused by accidents. The damage costs comprise medical costs, police, legal and insurance administration costs as well as the loss of productive output attributed to the accident victims.

Studies of accident costs in several European member states regularly update cost unit rates for different levels of accident severity. Usually, cost unit rates are applied to fatalities, severe and slight injuries and any associated property damage. This study applies standard uniform cost unit rates at the European level.

The comparison of accident costs between the “with” and “without” cases gives the cost savings which are regarded as safety benefits. These safety benefits become part of the aggregated benefits (step 12).

Step 8: Congestion Estimation

In the context of the proposed model, there are two ways in which congestion can be reduced. First, congestion reduction is a side effect of safety improvements. Usually, road accidents impede the flow of traffic until rescue services have provided first aid to the accident victims and the police have documented the incident. IVSS can contribute to an overall reduction in congestion because the avoidance of (a number of) accidents also avoids the related congestion. When IVSS influences accident severity or improves the efficiency of the rescue chain (e.g. eCall) the accident site can be cleared more quickly. The lowers the duration of the congestion. Obviously, congestion is related to losses of economic resources such as time, as well as fuel consumption and pollution. The economic consequences of accident-caused congestion are reflected by a single cost unit rate which includes all the related cost components.

The second effect on congestion is due to improvements in the traffic flow. Some IVSS, especially those which have an impact on longitudinal control of the vehicle, will reduce variations in acceleration. As a consequence, the flow of traffic will be smoother and more homogenous. When a substantial part of the total vehicle fleet is equipped with IVSS, this could contribute to a capacity enlargement of road infrastructure. The capacity effect reduces congestion caused by high traffic volumes. This effect is obviously restricted to those sections of the road network which operate near the capacity limit. Under these circumstances, reductions in time costs, vehicle operating costs and emission costs (CO_2 and pollutants) can occur. The calculation of these benefits is the object of the following steps.

Step 9: Calculation of Time Costs Due to Congestion

As with the assessment of accident costs, two situations (with/without IVSS) must be compared. The congestion reduction due to the capacity effect (previous step) results in a higher average speed on an affected road section. A positive capacity effect therefore reduces both passenger and goods transport travel times. In most cases, time savings comprise a substantial part of the total economic benefit. Time savings are appraised with the opportunity costs of using one hour travel time alternatively, e.g. being productive. Cost unit rates are available for different European member states and different vehicle types (e.g. passenger cars, lorries and buses).

Step 10: Calculation of Vehicle Operating Costs

When the capacity effect influences congestion due to high traffic volumes, vehicle operating costs are affected, too. Vehicle operating costs comprise the fuel consumption of the vehicles as well as a fixed cost term which reflects speed-invariant cost components (such as lubricant or tyre wear). Cost unit rates are differentiated according to vehicle types (fixed term) and fuel types (fuel consumption term: gasoline/petrol, diesel). IVSS (comparing with-/without-case) only usually influence the fuel consumption component. Since fuel consumption functions ($FC = f(v)$) are usually u-shaped, the impact direction depends on the speed level in both the “without” and the “with” case. This effect is, therefore, not always positive, but it will be compensated for in most cases by smoother traffic flow due to lower variances in acceleration. The smoother traffic flow offers potential for fuel consumption reduction. This effect has been demonstrated in several European research projects (e.g. STARDUST, CHAUFFEUR). In economic terms, savings can also be achieved in vehicle operating costs. These benefits are important because they can be attributed directly to the IVSS users.

Step 11: Calculation of Emission Costs Differentiated into CO_2 and Pollution

In general, savings in emission costs come from the same impact channels as savings in vehicle operating costs, but emission costs are composed of two different cost elements. The CO_2-emission costs represent the impact of fuel consumption on the green house effect. There is a direct proportional effect of fuel consumption on CO_2. Other greenhouse gases will not be evaluated. Damages to the environment caused by pollutants such as NO_x, CO and HC are reflected in the emission costs. The emissions are calculated using speed-dependent emission functions for different vehicle types. This step is then followed by aggregating the emissions of each pollutant weighted by its toxicity to NO_x units. The cost unit rate used for conversion to monetary units represents the economic damage for a ton of NO_x units. Although there is a wide range of cost unit rates in different European countries, a standard rate for EU-25 should be applied. Standardised European cost rates are used to make predictions for indirect accident costs based on congestion. The calculation suggests including the effects of time lost for all road users, for the additional operating costs of the vehicle (e.g. fuel consumption) and for the congestion caused emission costs (CO_2 and pollution).

Step 12: Aggregation of Cost Savings

As in the previous steps, the traffic-related costs (accident costs, time costs, vehicle operating costs, emission costs [CO_2 and pollutants]) must be performed twice to reflect the “with” case (using IVSS) and the “without” case (without IVSS). The cost savings in the “with“ case represent the benefits of the IVSS. Since all impacts have been converted to monetary units in the previous steps, they can now be aggregated to the total benefit. Usually, this amount represents the benefits of using IVSS for one year.

Step 13: IVSS-Specific Costs

The IVSS system investigated is connected to investment costs as well as operating and maintenance costs. The investment costs as a fraction of the total vehicle price are the most important cost element. Although these costs are borne by the users, they are also relevant in the context of a socio-economic impact assessment. Further cost elements include differences in operating and maintenance costs or infrastructure costs in the case of vehicle-infrastructure communication systems. For instance, the equipment of public safety answering points (PSAP) related to the eCall system can be classified as infrastructure costs.

Since benefits are calculated on an annual basis, the costs must also be converted to annual values. The annual costs take into account the service life and the depreciation rate of the IVSS.

Step 14: Calculation of Benefit-Cost Ratio

In the final step, the benefits of the IVSS are compared with the system costs, both on an annual basis. The aggregated benefits from step 12 (numerator) are divided by the system costs from step 13 (denominator). The benefit-cost ratio (the final result) indicates whether the introduction of IVSS is favourable from a socio-economic point of view. If the benefits exceed the costs (benefit-cost ratio above 1) the introduction of the IVSS would be beneficial to the society.

4.2.3 Differentiation between Passenger Cars and Heavy Duty Vehicles

Heavy duty vehicles and passenger cars both have a significant influence on traffic and safety. For a proper assessment of the effects of the introduction of IVSS, they must be considered separately. This means that the calculations must be performed twice, once for cars and a second time for heavy duty vehicles. The separate costs and benefits for cars and heavy duty vehicles must be added together and contribute to the overall benefit-cost-ratio.

The assessment of the effects of the introduction of IVSS for heavy duty vehicles follows the proposed methodology and does not differ from IVSS for cars. The data and parameters used may be different, however. The following paragraphs describe the differences in the specific steps of the impact assessment methodology.

Correlation of Heavy Duty Vehicles to Safety

Heavy duty vehicles are vehicles weighting more than 3.5 tons and up to 40 or even 65 tons. They count for less than 5% of the overall vehicle stock but more than 20% of the mileage driven. Looking at statistics heavy duty vehicles are involved in just a minority of the accidents on European roads. But if a heavy duty vehicle is involved in an accident, the correlating costs are higher compared to a car accident. In addition, technology and penetration of IVSS are different for heavy duty vehicles and cars. The impact assessment for cars and for heavy duty vehicles should therefore be performed separately.

IVSS Technology for Heavy Duty Vehicles

The technology used for IVSS is almost the same for cars and for heavy duty vehicles. Technology as a prerequisite for safety functions is used in a comparable manner. The differentiation in the safety function is due mainly to differing vehicle physics. Heavy duty vehicles are much heavier and longer and their centre of gravity is higher or even fluctuating (in case of liquid loads, for example). Safety systems therefore have to work with other parameters and will have different impacts on the vehicle and its dynamics.

The proposed assessment methodology remains valid for the assessment of the impact of the introduction of IVSS for heavy duty vehicles. Related to technology, the IVSS-specific parameters must be adapted to heavy duty vehicles. The same IVSS must therefore be defined as regards their use in heavy duty vehicles (step 1), the time factors and loss of control parameters for systems interaction (step 2) are different, and the curves for collision probability (step 3) and well as accident severity (step 6) must be heavy-duty-vehicle-specific.

IVSS Market for Heavy Duty Vehicles

Heavy duty vehicles are operated by drivers who do not normally own the vehicle. Buying patterns therefore, are usually governed by economic reasoning. Safety systems add to the investment and operating costs for a heavy duty vehicle in a very competitive business. In addition, it is assumed that the vehicle is operated by a trained driver. The willingness to invest in IVSS, however, remains moderate. Advanced cruise control and lane departure warning systems are examples. When a decision is made to install IVSS systems, it affects at least part of the investments for fleet renewals.

The costs for IVSS for heavy duty vehicles differ from the costs of comparable systems for cars. This is due in part to a more complex and robust integration. Systems may also have to be adapted to additional axles and trailers. The average lifespan of a heavy duty vehicle differs from that of a car and affects the IVSS investment depreciation. As with cars, professional statistics and forecasts for IVSS and market numbers for heavy duty vehicles are available or could be prepared within a few months for EU 25, up to 2020. This would affect steps 4 and 13 of the proposed assessment methodology.

IVSS Correlation to Traffic and Socio-Economic Effects

The mileage driven by heavy duty vehicles and for cars differs significantly. Heavy duty vehicles also drive mainly on motorways and do not exceed 100 km/h maximum speed due to legislation. If a heavy duty vehicle is involved in an accident, the expected obstruction (due to the size and load of the vehicle as well as the severity of the accident) is much higher compared with accidents which involve only cars.

In accordance with the proposed assessment methodology, heavy-duty-vehicle-specific parameters for congestion prediction and for cost-unit rates (steps 8 to 11) must be defined.

4.3 Technologies and Functions

4.3.1 Definitions

The full title of this study is “An exploratory study of the potential socio-economic impact of the introduction of intelligent vehicle safety systems in road vehicles”. It would be useful to start by providing a definition of intelligent vehicle safety systems. It has already become clear that several different terms are used to describe similar areas, that the same term might have different interpretations and that a mixture of technologies, systems and functions on different clustering levels are involved in the discussion.

Common terms in the field of safety systems are ITS, ADAS, VGS, AVCSS and IVSS. They may be defined as follows:

ITS (Intelligent Transport Systems and Services)

ITS describes any system or service that makes the movement of people or goods more efficient and economical, i.e. more “intelligent”. Whether offering real-time information about current traffic conditions, in-vehicle destination guidance, or online information for journey planning, the variety of ITS tools available today enable authorities, operators and individual travellers to make better informed, more intelligent transport decisions (Ertico 2004).

ADAS (Advanced Driver Assistance Systems), AVG (Automated Vehicle Guidance), AVCSS (Advanced Vehicle Control and Systems)

ADAS is a collective name for a whole range of ICT-based in-vehicle systems intended to support the driver in his driving task. ADAS applications are expected to enhance driver comfort, improve road traffic safety, and increase road network capacity. ADAS, AVG systems or AVCSS as they are known in North America, are products for which there is a market, and which are intended to provide additional safety and comfort to drivers. In addition, new highway infrastructure may enable such systems and related services to operate more effectively against broader criteria such as efficiency of operation or the environment (STARDUST 2004b and http://www.niwi.knaw.nl/en/oi/nod/onderzoek/-OND1293400/toon, October 2004).

IVSS (Intelligent Vehicle Safety Systems)

IVSS for road vehicles are systems and smart technologies which use modern IT for crash avoidance, injury prevention, and upgrading the road-holding capabilities and crash-worthiness of cars and commercial vehicles.

The difference between the aforementioned concepts lies in the system scope. These concepts begin with the single vehicle, continue through the road with all its users and their interactions, right up to the concept of “traffic”, which includes stakeholders, infrastructure and regulations. Safety is an important issue in all of the aforementioned concepts, but only IVSS (intelligent vehicle safety systems) relate directly and exclusively to safety.

Given this definition, cars and heavy duty vehicles are the subjects of this study. Pedestrians, bicycles and other road users are not considered vehicles and will not be the initial carriers of advanced technology. Having said that, these vulnerable road users stand to benefit considerably from the introduction of intelligent vehicle safety systems in road vehicles.

The OECD (Organisation for Economic Cooperation and Development) suggests a different clustering using the following categorisations:

- Vehicle-based systems
- Infrastructure-based systems (primarily roadside sensors which collect information and roadside equipment which issues warnings and advisories)
- cooperative systems (utilise both infrastructure-based and vehicle-based systems with communication links between them. The advantage of these systems is that information such as speed limits, traffic and road conditions is received from the infrastructure, and provided dynamically to individual vehicles at the appropriate time.)

Irrespective of the perspective from which they are viewed, intelligent vehicle safety systems in road vehicles must be part of the vehicle and should have a direct impact on improving safety. Such a system might need the support of the infrastructure or concepts of cooperative systems to work, but still remains an intelligent vehicle safety system covered by this study (e.g. eCall, refer to chapter 4.3.).

Another differentiation can be derived from the systems correlation to a crash. Five phases can be defined (see following figure):

- normal driving (the system provides support and information to the driver)
- warning/assistance phase (the vehicle predicts a dangerous situation)
- pre-crash-phase (the crash is unavoidable)
- in-crash-phase (the crash happens)
- post-crash phase (the crash has been happened and emergency services are approaching)

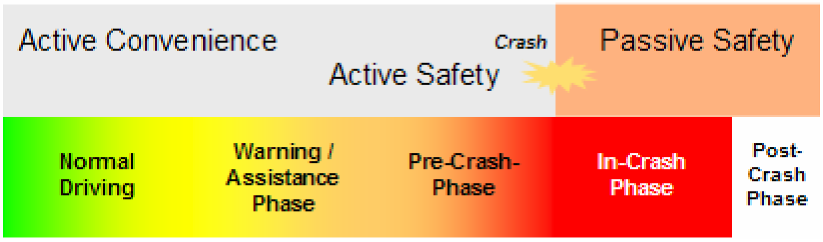

Figure 10: Crash development and correlating safety system (based on Robert Bosch GmbH)

Following this approach, intelligent vehicle safety systems cover phases 2 to 5, starting with warning and assistance, and ending with the post-crash phase. Nowadays safety-relevant systems are often introduced as comfort systems. We know from experience that buyers would rather pay for comfort than safety. In addition, various legal issues linked to safety systems remain unresolved. However, the trend clearly shows a mitigation of function towards safer vehicles. The following figure gives an overview of such systems.

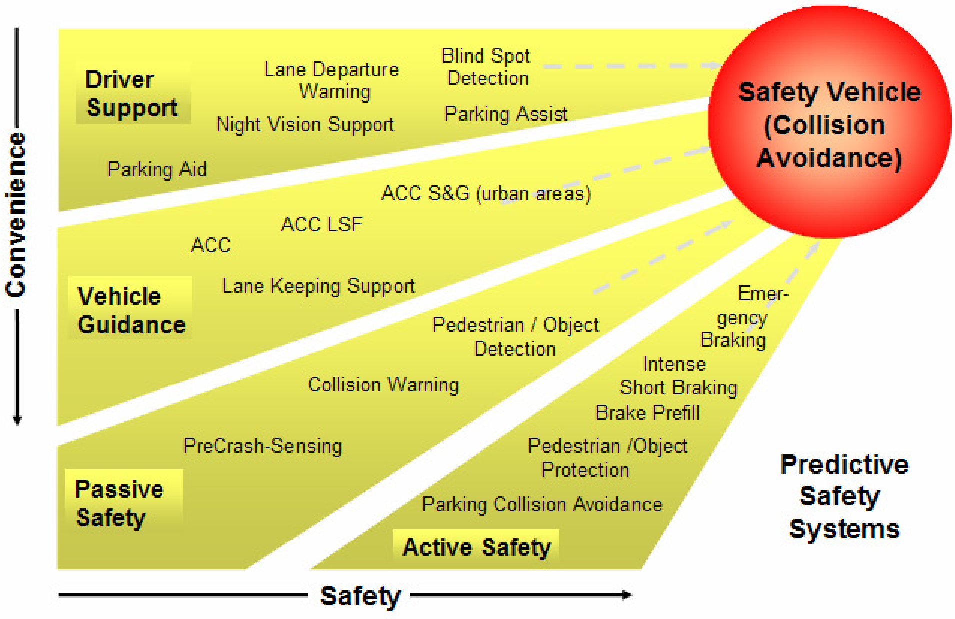

Figure 11: Correlation of terms and function, distinction between comfort and safety systems (based on Robert Bosch GmbH)

Once more, comfort systems, or systems sold as comfort systems, may contribute substantially towards safety. There has been widespread development in technologies which, although not expressly designed for safety purposes, but which could have a direct impact on road safety. There has been a considerable increase in the number of these technologies available. Although some (such as air conditioning) may make the task of driving easier and therefore safer, other technologies (such as mobile phones) can be distracting and can therefore have a detrimental effect on safety.

There has, in recent years, been rapid and significant development of numerous safety systems, not all of which are intelligent solutions. At one end of the scale are technologies which, in the long run, will use very complex system interaction to enable vehicles to drive safely in traffic independent. At the other end of the scale, some quite simple technologies (such as seatbelt wearing detection systems), which do not have signal processing capacities, could dramatically reduce fatalities if made compulsory for all seats in vehicles. Even in countries which, through publicity and enforcement campaigns, have achieved very high rates of seatbelt wearing (95 % or higher), drivers who are not wearing seatbelts are considerably over-represented in fatality statistics. These kinds of simple systems do not fall under the intelligent vehicle safety systems definition.

Historically, improvements in road safety have been decided upon using a reactive approach based on fatality and injury statistics. This is contrary to the approach used in many other health and safety areas, where proactive measures are implemented to avoid death and injury rather than after the fact. Since many of these technologies are only just being introduced onto the market or are still under development, their impacts on fatalities and injuries are not yet known (OECD 2003).

In summarising the different aspects involved in the definition of intelligent vehicle safety systems for road vehicles we conclude:

IVSS for road vehicles are systems and smart technologies which use modern IT for crash avoidance, injury prevention, and upgrading the road-holding capabilities and crash-worthiness of cars and commercial vehicles. According to the crash development systematisation (Figure 11) these systems actively improve safety within the warning and assistance, pre-crash, in-crash and post-crash phases. Comfort systems falling into this category could also be termed intelligent vehicle safety systems.

4.3.2 Introduction of Relevant Technologies and Functions

Based on the definitions in the previous paragraph, we can draw up the following list of relevant intelligent vehicle safety systems This list has been compiled from publicly-available forecasts (e.g. Mercer), data from European-funded R&D projects (e.g. ADASE 2 and SAVE-U), expert interviews (with representatives from Bosch and Hella, for example), as well from information provided by the first OEM workshop with BMW.

The remaining tasks include the quantification of parameter sets to correspond to the functions characterising costs, market deployment, systems interaction and the system safety potential. This data can be collected from expert opinion, from public projects, from the eSafety working group, or from professional reports such as those provided by Strategy Analytics.

ABS – Anti-Lock Braking System

This system prevents the wheels from locking during hard braking, thus retaining the ability to steer the vehicle (while braking)

Market introduction	1978, standard equipment in Europe
Requirements	Wheel speed sensors and brake system interface
Safety potential	High, but low rate of increase due to the market penetration already achieved
Investment costs	Medium
Operating costs	Low
Diffusion	All new European vehicles

ACC – Adaptive Cruise Control

This system automatically maintains a set speed. It allows acceleration and braking, where braking is limited to a maximum of 1/3 of the available braking power. The system’s limitations (as well as legal issues) define this system as a comfort system incapable of taking responsibility .

Market introduction	2000
Requirements	Long-range radar or infrared sensor, car interface
Safety potential	Low, also poor market penetration due to high system price
Investment costs	High
Operating costs	Medium
Diffusion	Optional as comfort function

Adaptive Light – Curve Illumination, Automatic Light

Intelligent light systems support better vision in severe conditions. Adjusting the light according to speed, gradient, curves, intersections and conditions enhances the driver’s vision – by far the most important sense. Future systems may include switching automatically between high and low beam.

Market introduction	2003
Requirements	Digital maps, navigation system, actuators, interfaces to the car
Safety potential	Medium
Investment costs	High
Operating costs	Medium
Diffusion	Optional as comfort function

Airbag System – Multi-Stage/Fire Scenarios

Multi-stage airbags, intelligent belt systems, multi-use components, passenger classification (weight, size, out of position). The passive safety system (including restraint) will continue to contribute to the reduction of the number of road fatalities. Intelligent passive safety systems, which use information from active safety systems to adapt to the parameters of the unavoidable collision, are expected to be more efficient.

Market introduction	Already introduced (airbags)
Requirements	Smart sensors and actuators
Safety potential	Medium (in addition to the safety potential of existing systems)
Investment costs	High
Operating costs	Low
Diffusion	New vehicles

Braking Assistance

Inert braking by the driver will be supported through full braking by the system. The system predicts an emergency braking situation.

Market introduction	2003
Requirements	Sensor on the throttle and brake control, interface to brake system
Safety potential	Medium, inert braking is an important issue
Investment costs	Low
Operating costs	Low
Diffusion	Standard function for selected models

Crash Avoidance

Following the interaction timeline of an intelligent vehicle safety system, crash avoidance comes into effect after information – warning – support. There is not enough time left for the human to avoid the accident. The system would therefore independently initiate appropriate action. In the future, vehicles might be able to adopt avoidance tactics which make accidents almost rare.

Market introduction	After 2015
Requirements	Predictive sensing, x-by-wire
Safety potential	High but very complex
Investment costs	High
Operating costs	High (passive and active elements)
Diffusion	Optional as safety function with potential to become mandatory

Crash Detection/Warning

Predictive sensors like infrared, radar, laser, ultrasonic and cameras calculate the likelihood of a crash. An appropriate warning system can inform the driver of dangerous situations in advance or activate crash avoidance or the pre-crash system.

Market introduction	2008
Requirements	Predictive sensors
Safety potential	High
Investment costs	High
Operating costs	Medium
Diffusion	Optional as safety function

Driver Monitoring – Driver Drowsiness

Driver monitoring systems currently being researched can unobtrusively detect driver drowsiness and/or lowered driver performance, and provide in-vehicle warnings or (in cases where there is no reaction) initiate emergency braking.

Market introduction	2009
Requirements	Camera or indirect driver action monitors
Safety potential	High, but low acceptance
Investment costs	Medium
Operating costs	Low
Diffusion	Optional or standard for selected models

EBS – Emergency Braking System

If an accident is unavoidable, this automotive system brakes the car with maximum deceleration. The crash cannot be prevented, but its severity will be reduced. This function needs predictive sensors for scanning the vehicle's surroundings as well as information about the car's speed, weight and direction. The results enable potential collision courses to be calculated. To brake the car automatically, the car must be equipped with (at least) an electronically-controlled braking system.

Market introduction	2009
Requirements	Sensors to detect the situation, interface to the brake system
Safety potential	High, reduces accident severity
Investment costs	High
Operating costs	Low
Diffusion	Optional, may become mandatory

eCall – In-Vehicle Emergency Call System

"The in-vehicle eCall is an emergency call generated either manually by vehicle occupants or automatically via activation of in-vehicle sensors. When activated, the in-vehicle eCall system will establish a voice connection directly with the relevant PSAP (Public Safety Answering Point), this being either a public or a private eCall centre operating under the regulation and/or authorisation of a public body. At the same time, a minimum set of incident data (MDS) will be sent to the eCall operator receiving the voice call." (eCall MoU 2004)

The trigger for the automatic call is normally the deployment of the car's airbags, but it may also be manually activated. The system, as it is already in service for premium cars, uses an in-car cellular phone to connect to a PSAP. The PSAP will try to speak to the driver/passengers of the car to ask about their health status. Based on their responses, or if no response is given, standard emergency procedures will be initiated. As it is used in premium cars, eCall is basically a software function, because all the necessary hardware is already available in the car. Emergency calling systems for the volume market might be based on a separate device. This device would need acceleration sensors for sensing a crash and a telephone (GSM) unit. GSM information could pinpoint the car's position to within a 500m radius. Using GPS/Galileo coordinates would be more accurate.

Market introduction	2003 (for premium cars for some OEM)
Requirements	Positioning system, phone and sensor
Safety potential	Medium (depending on infrastructure)
Investment costs	Low to medium (depending on car)
Operating costs	Low
Diffusion	Optional equipment, but may become mandatory

ESP – Electronic Stability Programme

The most promising system for mitigating lateral impacts is one which maintains stability (i.e. reduces the side-slip angle). Future automobiles may provide an even better platform for stability control. Steer-by-wire systems will enable ESP, not only to apply the brake on selected wheels, but also to influence the steered course directly. Precision navigation systems and digital maps will provide accurate information on the vehicle's position with respect to the environment. ESP will therefore no longer depend solely on the steer angle information to determine the desired vehicle trajectory.

Market introduction	1999, wide penetration in Europe
Requirements	Inertial sensors and interface to the braking system
Safety potential	High
Investment costs	Medium
Operating costs	Low
Diffusion	Standard function for (yet) selected models

Lane Change Assistant

If a lane change is initiated by the driver, the car checks for obstacles in the vehicle's path. A car in the blind spot, for example, could lead to a dangerous situation. An assistant would probably warn the driver of such a problem, but not yet act. The first action would, for instance, be a red flashing side mirror – a system with feedback in the steering wheel could be introduced later. The lane change assistant would need predictive sensors to scan the surrounding vehicles.

Market introduction	2005
Requirements	Lane recognition (cmos camera), blind spot monitoring and rear sensing
Safety potential	Medium, but together with other functions for lateral support high
Investment costs	Medium
Operating costs	Low
Diffusion	Optional equipment, sold as comfort function

Lane Departure Warning

If the car is leaving the lane in an unpredictable manner, the driver will be warned. This system is already in use for lorries; the steering wheel vibrates and a sound comes from the appropriate side.

Market introduction	2005 (cars)
Requirements	Lane recognition (cmos camera), HMI
Safety potential	Medium, but unintended lane departure is one of the most dangerous traffic situations
Investment costs	Medium
Operating costs	Low
Diffusion	Optional equipment sold as safety function

Night Vision

The night vision system increases the range of vision during night driving and “sees” beyond the lights of oncoming traffic which tend to blind drivers on country roads. It uses an infrared camera to detect the heat emitted by pedestrians, bikers, animals and broken-down cars. Because the system extends vision by up to five times the normal range, the driver can identify objects more quickly and react much earlier to avoid accidents. In addition to delivering a picture to the driver, this data can be used to detect obstacles and initiate appropriate automatic action by the vehicle. In future, augmented reality scenarios could provide additional information (even superimposing information on the driver’s field of vision) to alert drivers to potential hazards.

Market introduction	2006
Requirements	Active or passive infrared system
Safety potential	Medium
Investment costs	High
Operating costs	Low
Diffusion	Optional equipment sold as safety function

Pedestrian Protection

Passive systems sense a human impact and initiate systems like external airbags or the lifting of the hood. Active pedestrian protection systems can warn when the risk of a collision with a pedestrian or a vulnerable road user is high, and significant safety improvements can be expected in urban and rural areas. There is a strong link to (intelligent) passive safety systems.

Market introduction	Passive 2005/active 2010
Requirements	Sensor satellites/short range predictive sensors
Safety potential	High
Investment costs	Medium to high (passive / active systems)
Operating costs	Low
Diffusion	Mandatory equipment

Pre-Crash Systems – preparation of the car for an unavoidable crash

The activation of passive safety systems adapted to optimise protection (including systems for the protection of vulnerable road users).

Market introduction	2006
Requirements	Short-range predictive sensors
Safety potential	High
Investment costs	Low to medium
Operating costs	Low
Diffusion	Becomes standard equipment

Safe Following Systems – Adaptive Cruise Control / automatic stop and go

These systems will automatically maintain distance and (optionally) adapt vehicle speed. This function could be implemented through a class of collision mitigation systems, building on today’s cruise control systems, with added sensors, warning systems and communications. Most of the proposed systems require a well-controlled traffic situation, such as that found on motorways. Examples of these systems include collision warning, collision mitigation, ACC, platooning, stop+go, and vehicle-vehicle communication. The system, including stop and go, will be introduced for motorways first.

Market introduction	2005
Requirements	Long- and short-range sensors, car interface
Safety potential	Low for passenger cars, might be interesting for lorries
Investment costs	High
Operating costs	Medium (active and passive elements)
Diffusion	Optional equipment, sold as comfort function

Safe Speed – adaptive maximum speed of the car

These systems are designed to maintain a safe speed, whether in relation to the road conditions and environment, or when approaching curves, congestion or adverse road conditions. Examples of these systems include curve speed prediction, traffic sign recognition, speed advice, road status, and intersection support using vehicle-infrastructure communication. It is possible to develop systems linked to intelligent speed adaptation, based on satellite positioning or vehicle-infrastructure communications (using DSRC, for example) or a combination of the two which will alert drivers to the speed limit according to the current traffic situation.

Market introduction	As warning function (based on digital maps) 2006, after 2015 as an adaptive function
Requirements	Digital maps, positioning system, environmental data, information on vehicle limits
Safety potential	Very high; speed is one of the major causes of accidents
Investment costs	Low
Operating costs	Low
Diffusion	May become mandatory

Vehicle Collision Alert System

Many accidents occur on European roads due to poor visibility. Particularly in foggy conditions, the number of serious traffic accidents is significantly above average. Rear fog-lights and hazard flashers and the vehicle’s optical warning devices often provide insufficient warning for drivers of in the vehicles behind. Hazard warning systems based on sensors and direct vehicle-to-vehicle communication links could improve traffic safety significantly in such situations.

Market introduction	2007
Requirements	Car-to-car communication or infrastructure-based systems
Safety potential	High
Investment costs	Medium
Operating costs	Low
Diffusion	Optional equipment, sold as safety function. May become mandatory

4.3.3 Technology and Functions Dependencies

Discussing intelligent vehicle safety systems leads us to a discussion of vehicle functions. These systems and functions, listed in the previous subchapter, are based on the availability of technologies. There is strong competition among technologies to perform different functions. The introduction of a new sensor may make a new set of functions feasible/may give rise to a new set of functions. On the other hand, if a sensor does not meet expectations, this could lead to a much later introduction (several years) of a function or, even worse, its poor performance could damage user acceptance.

The following figure shows a correlation of this type for longitudinal stability systems. For ACC, for example, a radar sensor and active braking (the actuator) are needed. If both technologies are available, ACC can be introduced. ACC itself is the prerequisite for stop and go functionality based on additional sensor input (near area) and advanced actuation mechanisms (electrohydraulic braking). Technologies (grey) are invisible for the driver and functions (coloured) are directly related to the vehicle and the driver.

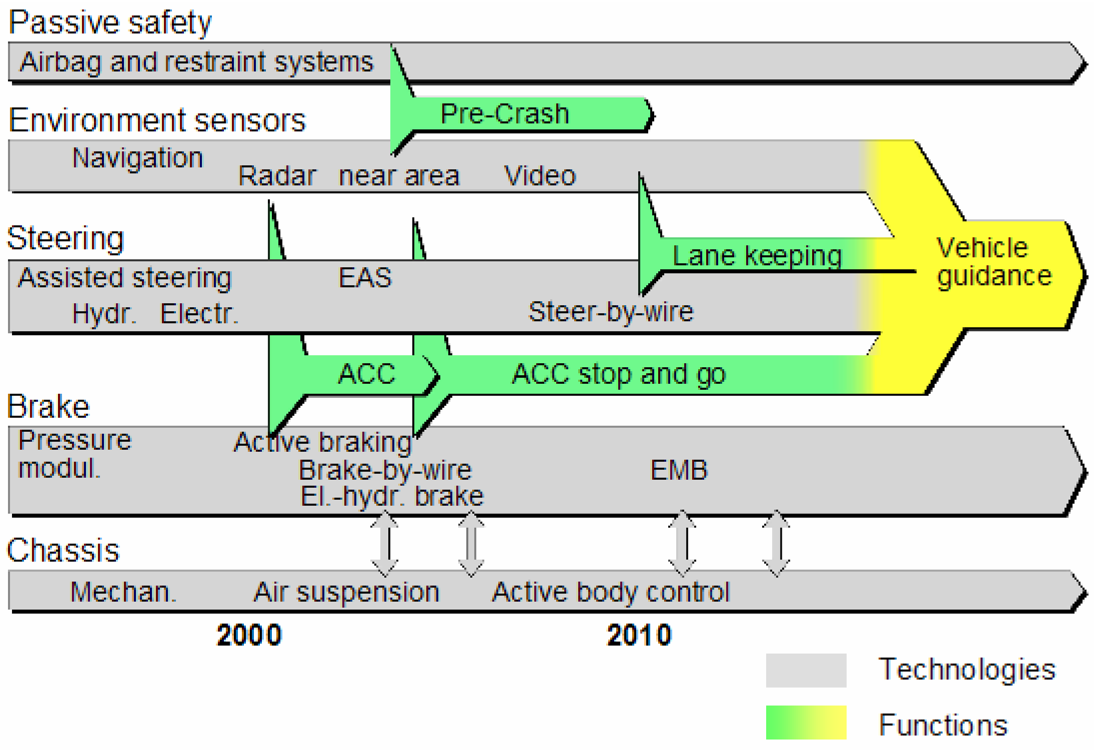

Figure 12: Connected technology and ADAS roadmap (based on Robert Bosch GmbH)

All technologies and systems are introduced on the horizontal time axis, providing a chronology of technology and vehicle system availability. Technologies are shown in grey, as they are invisible to the driver. In contrast, the coloured arrows symbolise the functions which are referred to as IVSS in this study. These interact with the driver and the vehicle's environment. Functions can build on each other or can work as a cluster of underlying standalone systems to provide vehicle guidance.

The technology and functions data collected must be displayed in a similar way in order to provide an overall picture of interdependencies and technologies and functions for the market.

The following figure introduces the IVSS roadmap:

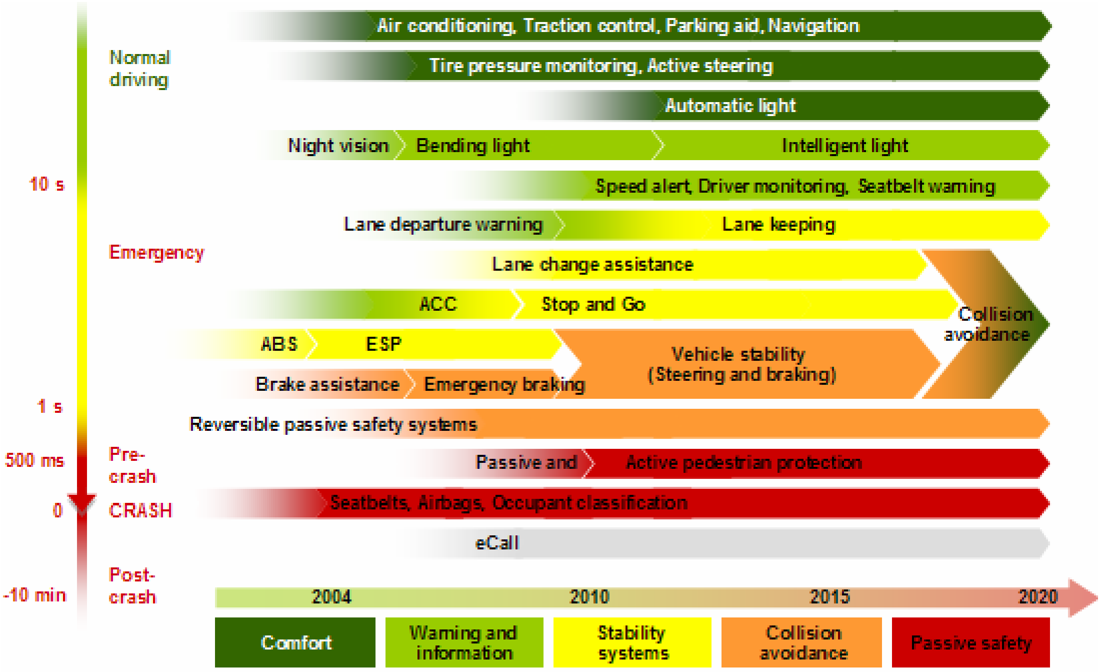

Figure 13: IVSS roadmap (author's figure)

The time axis shows various intelligent vehicle safety systems being introduced to the European market. Some of them build upon each other (this can be seen, for example, in ABS and ESP contributing to vehicle stability). The systems can be classified into different categories, beginning with comfort systems and ending with passive safety systems. This classification corresponds largely to the degree of accident mitigation provided by each system, beginning with normal driving and ending with an accident. The systems are coloured according to category.

Different IVSS may improve the vehicle's behaviour in the same type of accident. It was therefore necessary to find a methodology which combined the different potential safety features of vehicle functions in a manner which would show this. The following figure provides an overview of the interoperability of these functions:

	Rear end collision	Side collision	Left roadway accident	Head on collision	Merging and intersection collision	Vehicle – pedestrian collision	Collision with obstacle	Other
ABS – antilock braking system	🟦	🟩	🟩		🟦🟩	🟦🟩	🟦🟩	?
ACC – adaptive cruise control	🟦							?
Adaptive light – curve illumination	🟦		🟦	🟦	🟦	🟦	🟦	?
Airbag system – multistage/fire scenarios	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪
Automatic light – light on/off	🟦		🟦	🟦	🟦	🟦	🟦	?
Crash Avoidance	🟦	🟦	🟦	🟦	🟦	🟦	🟦	?
Crash detection/warning	🟦	🟦		🟦	🟦	🟦	🟦	?
Driver monitoring – driver drowsiness	🟦	🟦	🟦	🟦			🟦	?
EBS – emergency braking system	🟦		🟦	🟦	🟦	🟦	🟦	?
eCall – in vehicle emergency calls								
ESP – electronic stability programme			🟩	🟩		🟩	🟩	?
LCA - lane change assistance		🟦						?
LDA - lane departure warning		🟦	🟦	🟦				?
Night vision	🟦			🟦	🟦	🟦	🟦	?
Passenger classification – weight, size, out of position	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪
Pedestrian protection						🟦🟪		?
Pre-crash – preparation of the car for a crash	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪
Safe following – ACC in future versions	🟦							?
Safe speed – adaptive maximum speed of the car	🟦🟩		🟩	🟩	🟦	🟩		?

🟦 time correlation 🟪 passive safety system 🟩 LOS correlation ? unknown

Figure 14: Correlation of IVSS to accident types (author's figure)

This study proposes to merge systems potential based on time correlation. The blue markings represent this time correlation, while the green markings suggest that no time correlation can be made. Green markings symbolise a "loss of control" scenario, which in turn leads to the corresponding accident type. System interaction for these functions must be shown separately. The violet markings symbolise passive safety systems. They can be fitted into the suggested approach in accordance with accident mitigation and time calculation schemes.

The time correlation approach allows us to see an accident in reverse and to match it with windows of time. Each phase of an accident can be correlated to a time scheme as follows:

Post crash:	The first 30 minutes and the availability of proper help are decisive for survival
Crash:	Passive safety systems add the ability to absorb energy and therefore reduce the effects of an accident. If the same level of injury is assumed, the use of passive systems provides a time gain, which in turn translates to additional reaction time.
Pre-crash:	Depending on speed, about 500 ms the crash cannot be avoided and the vehicle systems prepare for the crash, active safety systems reduce the accident impact while (reversible) passive safety systems increase the energy absorption ability of the car's safety structure
Assistance:	Based on a dangerous situation, assistance will be provided in cases where there is not enough time for proper human reaction. Human reaction begins after one second. The assistance phase might therefore be initiated within the last three seconds before an accident, becoming shorter with increasing speed. IVSS could prevent the accident or at least reduce the effect of the impact.

Warning:	This phase defines the time between the detection of a dangerous situation and sufficient time for the driver to react. Depending on the vehicle's speed, this translates to a window of time of between 3 and 10 seconds. Assuming that the information provided is accurate and that the driver reacts correctly, an accident can be avoided.
Driving:	Non-safety assistance systems, such as air conditioning and hands-free phone systems, are making standard driving more comfortable. Other systems, such as ESP for use on curves and intelligent light for better vision, expand the car or driver limits. Other systems monitor safe limits such as speed or driver observation. The systems either prevent dangerous situations or enable a higher level of driver attention, leading to an improvement in reaction.
Prior to driving:	The systems could provide warnings about dangerous areas, weather conditions or traffic situations. These warnings could encourage drivers to use other, safer means of transportation.

The following figure shows these time-dependent IVSS correlations:

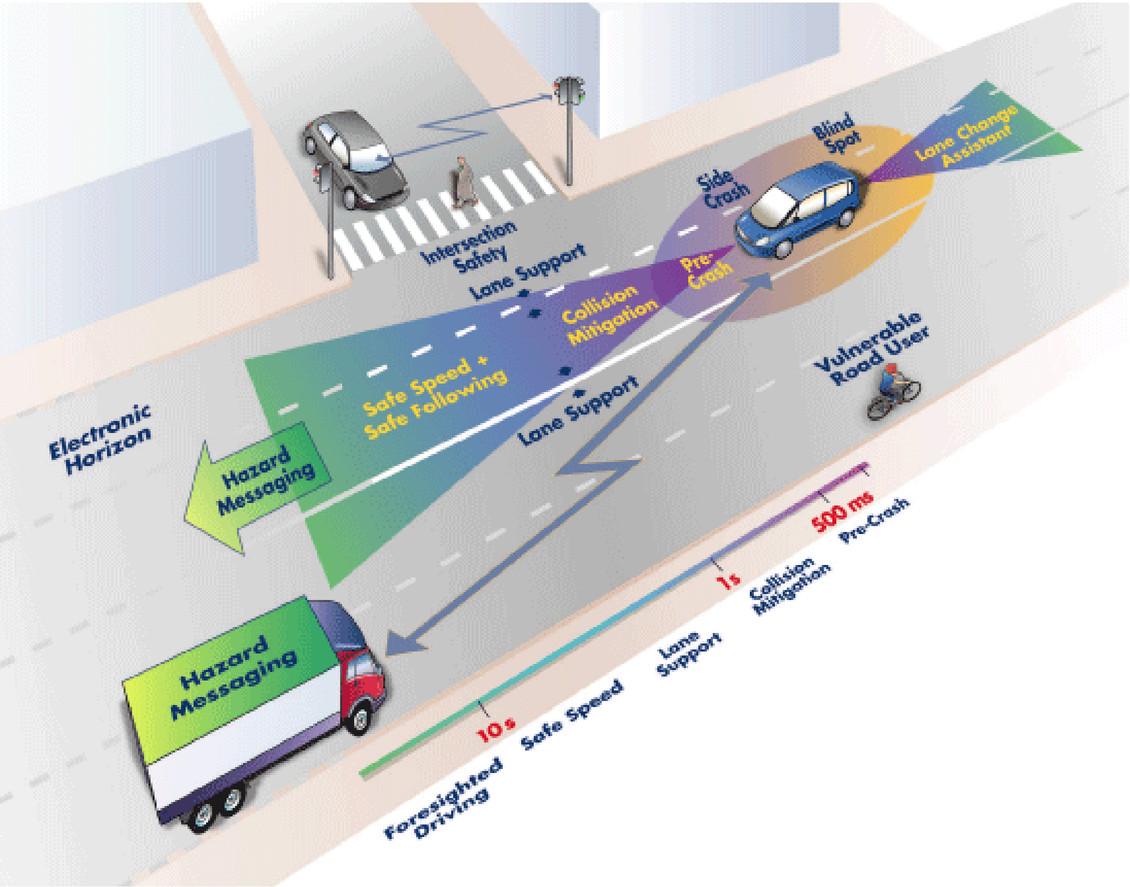

Figure 15: Traffic situation over time (based on PReVENT)

This figure shows specific IVSS working during specific phases. Depending on the system, the time gained or lost can be added or subtracted. The effort cannot exceed the time slot. The following table indicates the IVSS/time correlation. Green markings represent other, time-independent correlations. Blue systems can be translated into time added or lost, effective in the area marked. The time factors are speed-dependent.

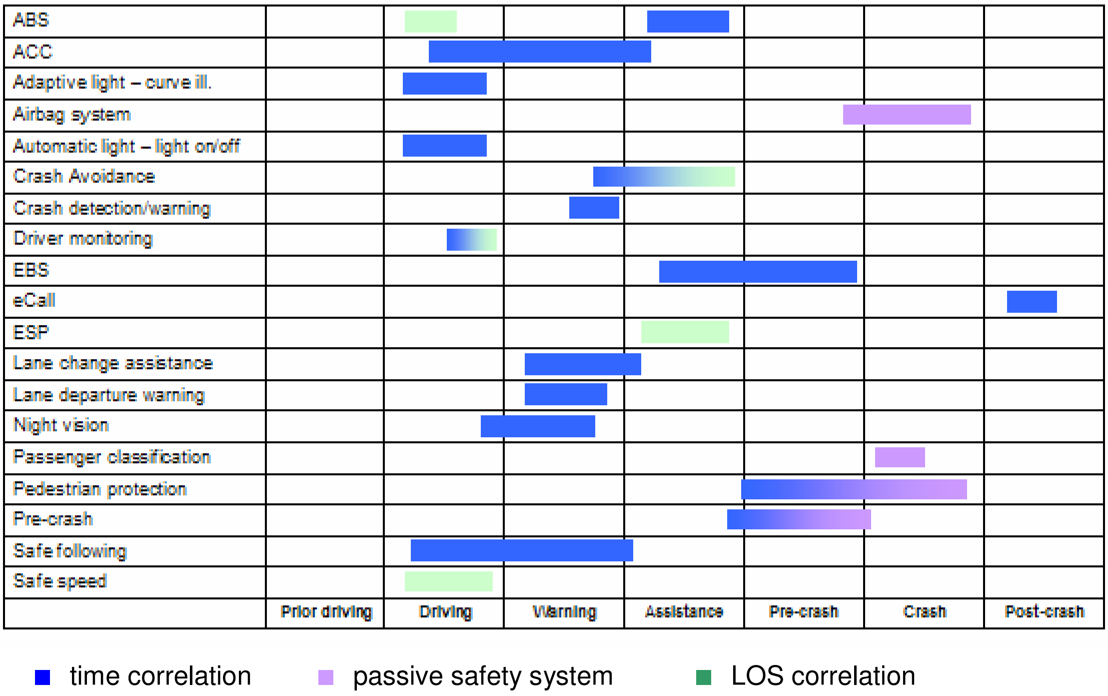

Figure 16: IVSS compared to accident mitigation (time axis) (author's figure)

The colours in the previous figure represent time dependence (blue), passive safety systems (violet) and loss of control dependence (green). For eCall, therefore, the figure shows that it is the only function working after the crash and therefore does not interfere with other functions. In the warning phase of accident mitigation in particular, several IVSS are working to increase the driver's attention, but the driver only needs to be made aware of an obstacle once. Warning does not seem to be an appropriate means of interaction in loss of control scenarios, however; there is therefore no function which corresponds to this phase.

The system/time correlation is in two dimensions, its effectiveness on an accident mitigation time line and its translation into time gained or lost. These correlations enable IVSS to be combined. There are accident characteristics which are independent of time, such as skidding, for instance. These properties have to be considered separately, parallel to the general matching approach. The interaction of IVSS related to these additional properties may appear minor, but it still requires further discussion.

4.3.4 System Safety Potential

The safety potential of each system must be assessed against accident types. Bearing in mind the availability of data in the CARE database, the suggested differentiation is:

- Rear-end collision
- Side collision
- "Left roadway" accident
- Head-on collision
- Merging and intersection collision
- Vehicle-pedestrian collision
- Collision with obstacle
- Other type

The “Other Type” collision category accounts for less than 10 % of all accidents. This category includes unassigned collisions from the other categories and a number of collisions not relating to the introduced clusters. The “Other Type” category is not taken into consideration in the evaluation of system safety potential. The planned failure analysis will show the correlating inaccuracy.

IVSS can be related to these accident types (see Figure 13). IVSS systems are translated into time savings or losses, which can be matched to accident types. Taking the physics and mitigation of accidents into account, these differing time constants will lead to a difference in the number and the severity of accidents. Correlating tables for the different accident types and speeds can be determined. The following figure shows a correlation of this type for collisions at intersections, collisions with oncoming traffic and rear end collisions.

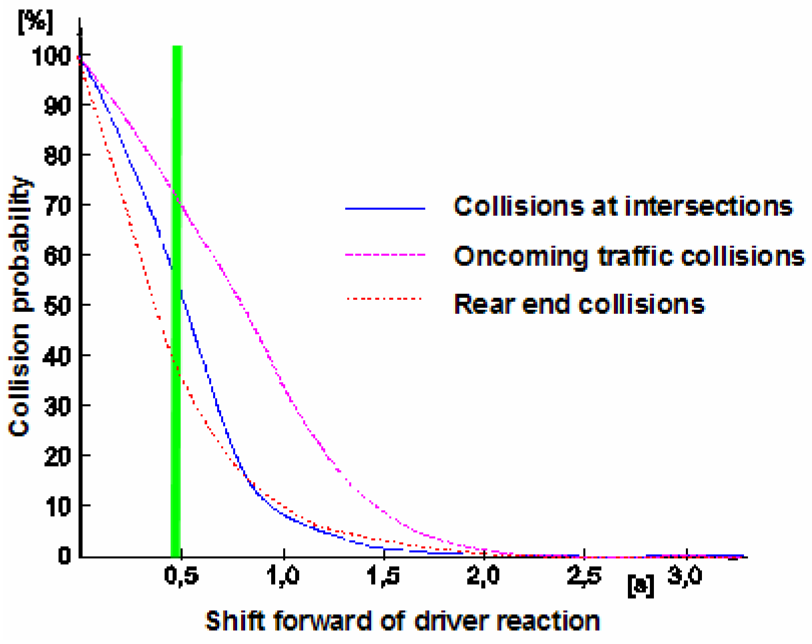

Figure 17: Collision probability related to the shift forward of driver reaction (Enke 1979)

Figure 17 shows the causality of time gains for collision probability. If either the driver or the vehicle reacts earlier or faster, a time gain builds up. These time gains must be standardised for different crash phases, speeds and accident types. These graphs should be derived from accident causation analysis and may be provided on an annual basis. They would allow comparisons between systems to be made.

The green line is an example of a positive time gain of 500 ms (milliseconds). On average this would lead to the halving of the collision probability for collisions at intersections, collisions with oncoming traffic and rear end collisions. Assistance systems, such as adaptive braking or ACC, are adding 50 ms by pre-filling the brake system and decreasing the collision probability by a few percent.

The safety system will, in correlation to time savings influence accident severity according to a cascade model. From the above figure can be deduced that for these three accident types, a gain of 3 seconds would prevent a collision. Based on data availability, the proposed severity cascade is:

- Fatalities to
- Severe injuries to
- Slight injuries.

The more time for driver or vehicle reaction is provided by the IVSS, the lower the impact severity will be. Passive safety systems add to the energy absorption potential of the vehicle. The final calculation on accident severity should be made for impact speed based on time patterns. The given information on time savings or energy absorption potential related to speed (urban, rural, highway) can be transformed into the remaining impact speed.

Analogous to the prediction of the collision probability, collision severity figures can be determined (refer to following figure). These can be used to determine the correlating accident severity for a specific IVSS setup can be determined. These curves should be provided on a standardised basis. If detailed calculations are required, we recommend partnering with accident causation analysis experts.

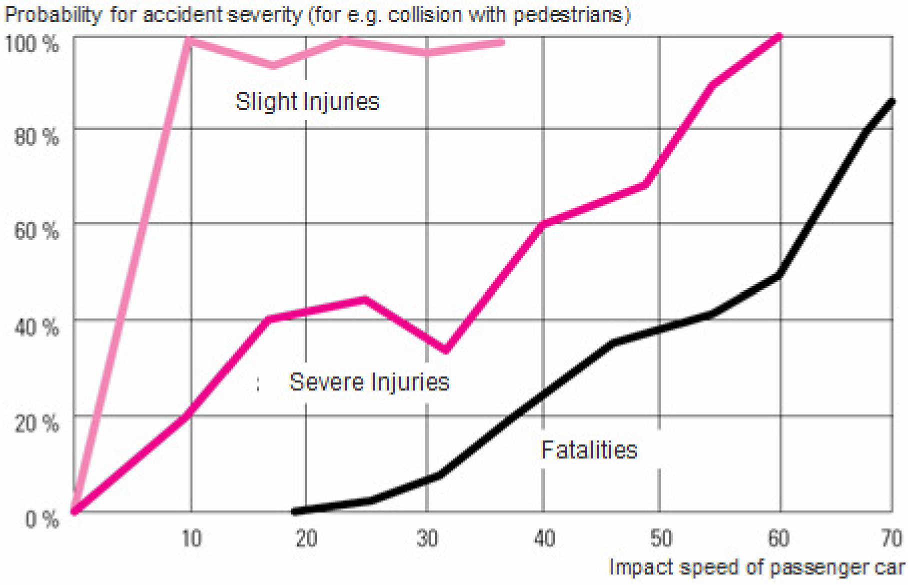

Figure 18: Accident Severity Based on Impact Speed

The accompanying discussions have shown, that not only the technical safety potential might be appropriate for further calculation. Giving the fact that the same system is sold by the supplier to different OEMs, they might adapt their specific HMI (Human Machine Interface) to create a complete function. In the early phases of a critical situation, the design of the HMI (and thus the communication between vehicle and driver) will affect the safety system's effectiveness.

Discussions with experts have shown that the influence of HMI is minor compared to other influences in the model, such as assumptions for safety potential, market deployment or traffic related cost unit rates. The planned failure analysis will define how this issue should be handled.

Summarising, it can be stated that common scientific approaches are used to value system interaction and to predict accident probability and severity. Quantitative data on accident mitigation, IVSS/time correlations and IVSS/energy absorption potential is not yet available for the project. It has been shown that this data is generally available. Further projects should provide sufficient standardised information on accident causes.

4.3.5 Costs for IVSS

An important factor in determining the benefit-cost ratios for IVSS is the definition of costs – in this case the costs for IVSS. These costs are system-specific; they are input parameters correlated to specific Intelligent Vehicle Safety Systems. The proposed assessment methodology divides these safety-system-specific costs into three dimensions:

- Investment Costs
- Maintenance Costs
- Operating Costs

All of them contribute to the calculations in step 13 "System Costs". They are different for cars and heavy duty vehicles. They also differ according to vehicle model and for OEMs, where they might be part of marketing strategies. The presumed costs change over time, giving us different figures for 2010 and 2020.

For the impact assessment, average system costs for all cars (regardless of model and OEM) and for heavy duty vehicles are presumed. Only the investment costs are considered to change; maintenance and operating costs are considered stable costs.

The anticipated costs have two effects – a direct effect and an indirect one. They directly influence the IVSS costs (step 13) and indirectly influence the equipment rate (step 4 in the proposed methodology). Consumers' willingness to invest in these technologies falls as prices increases. This effect will be discussed in more detail in the following chapter but will not be taken into account in the proposed methodology. The equipment rates are part of professional forecasts and take price variations into consideration. Below are the direct costs, called system costs in the model, in more detail:

Investment Costs (Production Costs and Sales Prices)

Investment costs are the initial costs for a specific IVSS for the final consumer. They correspond to the average price of OEM price lists (if they are optional functions) or equal production costs for the OEM (if they are standard equipment and are therefore included in the total price of the vehicle).

Prices for optional functions are normally much higher than the production costs because they include profit margins. Because these margins depend on the OEM`s marketing strategies, they might change in the short term, which would drastically affect equipment rates.

This may be especially true for high-cost systems, such as ESP or ACC. ESP did not have wide market penetration while it was offered as an optional system. This changed with its introduction as standard equipment for cars – with than moderate investment costs for the consumer based on production costs. Nowadays ACC is offered as an optional comfort function priced at over 2,000 euros. The production costs are a fraction of that figure.

High prices are also rewards for the high R&D investment costs incurred by suppliers and OEMs. Innovative companies therefore expect a feasible return on their investment. But over time prices are dropping. There are at least three reasons for this: increasing competition between OEM and their suppliers (leading to margin cuts), reasons based on economies of scale (lower prices for high volume production) and the introduction of next generation technologies (which tend to be less expensive while maintaining or even increasing functionality). For ACC, for example, this leads to the assumption that prices will drop for the year 2010 to 750 euros and for 2020 to 400 euros.

Some Intelligent Vehicle Safety Systems may also require public investment. eCall is one such system – where an infrastructure outside the car is required to ensure the connection to assistance services. Such additional costs directly tied to IVSS must be included in the calculation.

System prices, like market numbers, are published or forecast by professional organisations and should be used within this methodology at this aggregated level.

Maintenance Costs

Depending on a system's complexity and robustness, IVSS maintenance may be required. Currently, safety systems are built for the lifetime of the vehicle. The costs therefore involve mere fault repair and can be discounted in the first run. This might be different for other systems, particularly roadside installations.

Operating Costs

IVSS are active parts of the vehicle and therefore add mass and consume energy. Both of these can be translated into fuel consumption and then correlated to costs. For example, studies showed that cars using their headlight during the daytime on average consume an additional 0.2 litres of fuel per 100 km driven (VDA 2003: 189 f).

The correlating numbers can be derived from expert calculations or field tests.

4.4 Market Deployment

The main goal of integrating the market perspective in the proposed model is to find a way of forecasting the diffusion of intelligent vehicle safety systems (IVSS) within the vehicle fleet of the countries considered, or, in other words, of predicting the market deployment. Previous projects have revealed some important issues regarding the deployment of Advanced Driver Assistance Systems and Automated Vehicle Guidance Systems which must be addressed to reach a level of use which will significantly influence socio-economic benefits (STARDUST 2004: 16):

- Legislation (mandatory or not)
- Infrastructure investment
- Combinations with other applications
- Robustness of the system in different traffic situations
- Liability issues
- Market needs (user acceptance, training, long-term effects, maintenance).

The target figure for capturing the level of use in this model is the rate of equipment with intelligent vehicle safety systems. This figure has a major influence on the socio-economic impact of IVSS for two reasons. The first is that both vehicles which are equipped with IVSS and vehicles or other road users which are involved in crashes with those vehicles benefit from the advantages of the crash avoidance or crash mitigation effects of the IVSS. Only those vehicles which are equipped with IVSS therefore influence the overall socio-economic impact. Secondly, some IVSS may need a certain equipment rate to fully exploit their potential benefits. Car-to-car-communicating systems, in particular, need a minimum number of equipped cars for the technology to function correctly.

4.4.1 Determining the Equipment Rate

There are several research institutes which specialise in forecasting market developments in the automotive industry. Figures for equipment rates of intelligent safety systems are available. Since these forecasts are generally very elaborate, they should be used wherever they are available. In addition to traffic developments, research institutes also take into account the technological developments of specific OEMs.

Not all of the intelligent vehicle safety systems are covered by these analyses, however. Additionally, most of the research carried out by professional research institutes does not cover the time span to be reflected in this study. It is therefore necessary to develop our own approach to forecasting market development to fill the emerging gaps. Two steps must be taken to forecast market deployment, i.e. to calculate an equipment rate at a given point in time. Firstly, the time of market introduction must be assessed. Secondly, a market penetration channel must be decided upon. Four different market diffusion scenarios are developed in the following sections. Based on this model, it is possible to forecast the equipment rate for a specific intelligent safety system at a certain point in time.

4.4.2 Market Introduction

The first step in forecasting market deployment is to establish a picture of when specific IVSS will be introduced to the market. There are three main driving forces behind market introduction in general, namely OEM strategy, customer demand (considered here only as specific forces involved in the deployment of IVSS), and political influence. These driving forces correspond to three key actors which have different interests in the introduction of advanced driver assistance systems and which are to be considered in an a priori assessment of user acceptance: vehicle and system manufacturers, the users, and authorities and administrations (ADVISORS 2003: 46). The consideration of these driving forces enables us to define a set of diffusion patterns which show specific rates of equipment with IVSS.

4.4.3 OEM Strategy

Market deployment of IVSS is substantially influenced by the strategies of the original equipment manufacturers (OEM) on how and when to introduce intelligent safety systems to the market. The availability of a new intelligent vehicle safety system as a precondition for market introduction depends to a great extent on the introduction of technologies and is therefore firmly correlated to technology roadmaps. Since the OEM and its suppliers are the ones developing new technologies, OEM strategy is the most important driving force for market introduction. After all, a new technology or function has to be implemented before customers (end users, fleet managers, public transport operators, etc) can decide whether or not they see a benefit. Producers of new systems are interested in innovation costs, probable sales volume, internal spill-over effects, profitability and company status (ADVISORS 2003: 58).

To sum up, OEM will consider the financial risk of implementation on the one hand and their potential return on investment on the other. There are three different ways of market introduction which should principally be considered.

- IVSS as an upgrade feature

  OEMs offer IVSS as stand-alone systems which can be bought and implemented at any time, provided that the necessary interfaces are available in the vehicle. From a defined time onwards, only consumer acceptance of the new technology will influence its deployment (e.g. parking aid).

- IVSS as a basic function

  Every new car – independently of its segment – is equipped with the new features. From market entry onwards, all new cars are equipped with the new features. The equipment rate is influenced by the vehicle renewal rate. Full penetration is achieved when the vehicle fleet is completely renewed. Obviously, this process will take more than one decade (as with ABS, for example).

- IVSS as a premium function

  To optimise the return on investment, the new feature will initially be implemented only in luxury class vehicles and be sold at a premium price. There will then be a cascading effect as the feature is implemented in the next generation of vehicles one segment lower, and so forth. It takes around a decade for every new car to be equipped with the new feature and it has thus become a basic function (e.g. ACC).

It will be almost impossible to obtain first-hand information on the strategies chosen for the different intelligent vehicle safety systems which are not yet publicly available. As representatives of OEMs pointed out, this type of strategic marketing data is extremely sensitive. Competitive advantages are generated by the anticipating the introduction of new vehicle features correctly.

4.4.4 Specific Drivers for the Deployment of IVSS

The overall development of traffic, which is influenced by mobility and transport needs, socio-demographic developments, the growth of gross domestic product (GDP), etc., in turn influences the deployment of intelligent vehicle safety systems. Since these developments are considered in forecasts on the development of vehicle stock and mileage, they will not be considered further at this stage of the model.

There are, however, specific factors which influence the deployment of IVSS (and therefore determine the rate of equipment) which have to be taken into account. These factors can be differentiated according to customer groups. The purchasing decisions of individuals, for example, are influenced by a different set of determinants than those of professional managers of vehicle fleets.

According to ADVISORS 2003: 58, individual users are concerned with:

- full user cost
- driver comfort
- driver safety
- journey time

User acceptance and demand are also influenced by such factors as:

- available income
- age
- preference for technology use

  Professional fleet managers, on the other hand, base their decisions on different factors. Technologies which might not be implemented by individuals because they enforce inconvenient behaviour patterns, might still be implemented by professionals because other factors are of higher relevance in their decision-making process. The most important factor here is
- return on investment.

  Research has shown that people who were correctly informed about the possibilities and limitations of a system tended to view it more favourably than those who were not informed. Information campaigns would thus be useful before launching a system on a wide scale (STARDUST 2004: 6).

The factors determining the purchasing decision directly will not be worked out in more detail. Instead, this study is more concerned with the question of how the three drivers work together and influence different diffusion curves. It would, however, be interesting to explore these factors in a consecutive study to learn more about the driving factors in customer decision-making.

4.4.5 Political Influence

Another influence category is political influence. It covers specific measures by which transport policy aims to stimulate market penetration of IVSS. Besides following a diffusion path influenced solely by OEM strategy and user acceptance it can be favourable for transport policy to speed up market deployment and penetration. As representatives of society, politicians are concerned with public expenditure associated with the introduction of new systems, the environmental effects (impacts on emissions, noise, etc.), overall safety, full social implementation cost, network efficiency and acceptability (ADVISORS 2003: 58). They can intervene using either legislative measures which would define systems as standard equipment in future, or using financial measures (e.g. investment premiums, tax reductions) to support a system's implementation. Although costly in the case of financial support, these methods mean that traffic safety can be improved sooner than it would have been according to the natural diffusion curves.

This type of influence will not be explored in greater detail in this model. The aim of the model is to provide an answer to the question of which technologies have the greatest socio-economic impact. Political influence might therefore be a consequence of the results of this study.

Political influence is, however, of interest for a specific question. The interaction of the three driving forces for market introduction is crucial in deciding the diffusion path a new intelligent vehicle safety system will take. For some intelligent vehicle safety systems, it might already have been decided that political intervention will take place. This aspect must not be neglected in forecasting its equipment rate.

4.4.6 Market Diffusion

In order to calculate an equipment rate, a probable curve of market diffusion has to be considered in addition to the probable moment of market introduction. The interaction of the three drivers for market introduction – OEM strategy, specific drivers for the deployment of IVSS, and political influence – influence the pattern of diffusion to be arrived at.

In a previous project, two key factors which will significantly determine the future market situation of advanced driver assistance systems (ADAS) were identified: the usability of ADAS and the financial risk for the OEM and suppliers (RESPONSE 2 2004).

In keeping with this approach, two factors have been chosen to determine specific diffusion curves for the proposed model. The financial risk of market introduction depends on recall campaigns, public image, and liability claims (RESPONSE 2 2004: 30ff.). This aspect is also particularly relevant for an assessment of probable diffusion curves, because OEMs and suppliers are actually developing the new IVSS and therefore have the highest influence on market introduction and diffusion. For the development of market introduction scenarios, usability has been evaluated to be the second key factor. Usability of ADAS comprises the ease of use of a system as regards ergonomics, effectiveness, efficiency, dialogue concept and safety of use (RESPONSE 2 2004: 35ff.). For the assessment of probable diffusion curves for IVSS it is not so much the usability of the system which is important, but another specific aspect, the safety impact of the correct use of an IVSS. The safety impact of a system was therefore chosen as the second key factor for this model.

The combination of safety impact on the one hand and financial market introduction risk on the other leads to a coordinate system in which the quadrants show the driving forces involved in market introduction. This leads to specific diffusion curves which are described below.

In this coordinate system, one axis shows whether the financial risk of market introduction is high or low for the OEM. The classification of this risk depends on the OEM’s assessment of

- business risk (return of investment),
- (product) liability risk,
- cost of recall campaigns.

The approximate return on investment (ROI) is the most important basis for an assessment of risk. If the ROI is low, the risk of introduction is higher than if one knows in advance that ROI will be high. Liability will also have an influence on the assessment of risk. This refers to the risk that the intelligent safety system might not function correctly or that it may be used improperly. If the chances of this happening are high, the risk assessed will be higher. There is also factor which also influences the risk assessment - extremely serious functionality problems may result in call-back campaigns. The actual cost of such a campaign and the damage caused to manufacturer’s image as a result increases the financial risk of market introduction. These factors will lead to the financial risk involved in the market introduction of a new intelligent safety system being judged as either high or low by an OEM.

The other axis in this coordinate system shows, first of all, whether the safety impact of the intelligent safety system is high or low. This represents the technological crash avoidance probability or how minimizing the crash effects are, respectively. A first approach puts the safety benefit of an individual in the centre. But safety impact can also be assessed on a more abstract level; it can be described as the benefit of a new intelligent vehicle safety system for the general public.

The resulting coordinate system is shown in the following figure.

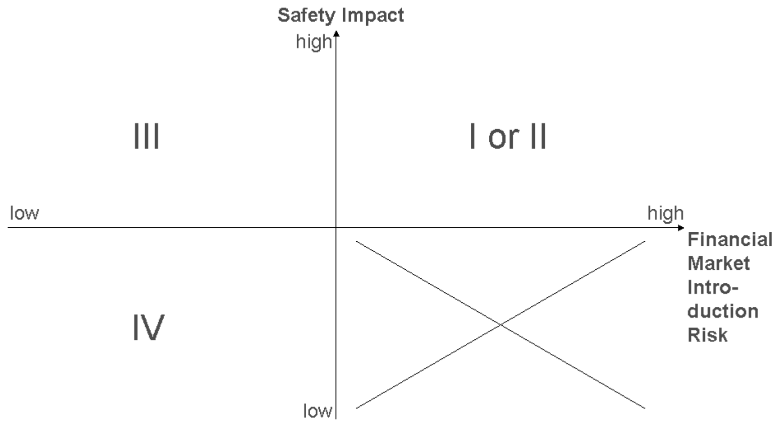

Figure 19: Driving forces behind market introduction determine probable diffusion curves (author´s figure)

The quadrants show who or what are the driving forces behind market introduction. A typical diffusion curve can be differentiated for each quadrant. This diffusion curve illustrates how the equipment rate for a given point in time is determined. The most important difference between these alternative paths is the speed of diffusion.

The quadrant in the lower left corner makes the OEM the driving force. Since the financial risk is low, it will introduce the new intelligent vehicle safety system. This leads to diffusion curve IV "cascade of innovation". The quadrant in the upper left corner shows the OEM and the customer as the driving forces. This is the fastest diffusion according without (political) interventions. Once the first OEM has introduced a new system to the market, other OEMs will soon follow. Since customers are the driving force, demand is high. This results in diffusion curve III, which can be called the "interrupted cascade of innovation". Conditions in the upper right quadrant are somewhat more complex. Since the risk of introducing a new technology is high, OEMs are not the driving forces for market introduction. Even if the safety impact on an individual level is high, this might not be sufficient to justify a market introduction. But if the safety impact is high on an aggregate level, this is a case for political involvement to push market introduction. Depending on feasibility and cost, politics might use its power to have all new vehicles equipped with the IVSS, or even upgrade all vehicles in stock. These two alternatives result in diffusion curves subsequently described as II and I. The higher the financial risk, the less probable these diffusion curves become, especially since upgrading the existing vehicle stock is often limited by compatibility problems. The quadrant in the lower right corner will remain empty. If there is almost no safety impact of a system and a high risk for the OEM, there are no driving forces for market introduction.

Besides these three driving forces, there are numerous factors which are directly or indirectly influencing diffusion curves and speed, which must also be taken into consideration. There might be bottlenecks in the domain of regulations, insurance, standards, or current legislation (ADVISORS 2003: 63).

The curves described in the consecutive sections are used to illustrate typical dissemination methods. In reality there will, of course, be contextual influences and delays. The most prominent distinction between these curves is the diffusion speed. The description of the curves starts with the fastest path of diffusion.

Diffusion Curve I: Introduction for all newly-registered vehicles and upgrade of vehicle stock

The fastest method of diffusion for a new intelligent vehicle safety system is introduction at a specific time. From a given point in time onwards, all newly-registered vehicles must be equipped with the new intelligent vehicle safety system and all vehicle stock must be upgraded. Equipment rate will therefore be 100% from a certain point onwards. This is represented in Figure 20 by the coloured area, assuming a fictional introduction in 2005.

In reality, there will be time allowed for upgrading and for producers to adjust their production facilities. This method is seldom used. Only political intervention can make it possible, since there are no market-driven forces which lead to this diffusion curve.

An example for this diffusion pattern is Toll Collect for heavy duty vehicles.

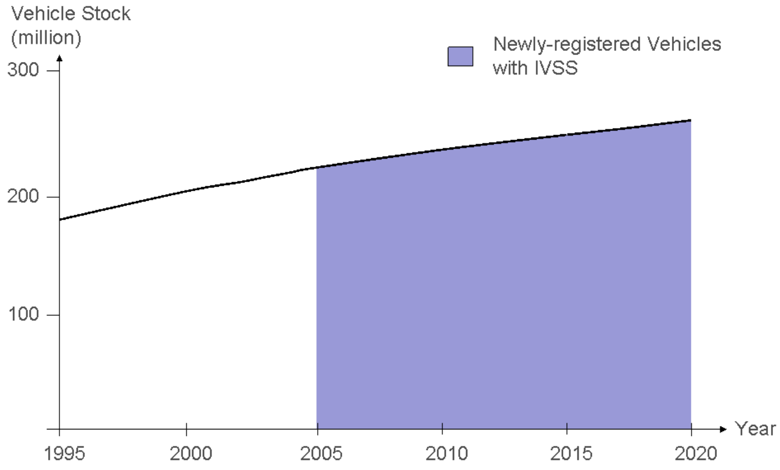

Figure 20: Diffusion Curve I: Introduction for all Newly-registered Vehicles and Upgrade of Vehicle Stock (ProgTrans 2004, own calculations)

Diffusion Curve II: Introduction for all newly-registered vehicles

This curve describes the diffusion pattern followed if all newly-registered vehicles are equipped with a new intelligent vehicle safety system. This is a probable curve for systems which are comparably low in price.

An example for this diffusion pattern is the pedestrian protection being introduced in 2005 (2010 for active systems). This introduction is enforced by legislation even though it is linked with relatively high costs.

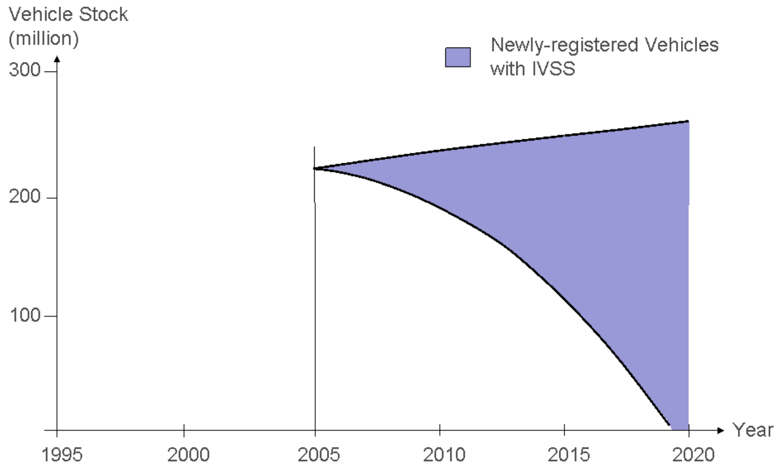

Figure 21: Diffusion Curve II: Introduction for all Newly-registered Vehicles (ProgTrans 2004, own calculations)

In Figure 21 the coloured area shows the share of equipped vehicles for specific years, if market introduction for all newly-registered vehicles started in 2005. Around the year 2019 all vehicles in stock will be equipped with the new IVSS.

The rate of equipment is calculated by adding the newly-registered vehicles from the moment of market introduction onwards. The proportion of vehicles equipped with the new IVSS rises over time. The principle method of defining the rate of equipment is described in the figure below.

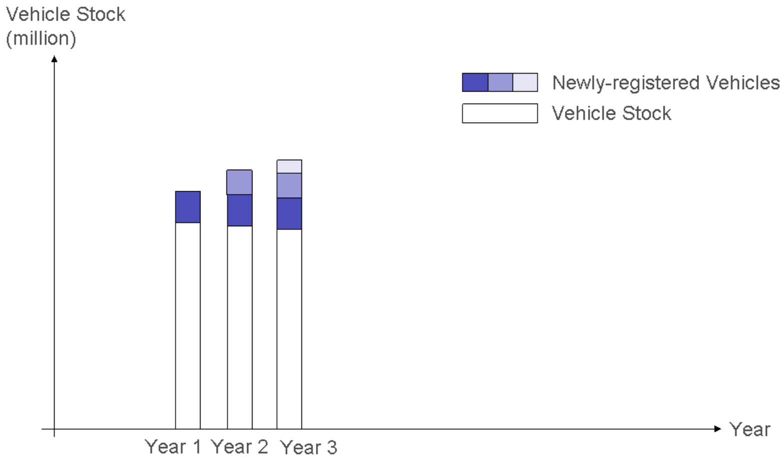

Figure 22: Detail of Diffusion Curve II: Principle Calculation of Equipment Rate (author´s figure)

An example for this diffusion pattern is ABS being standard equipment in Europe beginning in 2004. This was a commitment undertaken by the automotive industry.

Diffusion Curve III: Cascade of Innovation

The most probable way for the diffusion of new technologies can be described as "cascade of innovation". As soon as a new and promising function is available, it will be introduced in the highest vehicle segments; this is where the highest prices can be achieved. Drivers of luxury cars are also (generally speaking) the most technology-friendly users and therefore appreciate new systems. After it has been introduced in the highest class of vehicle, the new system will be introduced in executive vehicles and so forth, until it has reached the lowest class. Following the cascade of innovation, the introduction of a new IVSS to all new vehicles takes a vehicle generation, which today is six to nine years. The trend towards modularisation helps to make this time span even shorter.

In approximating the diffusion rate, we can assume that the new IVSS will be introduced to the next class after two years. The equipment rate can then be calculated using the numbers of newly-registered cars in the highest class for two years, then adding the figures for the highest plus the next highest class for another two years, and so on. Each year the amount of equipped vehicles from the previous year has to be added to the amount of newly-registered vehicles that are equipped with the new IVSS. Differentiations between six and ten segments are common. The following figure shows the principal method of determining the equipment rate. The "cascade of innovation" results in a slower rate of diffusion, because not all newly-registered vehicles will be equipped with a new IVSS, but only the ones in higher classes.

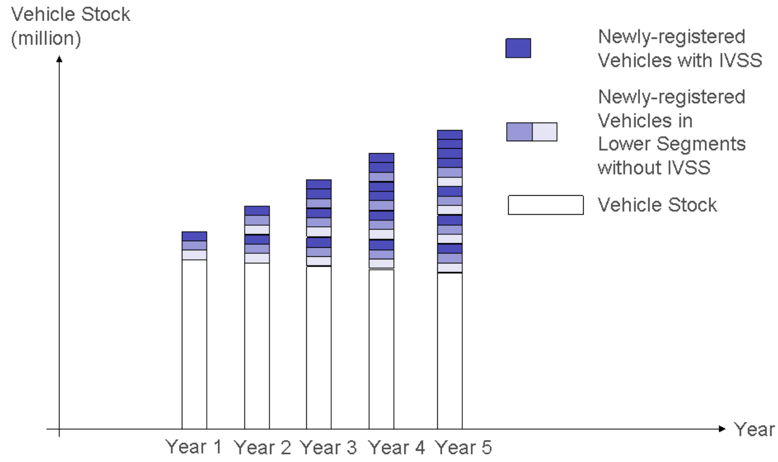

Figure 23: Detail of Diffusion Curve III: Calculation of Equipment Rate (author´s figure)

Assuming that other producers follow suit rapidly after the IVSS has been launched by one OEM, the cascade of innovation will be run through for all producers with only a few years' delay. Once the cascade of innovation has been run through completely for all producers, all newly-registered vehicles will be equipped with the new IVSS. A typical curve is shown in the following figure.

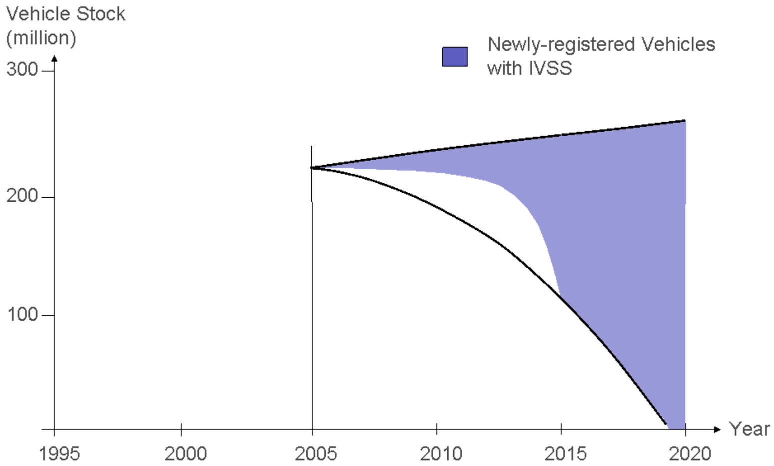

Figure 24: Diffusion Curve III: Cascade of Innovation (ProgTrans 2004, author´s calculations)

Deviating slightly from the typical form of the cascade of innovation is the “interrupted cascade of innovation”. In this case a new system is so well-received by the customer that other producers decide not to follow the cascade of innovation themselves, but instead to introduce the new system to all vehicle types at the same time to profit from the economies of scale involved in producing more systems at lower costs. In this case, after starting on the trickle-down path, the new IVSS will be introduced to all newly-registered vehicles at a certain time, because after one manufacturer started, other OEMs will be forced to introduce the system in all their vehicles also. This is especially true for safety systems, because customers understand safety systems as mandatory standard features. In contrast to comfort systems, consumers are much less willing to pay for these systems but are much less willing to abstain from these systems if they are offered as a feature in vehicles produced by other manufacturers. The typical route for the interrupted cascade of innovation is shown in the following figure.

An example for this penetration pattern is night vision.

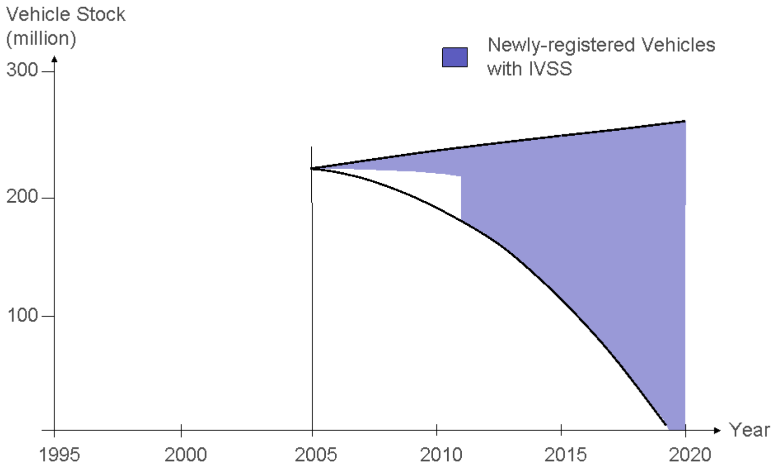

Figure 25: Diffusion Curve IV: Interrupted Cascade of Innovation (ProgTrans 2004, own calculations)

In order to calculate the equipment rate according to these diffusion curves, the market needs to be characterised by three indicators:

- vehicle stock (cars, buses/coaches) per year
- newly-registered vehicles (cars, buses/coaches) per year
- newly-registered vehicles (cars, buses/coaches) per year broken down into segments (e.g. Mini, Small, Compact, Medium, Executive 1, Executive 2, Luxury, Super Luxury, Sports, MPV, SUV)

The figures for these market characteristics can be taken from publicly-available data sources, particularly from research institutes which specialise in forecasting market developments in the automotive industry.

Since there is a great deal of differentiation within the European Union, the backgrounds of the different nations or groups of nations should be taken into account when developing the proposed model further.

4.4.7 Exemplary Calculation of the Equipment Rate

Since not all intelligent vehicle safety systems are covered by analyses of professional forecast institutes, it is necessary to develop an own approach to forecasting market development in order to fill the emerging gaps. Two steps have to be taken to forecast market deployment, i.e. to calculate an equipment rate in a given point in time. Firstly, the time of market introduction of an intelligent vehicle safety system has to be assessed. It depends to a great extent on the introduction of technologies and is therefore firmly correlated to technology roadmaps. Secondly, a probable way of diffusion into the market has to be decided upon. Four scenarios for market diffusion have been illustrated in the sections above. The three main driving forces behind market introduction and diffusion are OEM-strategy, the demand of customers, here only looked at as specific drivers for the deployment of IVSS, and political influence. Their consideration allows to define a set of diffusion patterns that lead to specific rates of equipment with IVSS. Following this model the forecast of an equipment rate of a specific intelligent vehicle safety system at a certain point in time is possible.

Cascade of Innovation

The most probable way for the diffusion of new technologies can be described as "cascade of innovation". As soon as a new and promising function is technologically available it will be introduced in the highest vehicle segments because here the highest price can be achieved. Additionally, drivers of luxury cars are normally the most technology-friendly users and therefore appreciate new systems. After introducing it to the highest vehicle segment the new system will be introduced in the following one of executive vehicles and so forth until it has reached the lowest segment. Following the cascade of innovation, the introduction of a new IVSS to all new vehicles covers the time span of a vehicle generation. The trend of modularisation helps to even reduce this amount of time. The principle way of calculating a diffusion curve is illustrated in the following section.

Vehicle Stock

To forecast vehicle stock professional data can be obtained. ProgTrans uses an individually developed method of forecasting the private car stocks and their utilisation (ProgTrans 2004: 10). Data is available broken down to member states and on the aggregate level EU25. The time span covers the years up to 2015 in the newest edition of the European Transport Report (years in the forecast are 1995, 2000, 2002, 2003, 2004, 2005, 2010, 2015).

	2010
EU 25	239.100.000

Table 4: Cars - Vehicle Stock (ProgTrans 2004: 336)

Assuming that a linear curve approximated with the least squares method is suitable to describe the future development, vehicle stock in the year 2020 can be calculated based on the available data for the years 1995, 2000, 2005, 2010, 2015.

	2020
EU 25	261.200.000

Table 5: Cars - Vehicle Stock (authors`s calculation)

New Passenger Car Registration

The European Automobile Manufacturers Association (ACEA) provides several statistics related to the European automotive industry on its website (www.acea.be). Here the new passenger car registrations for the years 1990 to 2003 broken down to member states can be found for EU 15. Data covering the member states (EU 23) can be found from 2003 on a monthly basis (ACEA 2004a).

To illustrate the principle way of calculating diffusion curves, it is not necessary to make a forecast for new passenger car registration, instead it is sufficient to base the following discussion on the assumption that around 15 million vehicles are registered newly each year in Europe (EU 25). This figure is arrived at by taking the average number of new registration in the last 14 years for Western Europe (EU 15), adding an average for the new member states, which is only based on data of the last 17 months. For a more detailed analysis it is necessary to rely on a specific forecast for new registrations. For example the available data shows that there is a slight increase of new registrations in the last years which has to be taken into account for more accurate calculations.

New Passenger Car Registration by Segments

Data on new passenger car registration broken down by segments is also available from ACEA (ACEA 2004b). In an average over the years 1990 to 2003 the segments show the following distribution for EU 15.

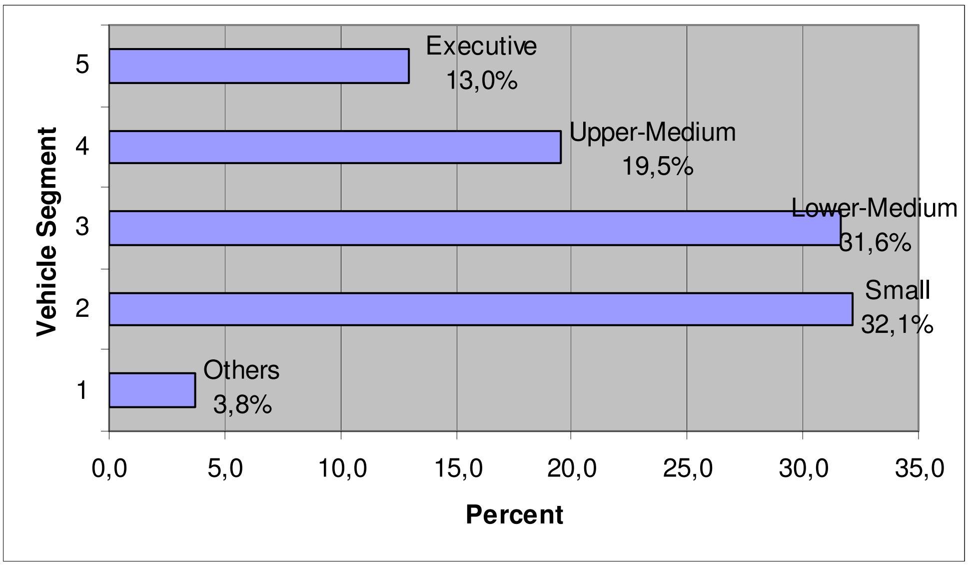

Figure 26: Distribution of New Passenger Car Registration – Breakdown by Segments

To approximate the diffusion rate one can assume that in the first year the new IVSS will be introduced in the executive segment. After the time span for the renewal of vehicle models, the new IVSS will be introduced to the next lower class. Normally the renewal time of vehicle models is supposed to be two years. This is based on a differentiation into eight or ten segment. Since the available data only differentiates between five segments, the renewal time for the calculation has to is too selected as longer. For the exemplary calculation therefore a renewal time of three years will be taken. The equipment rate can now be calculated by adding the numbers of newly-registered cars in the highest class for three years, after that for the highest and the following class for another three years and so on.

Based on this assumption, an IVSS that is introduced to the market in the year 2002, will result in the following equipment rates:

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Vehicle Stock EU 25	212,6	216,2	220,3	224,8	228,7	233,0	237,1	238,1	239,1	245,6	249,1
New Registrations	15	15	15	15	15	15	15	15	15	15	15
Diffusions start 2002	1,95	1,95	1,95	4,88	4,88	4,88	9,62	9,62	9,62	14,43	15,00
Equipped Vehicle Stock	1,95	3,90	5,85	8,78	13,65	18,53	23,40	33,02	42,63	57,06	72,06
Equipment Rate	1%	2%	3%	4%	6%	8%	10%	14%	18%	24%	29%

*Table 6: Vehicle Stock EU 25: (ProgTrans 2004: 336; *= own approximations*
New Registrations : own approximations, based on ACEA 2004)

Using these assumptions means that all new registrations will be equipped with a new intelligent vehicle safety systems after 10 years. After these 10 years almost 30% of all vehicles will be equipped with the new system. Comparing these approximated figures to available data on different IVSS shows that professional forecast institutes usually expect longer time spans until all newly registered vehicles are equipped with a new function. This is due to the fact that this calculation is based on a small number and on rather rough assumptions. The following sources for mistakes have to be taken into account.

Forecasts of vehicle stock should not only be extrapolated from existing figures, but take into account societal and individual trends of traffic development, country specific aspects, and so forth. The same is valid for forecasts of new passenger car registrations. Next to aspects of traffic developments in the considered countries these have to take into account, that different supplies are offered by vehicle manufacturers. A differentiation into five segments is rather rough. Usually a breakdown into eight or more segments is used for forecasting. For the share of vehicles that are equipped with new IVSS it has to be considered that not only non-equipped cars will be scrapped, but also a share of newly equipped vehicles. Therefore the share of equipped vehicles will increase slower.

Furthermore this approximation does not take into account that differentiations have to be made for different technologies and functions as well as different vehicle manufacturers. Not all diffusion decisions will end with a start of introduction in the highest vehicle segment. Some introductions may begin in medium class vehicles.

All this taken together shows, that for forecasting the equipment rate with new IVSS a detailed analysis is necessary. Looking back it can be seen that the diffusion of Anti-lock Braking Systems took more than 20 years. Proceeding from passive to active safety systems and the overall trend to modularisation will speed up the diffusion of new intelligent vehicle safety systems. Nevertheless a close look has to be taken at each single function to make a forecast that is reliable enough to be used in a model like the proposed one.

4.5 Road Traffic Development and Safety Performance

The objective of this section is to integrate main traffic and safety indicators into the proposed model. After screening the different IVSS technologies and discussing their market perspectives, traffic data will be needed to explore the socio-economic benefits. Obviously, intelligent vehicle safety systems (IVSS) can only provide benefits when the systems are introduced in the market and used in road traffic. Road traffic development and safety performance for the target years 2010 and 2020 will therefore be described in the following section by indicators such as:

- Transport performance (passenger transport: in pkm, goods transport: in tkm),
- Vehicle mileage (in vehicle km),
- Number of accidents, classified by severity

Since EU-25 represents the geographical coverage and the years 2010 and 2020 are the target years of the study, three recent forecasts provide substantial parts of the required data:

- ProgTrans European Transport Report (ProgTrans 2004) is a publication which is updated regularly every two years. It provides forecasts for 27 European countries (EU-25 plus Switzerland and Norway). The time horizon of the recent publication is 2015. The indicators are presented at five-year interval (2005, 2010, 2015).
- As a result of long-range energy demand modelling (PRIMES model), the European Commission's DG TREN has released a long-term forecast on European Energy and Transport Trends to 2030 (DG TREN 2003). The publication was produced by the National Technical University of Athens. It covers a wider geographical area (30 countries) by including three candidate countries (Romania, Bulgaria and Turkey). The indicators are presented in five-year intervals up to 2030.
- The TEN-STAC study (Scenarios, Traffic Forecasts, and Analyses of Corridors on the Trans-European Transport Network, NEA 2003) forecasts road traffic for the enlarged European Union up to 2020.

Each of these studies is focused more on one specific topic than on others. The DG TREN study focuses on energy demand. While transport indicators are addressed in the forecast, therefore, they are not the central concern. The aim of ProgTrans 2004 is to explain how transport performance results in vehicle mileage. Vehicle mileage is an important indicator for the socio-economic impact assessment because for a given technology status of vehicles the total number of accidents is correlated with vehicle mileage. TEN-STAC considers the impact of several different transport policy scenarios on transport performance.

4.5.1 Transport Performance

Transport performance is the key indicator for transport demand. Transport performance is composed of a load component (expressed in people [passenger transport] or in tons [goods transport]) and a distance component (in km). Transport performance thus reflects changes in socio-demographic and economic indicators (such as population, gross domestic product [GDP], gross value added in industrial production and external trade). These indicators are used as data in the proposed model since the exploratory study does not compile its own forecasts for these indicators.

As stated above, there are several forecasts for transport performance. In order to validate the data sources the predicted traffic growth between 2000 and 2020 will be compared in the following figure. Note that the time horizon for ProgTrans 2004 is currently 2015. The transport performance forecast for 2015 has therefore been extrapolated to 2020 by using ProgTrans annual growth rates for the period 2010 to 2015. This approach can be justified since there is currently no evidence to justify an adjustment in the growth rates.

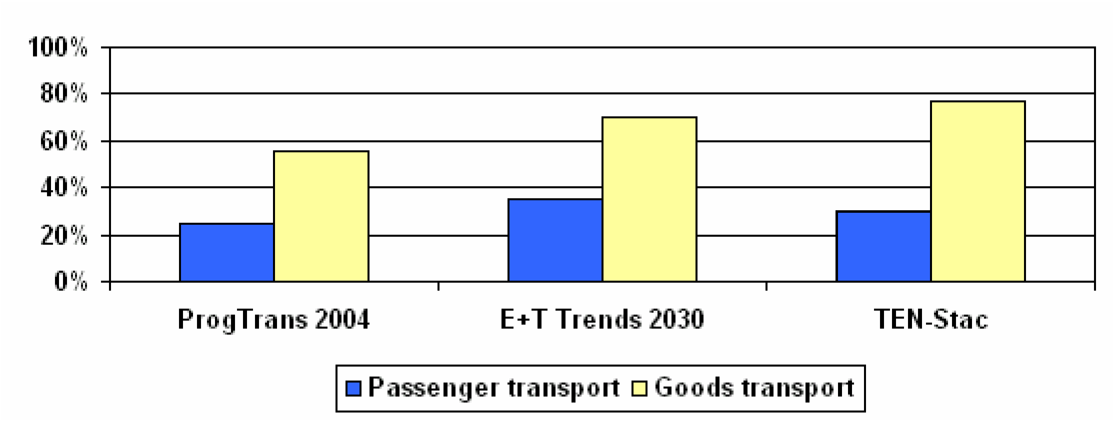

Figure 27: Comparison of forecast road traffic growth between 2000 and 2020 (ProgTrans 2004, DG TREN 2003, NEA 2003; author's figure)

The figure shows that all forecasts predict significant increases in the volume of traffic growth on European roads for the two decades to 2020. Goods transport is expected to grow dynamically with growth rates between 55% and 76%, whereas passenger transport should increase moderately, with growth rates between 25% and 35%. The higher growth rates in goods transport can be attributed to economic growth and the deeper integration of new EU member states into the Common Market.

It should be noted that most forecasts show how the demand for mobility of passengers and goods develops in a given period. The supply side of transport, the evolution of transport infrastructure, is not specifically modelled. Instead, it is considered at a global level. This is where the TEN-STAC study provides further insights by showing how different levels of infrastructure improvement will affect transport demand. As a general rule, infrastructure measures do not substantially influence the level of transport demand. Instead, they influence its modal split. With that, infrastructure supply contributes to rebalancing the modes as aimed at in the White Paper on Transport.

4.5.2 Vehicle Mileage

Based on the comparison of traffic forecasts, ProgTrans 2004 provides a suitable basis for the estimating transport performance in 2020. The next step is to see how transport performance can be attributed to the roads. ProgTrans 2004 determines vehicle mileage forecasts by dividing transport performance by average vehicle occupancy rate (passenger transport) or by average load factor (goods transport).

The following figure provides an overview of the current and forecast vehicle mileage. The 2002 and 2010 data are originally from ProgTrans 2004. The figures for 2020 are calculated – as explained in the previous chapter – by extrapolating the 2015 figures. In total, vehicle mileage in EU-25 is set to grow from about 3,200 billion km at present to about 4,000 billion km in 2020. As the growth rate of goods transport is higher, the share of goods transport is set to increase from 17.9 to 18.7 per cent.

	Vehicle Mileage in EU-25 in Billion Vehicle Kilometres		
	2002	**2010**	**2020**
Passenger transport	2,601.0	2,956.0	3,273.6
Goods transport	568.1	667.2	754.0
Total	3,169.1	3,623.2	4,027.6

Figure 28: Forecast of vehicle mileage road traffic growth between 2000 and 2020 (ProgTrans 2004, author's calculation)

The question we are now facing is that of where those vehicle kilometres will be driven. This is an important issue for road safety considerations because motorways have the highest safety level (commonly expressed in terms of accidents per million vehicle kilometres) in the road network. It is therefore important to know whether or not this traffic growth will be equally distributed within the road network.

The following section distinguishes between motorways, rural roads and urban roads. Generally, the expansion of the motorway network (adding new links, 6-lane or 8-lane extension) leads to a larger share of motorway traffic in the total vehicle kilometres. This trend can be regarded as a Union-wide one. Over the last decade, the Eu-15's motorway network has grown by 30% from 39,242 km (1990) to 51,625 km (2000). Some member states (such as France and Spain) have extended their networks, while others (such as Greece, Ireland and Portugal) have built up substantial initial networks. The total length of motorways in the ten new member states (2,863 km, 2000) amounts to just 5.2% of the EU-25 motorway network. The new member states will expand their network rapidly within the next years. This will also improve road safety considerably because of the higher safety performance of motorways.

It remains difficult to attribute vehicle kilometres precisely to road categories because road typology is differs between member states and the database is not very comprehensive. There are, however, results available for some member states which allow the attribution of vehicle kilometres (André 1999, Lensing 2003). After all, these member states represent more than half the total EU-25 vehicle kilometres. The results (see the following figure) show that roughly 20% of vehicle kilometres can be attributed to motorways. In Germany, with its dense motorway network, this share is considerably higher. Approximately 40% of vehicle kilometres are attributed to rural roads and urban roads.

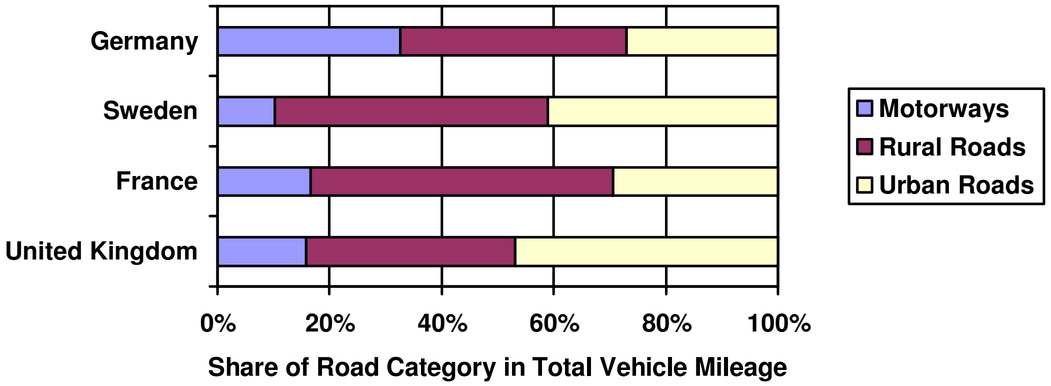

Figure 29: Distribution of vehicle mileage in road network for selected EU Member States (André 1999, Lensing 2003, author's calculation)

An issue closely related to network distribution of vehicle kilometres is the typical speed pattern for different road categories. It is important because some IVSS only work within a specific speed range. For instance, Adaptive Cruise Control is designed for higher speeds from 30 km/h onwards to 200 km/h. This implies that ACC will not be suitable for most urban situations and is also not designed as a system for use in city traffic (STARDUST 2004). As a consequence, the share of vehicle kilometres which accounts for urban roads cannot be excluded when estimating the potential benefits. Instead, an ACC which also covers low speed situations (ACC Stop+Go) will close this gap. That is why ACC Stop+Go can be seen as a functional enlargement of ACC.

Table 7 shows estimations for average daily speeds on different road categories. For each road category, a speed range is given which reflects the influence of different junction numbers as well as the variations in traffic flow throughout the day. Obviously, high traffic volumes correspond with low average speed and vice versa.

	Average daily speeds (in km/h)	
Road Type	Light Vehicles (cars, light heavy duty vehicles)	Heavy duty vehicles
Urban roads	23 – 49	23 – 49
Rural roads	39 – 87	40 – 77
Motorways	91 – 109	76 – 84

Note: A lower term of speed interval represents a high number of junctions and high traffic flow, while higher speeds imply a low number of junctions, low traffic flow.

Table 7: Range estimations for average daily speeds (André 1999)

4.5.3 Safety Performance: Accident Numbers and Severity

Safety performance is an important indicator within the SEiSS model framework because it provides the link between road traffic (in terms of vehicle kilometres) and road accidents. Safety performance can therefore be defined as follows:

- number of accidents per billion vehicle kilometres
- number of fatalities per billion vehicle kilometres.

Historical data on safety performance is provided by the CARE and IRTAD databases, or can be calculated based on the information provided by these databases. Based on results of the RECORDIT project (EC 2003), the risk exposure related to different road categories is as shown in the following figure.

Region		Infrastructure	Accident risk (fatal accidents per billion vehicle km)
EU-15	Best-performing countries	Motorway	2 – 4
		Extra-urban	3 – 5
	Worst-performing countries	Motorway	9 – 15
		Extra-urban	15
EU acceding countries		Motorway	10 – 20
		Extra-urban	17 – 24

Table 8: Risk of a fatal accident on different road categories (EC 2003a)

The table shows that the risk of a fatal accident differs considerably between old and new member states. Even within EU-15, there is a remarkable difference the between best- and worst-performing countries. The fatal accident risk in the worst-performing countries is three to four times higher than in the best-performing EU-15 countries.

Furthermore, it becomes clear that safety performance also differs according to road category. Independent of region, motorways are safer than other roads. In this context, enlargement of the European motorway network (TEN road network) can also be seen as a measure to improve traffic safety in the EU. Coming back to the different regional safety performances, there are several arguments which could explain the differences. One is that the roads in the best-performing countries are in better condition than those in the worst-performing countries. Another argument is provided by the hypothesis of different driving attitudes between member states.

From an economic point of view, the differences in safety performance between EU countries can best be explained by the different GDP levels. In the private sector, the GDP determines the disposable income for individuals, which can be used, for instance, for buying cars (reflecting the current level of safety technology). GDP also determines (via tax revenues) the public expenditure which can be used for enlarging, upgrading and maintaining national road networks.

In order to illustrate the argument, GDP will be correlated to safety performance based on 2002 data for EU-25. Both indicators are expressed on per capita basis. Hence, safety performance is indicated by the number of fatalities per million inhabitants. In the next step, both variables for each member state are related to the EU-25 average. The EU-25 average for both variables is represented by an index of 100.

The result of the analysis is shown in the following figure representing the combination of economic and safety performance for each member state. Obviously, GDP and safety performance are inversely correlated as it has been argued in the previous section. By introducing the lines of average GDP and average safety performance a four quadrant scheme emerges from the analysis. Member states which can be found in the lower right quadrant (economic performance above average, safety performance above average) can be identified as belonging to the group of best performing countries. Member states which can be found in the upper left quadrant (economic performance below average, safety performance below average) can be identified as belonging to the group of worst performing countries. Member states in the upper right cannot be clearly identified as belonging to one group or the other. Characterised by above average GDP and below average safety performance these countries lie in between.

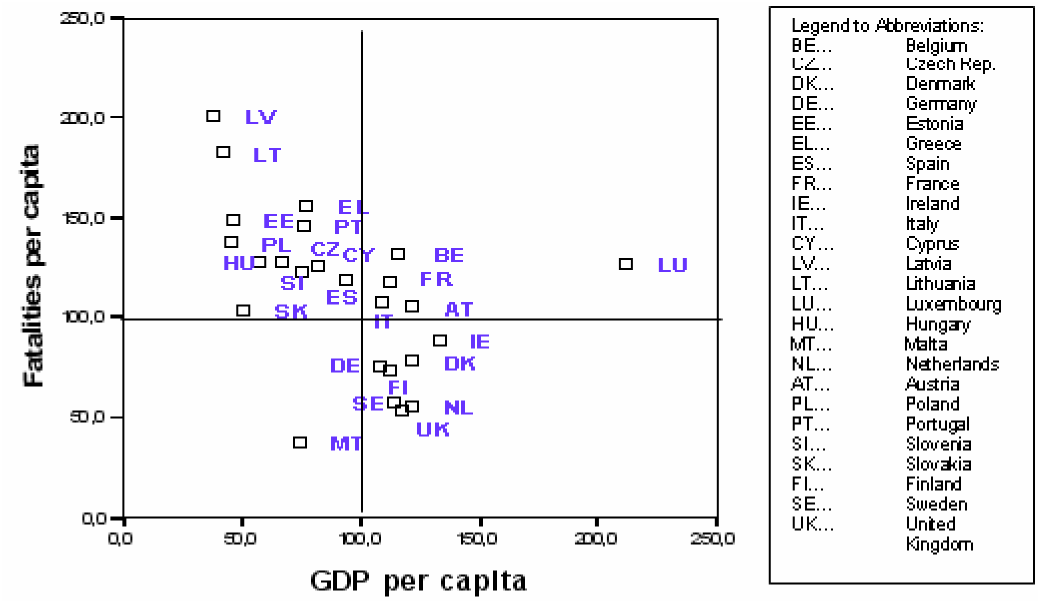

Figure 30: Correlation between economic performance and safety performance (author´s figure)

Over the last decade, the decade in which most IVSS were developed, road safety in the EU-15 has been continuously improved. This can be illustrated by CARE and EUROSTAT data. Data covering the whole EU-25 for this period is currently not available. The number of road fatalities has been reduced from 56,027 (1991) to 39,849 (2001). This is equivalent to an annual reduction of 3.3%. However, due to the traffic growth of 1.8% per year, the safety performance (fatalities per billion vehicle kilometres) has improved by as much as 5.1%. Obviously, there has been a greater drop in the number of fatalities has than in the number of accidents. This fact reflects the better safety performance of the recent vehicle fleet compared with previous vehicle generations.

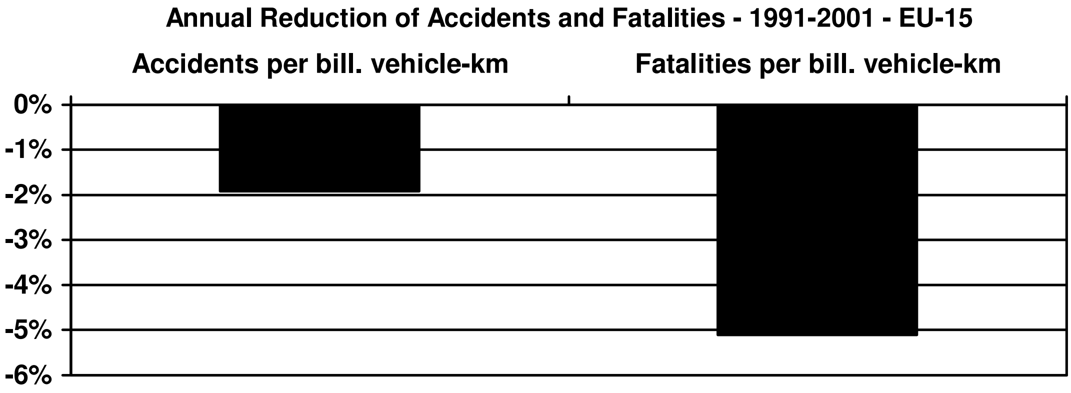

Figure 31: Development of Road Safety Performance Indicators (EC 2003a, author's figure)

In the context of exploring the socio-economic impacts of ISS the challenge is to forecast the future level of road safety. Obviously, increasing vehicle kilometres will result in a slower reduction in the number of accidents. The important question, however, is how safety performance will develop. According to the French ARCOS project, there are several future development scenarios are possible:

- Accidents will decrease according to the trend (straight line projection),
- Accidents will encounter a barrier to continuously decreasing numbers (return to an asymptote) due to risk compensation and poor driver behaviour,
- Accident development will reflect an enduring change in driver behaviour

Accident Severity	Annual Reduction in %		
	Return to an Asymptote	Straight Line Projection	Enduring Behavioural Change
Fatal	- 1.0	- 3.4	- 6.0
Severe injuries	- 0.5	- 5.4	- 7.0
Slight injuries	- 0.5	- 3.3	- 5.0

Table 9: Scenarios for road safety development (based on ARCOS 2004)

The question we are now facing is "Which safety development is the most likely?". Basically, it can be expected that the trend towards lower accident numbers and fewer fatalities will continue. On the other hand, the trend is influenced by the incremental market penetration of Intelligent Vehicle Safety Systems and political measures to ensure that the White Paper goal of halving the number of road fatalities by 2010 will be reached. Recent safety indicators support the view that we are currently experiencing a progressive reduction in the number of accidents and fatalities (EC 2004).

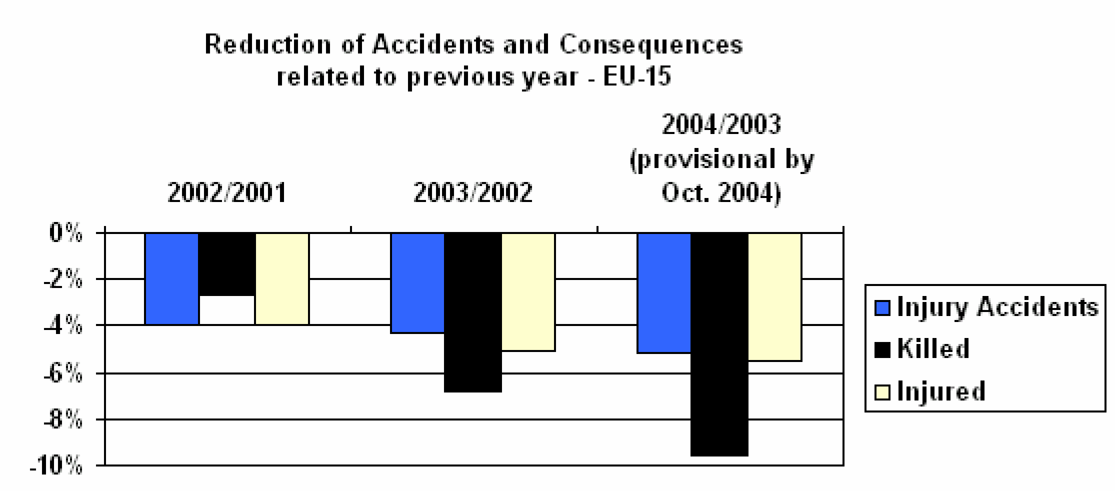

Figure 32: Road safety development (EC 2004; author's figure)

However, it is still uncertain whether or not the depicted development of progressive reductions will continue. It can conservatively be assumed that the trend towards a reduction in the number of accidents and casualties will develop as it has over the last decade. As argued above in the time series analysis, the trend represents an annual reduction of fatalities of more than 3%, which is equivalent to a 5% reduction of fatalities per billion vehicle kilometres. These numbers follow the linear trend towards reduction projected by the ARCOS project. Taking into account the estimated traffic growth, the following road safety improvements can be expected:

- The number of accidents should decrease by 2% per year,
- The number of casualties (fatalities, severe and slight injuries) should decrease by 3% per year.

The White Paper on Transport aims to halve the fatalities on European roads in the first decade of the 21st century. Meeting this goal would require an annual reduction of 4%. The reduction of 3% per year will, over ten years, lead to a cumulated reduction of 34%. Following the straight line projection will therefore not be sufficient to reach this ambitious goal.

Additional safety potentials will therefore have to be developed. In the context of stimulating road safety the market introduction of IVSS plays a significant role. Obviously, market penetration is considerably low in the first years after market introduction. Most systems will exhibit the "cascade of innovation" pattern described in Section 4.4, in which IVSS are introduced first in luxury or upper class segments and trickle down sequentially to medium and compact class vehicles. IVSS therefore has a limited impact in the very short term. It is, however, necessary to estimate the potential socio-economic benefits of IVSS in order to assess their potential contribution to future improvements in road safety.

4.6 Socio-Economic Evaluation

The socio-economic evaluation of IVSS may be based on a need to:

- reduce accidents and/or accident severity,
- support the approval of IVSS,
- find out the efficient and effective IVSS,
- support transport policies priorities,
- implement legislative change and or public support to enforce IVSS.

The most general objective of IVSS is to avoid accidents and/or reduce the harm of accidents. Therefore, the evaluation process has to work out clearly the effects on accident costs of IVSS. Beneath that the assessment in terms of accident costs is not sufficient, because IVSS lead to other effects, which have to be considered within the final decision process on strategies for intelligent safety systems.

IVSS, normally, cover a wide range of technological solutions. A full implementation of all what is technically possible is not achievable due to financial constraints and/or market barriers. Each IVSS has to be judged in an objective manner to find out the benefits and costs. The evaluation of each possible intelligent safety technology has to guarantee that the results in terms of benefits and costs are comparable between the technologies. That, finally, allows a ranking of different IVSS solutions. The ranking process has to fulfil the principle that the most efficient and effective intelligent safety solutions will be chosen. These outcomes of the ranking procedure allow transport policy to identify the priorities for the future introduction of IVSS into the market. Furthermore, it is indicated what implementation strategy might be appropriate for any intelligent safety system solutions.

4.6.1 Available Evaluation Methods

Following evaluation methods are used for assessing the introduction of new technologies:

- Financial Analysis (FA): assesses the impacts of an activity on the own financial costs and revenues of the acting institution.
- Cost-effectiveness analysis (CEA): An assessment of the costs of alternatives (e.g. technology A compared to technology B) which all achieve the same objective. The least-cost alternative of achieving the objective is chosen.
- Break-even analysis (BEA) can be defined as a 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 stakeholder (system user, system provider).
- Business case calculations (BCC) are a detailed investment proposal. It provides an analysis of the costs, benefits and risks associated with a proposed investment and offers reasonable alternatives. It provides information necessary to make a decision about whether a project should proceed.
- Benefit-cost analysis (CBA): Both the potential benefits and the potential costs of a measure/technology are estimated across a set of impacts and converted into monetary terms by multiplying impact units by prices per unit.
- Multi-criteria analysis (MCA) has the goal of maximizing with respect to a set of socially based objectives rather than market values.

The evaluation methods can be generally distinguished into two groups due to their evaluation perspective:

- Information to support decision of stakeholders is given by financial analysis, cost-effectiveness analysis, break-even analysis, and business case calculations.
- Information on overall societal effects is provided by benefit-cost analysis and multi-criteria analysis.

4.6.2 Benefit-Cost Analysis

4.6.2.1 Analytical Framework of Benefit-Cost Analysis

Considering the methodological framework a widespread approach for assessing the potential socio-economic impact is the welfare economics-based benefit-cost analysis (CBA). The favorability of intelligent safety systems from the society point of view can be illustrated by confronting the socio-economic benefits with the system costs (investment, operating and maintenance costs). Benefit-cost ratios of more than 1, indicate the public rentability of the system deployment.

The following figure represents the evaluation steps for performing a full benefit-cost analysis of Intelligent Safety Systems.

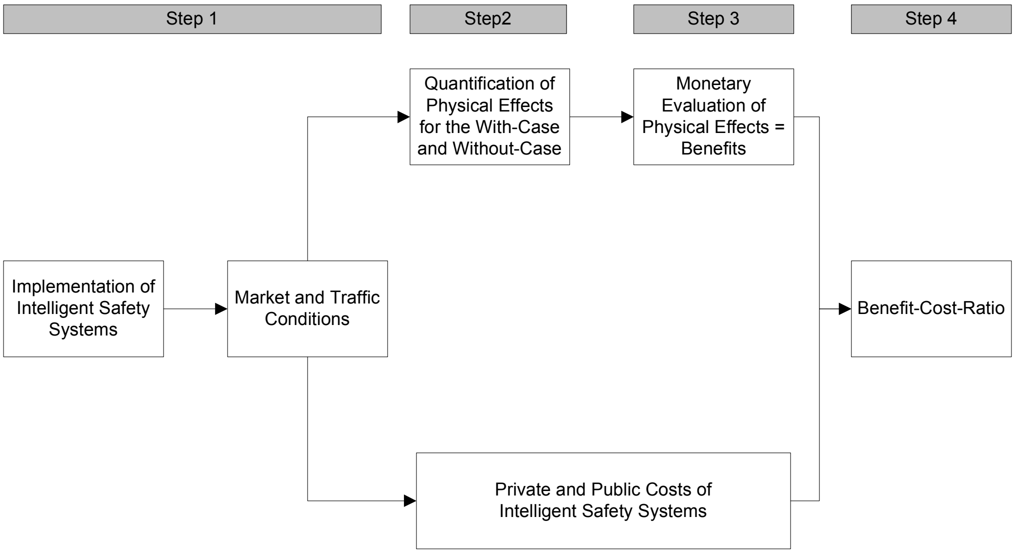

Figure 33: Steps of monetary evaluation of Intelligent Safety Systems (author´s figure)

The CBA consists of a four step calculation procedure. The four steps can be characterized as follows:

First Step:	Specify the general framework conditions for the analysis and define the relevant alternatives that will be compared (without-case: IVSS is not used, with-case: IVSS will be used),
Second Step:	Analyse the impacts of each case by traffic and safety indicators such as traffic flow, vehicle speed, time gaps and headways,
Third Step:	Work out the physical dimensions of the traffic impacts such as total transport time, fuel consumption, level of pollution, number of accidents,
Fourth Step:	Calculate the benefits by valuing the physical effects with cost-unit rates, aggregate the benefits and work out the benefit-cost ratios.

Within the **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 behaviour 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.

In the **second step** the traffic effects of IVSS have to be quantified. The traffic effects determine if IVSS lead to overall benefits or not, because the traffic effects determine how the economic factor resources of traffic are affected by IVSS. The economic factor resources for traffic are time, energy, accidents, and environment.

Conceptually, the main effect of intelligent safety systems is the reduction of hazardous situations. But additionally, corresponding to the overall system characterization other important traffic effects can be caused which lead to a considerable range of socio-economic benefits. The following figure gives an overview over general system impact channels on hazardous situations and their economic consequences.

The relevant economic impact of intelligent safety systems is first the avoidance of accidents (safety critical effects of hazard situations). Using the systems compared to a situation without them will lead to different consequences of hazardous situations. Consequently, hazardous situations which normally lead to accidents will be defused by system use. Hence, it will be possible that the number and/or the severity of accidents can be avoided. As a consequence, accident costs can be lowered. Avoiding accidents is furthermore related to additional traffic effects, because the number of congestions due to accidents can be lowered too. Avoiding congestions then reduces time and vehicle-operating costs, emission and CO_2-costs. These socio-economic impacts are also addressed by non-safety critical effects which may play as side effects a considerable role with respect to the overall economic benefits

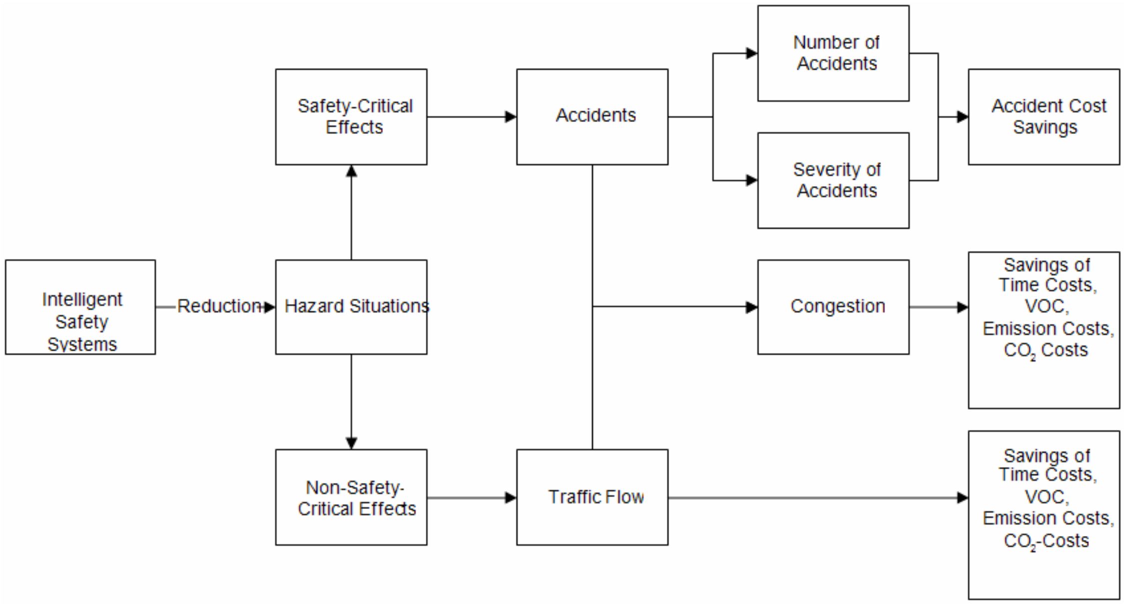

Figure 34 System impact channels on avoiding hazard situations (author´s figure)

Beneath the reduction of hazard situation the usage of IVSS 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 12 shows the impact channels of the additional traffic effects on economic costs.

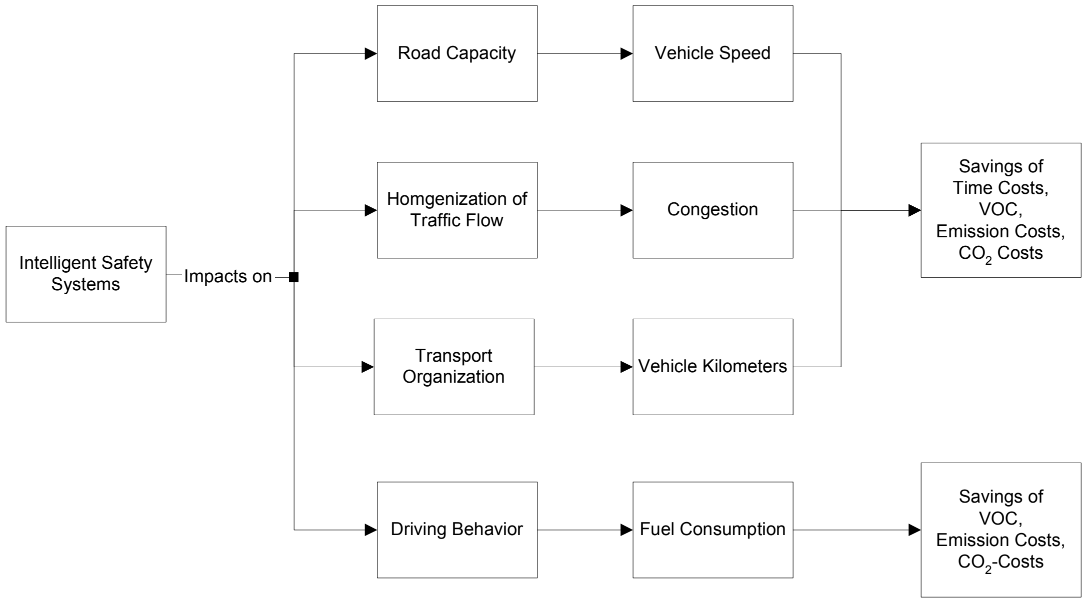

Figure 35: Further possible traffic impacts of Intelligent Safety Systems (author´s figure)

Differences in the driving speeds between vehicles improve the efficiency of net sections. Substantial speed differences cause frequent lane changes and overhauling manoeuvres. IVSS 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 IVSS comes up, if IVSS is used in road freight transport. The traffic improvements and possible cost savings of IVSS 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-kilometres. In the case of decreasing vehicle-kilometres cost savings can be realized. Increasing vehicle-kilometres have a reverse effect.

Road users might reach direct cost savings, if IVSS lead to lower fuel consumption by influencing the individual driving behaviour. Furthermore, lower consumption reduces also emission costs and CO_2-costs.

IVSS have an effect on the traffic conditions in the road system. Normally, IVSS 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 IVSS 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, IVSS 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 IVSS.

In another case, it is possible that IVSS 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.

In the **third step** altogether the change of traffic parameters caused by the traffic effects of IVSS 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 benefit-cost analysis.

To get the benefits of IVSS it is necessary to define two possible cases:

- The with-case, which means IVSS will be introduced.
- The without-case, there will be no-introduction of IVSS.

The difference between the costs of the without-case and the with-case is the benefit of IVSS. 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 IVSS. The annual social benefits over the life cycle of IVSS 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 IVSS have to be determined. The costs of IVSS 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 centre) are necessary for the functioning of IVSS.

Within the **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

B_t := benefits estimated for the year t

C_t := 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 IVSS. This proceeding implies information about the economic objective of maximisation/minimisation of benefits/costs and helps to avoid false decisions and bad investments.

4.6.2.2 Monetary Evaluation Methods

The quantification of the changes of resource inputs by IVSS (=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 monetarisation of accident savings plays an important role, because IVSS 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. 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 shows which kind of evaluation methods are practically in use.

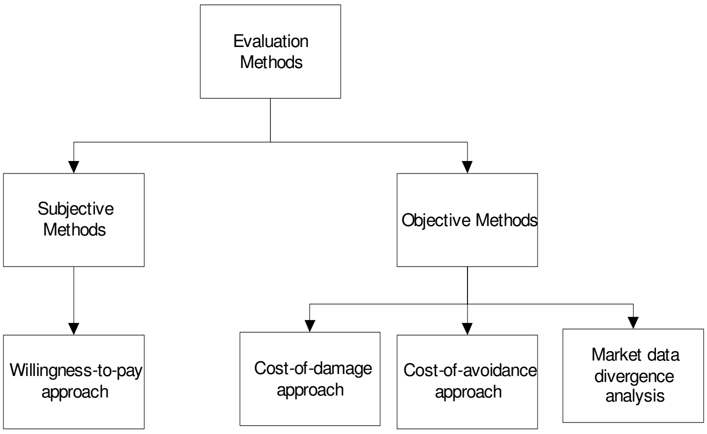

Figure 36: Overview of evaluation methods (author´s figure)

The evaluation methods can be characterised as follows:

- 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; a basic criterion 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).
- 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.

To illustrate possible differences within the cost-unit rates given by different methods the following table 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.

Accident severity	Cost-of-damages	Willingness-to-pay
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	--

Table 10: Comparison between cost-of-damages and willingness-to pay (1996)

Annotation: Injury Levels correspond to the accident severity scale of the American Association of Automotive Medicine

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 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.

4.6.2.3 Resource oriented Approach

The support of transport policy for any kind of intelligent safety system can cover a wide range of policy interventions (e.g. safeguards only, general-awareness raising, supporting actions, highlighting best-practices, setting standards and rules, economic incentives, legal changes, regulation). However, policy interventions should demonstrate optimality, which at least means in economic terms allocative efficiency.

The general formulation of this optimality objective is that by introducing any kind of intelligent safety systems at least one individual is made better off and no individual is made worse off. Obviously, the consequent application of this criterion is impractical because it would be impossible to identify all winners and losers of IVSS.

Consequently, a potential Pareto optimum – the Hicks-Kaldor criterion – is generally applied by which considers an intervention as acceptable if the amount by which some individuals gain is greater than the amount that others lose. That means it is important to reach a net-benefit, so that, in principle, winners could compensate losers for their costs. No actual cash transfer is required. An intervention may therefore be considered efficient even if some individuals lose, as long it generates net benefits (Boardman et al, 1996: 29-34).

In this way, the principle of allocative efficiency is underpinned by an assumption that social welfare may be enhanced by the redistribution of resources within society, even where this entails redistribution from the poor to the rich. Monetary value can be used as a common denominator for the assessment of the relative merits of public interventions, taking into account their costs and benefits to society.

The objective that the evaluation of IVSS should be optimal means that the focus of the assessment should lie on the consequences of IVSS to the resources used within society. Relevant resources in the context of IVSS are for example changes of traffic amount in terms of

- time,
- energy (fuel),
- accidents,
- environment (noise, emissions, green-house gas).

The CBA itself is an instrument to calculate the resource savings coming up from any kind of measure. Therefore, CBA is the appropriate approach to safeguard the optimality requirement for transport policy judgment of IVSS. Furthermore, CBA establishes greater control over resource allocation. Once completed, CBA can also be used to assist resource allocation on an on-going basis.

4.6.2.4 Estimation of Benefits

Accidents Cost-Unit Rates

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.

Monetary evaluation of accidents is important for two reasons:

- to ensure that safety is consistently considered in the resource allocation for the research and development of IVSS;
- to ensure that any expenditure for IVSS can be justified because of their accident cost savings, which guarantees the cost-efficiency of IVSS.
- 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, hospitalisation, 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.

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 table) 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

Table 11: International comparison of human costs in Euro

Altogether the table 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.

The derivation of the other cost positions in the frame of the resource cost calculation is not afflicted with such methodical problems. Figure 37 gives an overview over the elements, which are regularly incorporated in the accident cost analysis.

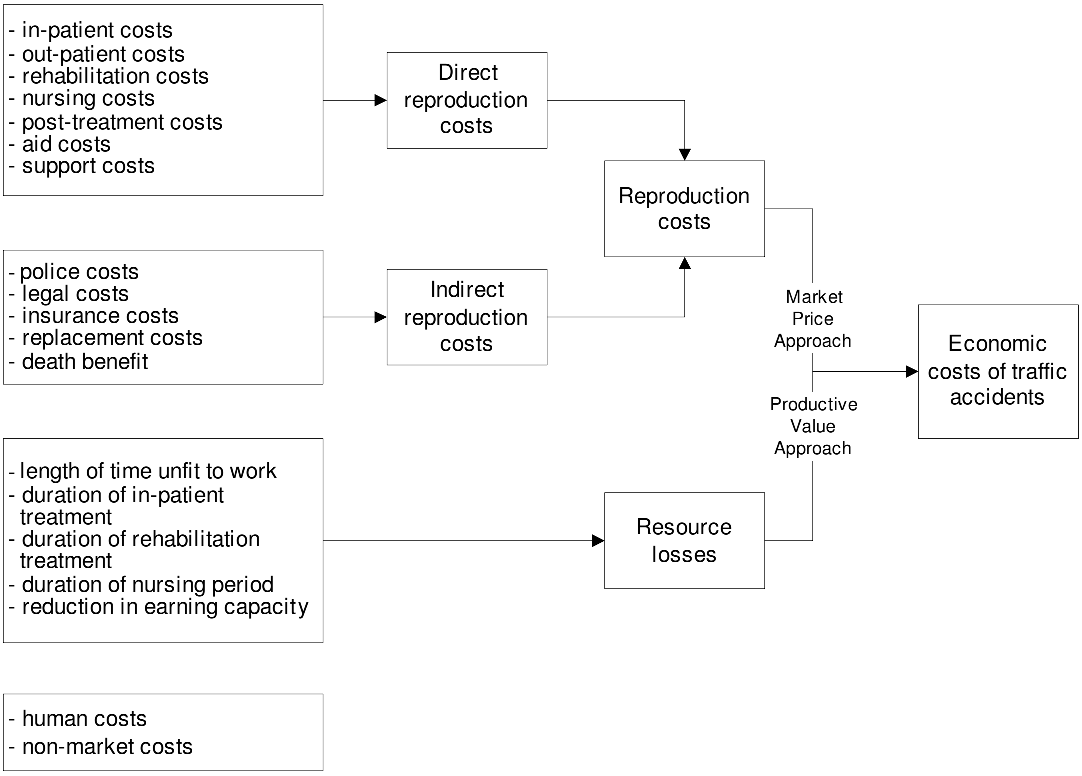

Figure 37: Elements of accident cost analysis (author´s figure)

Table 12 shows the proposed cost-unit rates for accidents with fatalities, severe injuries and slight injuries. As mentioned above the cost-unit rate are only reflecting the costs of accidents with personal injuries. Therefore, they are not reflecting the costs for the accidents with property damages.

Type of Accident	Cost-unit rate per Accident
With fatalities	1,000,000 €
Severe injuries	135,000 €
Slight injuries	15,000 €

Table 12: European Cost-unit rates for Accident Evaluation in Euro per accident (EC 2003b)

Actually, each accident with personal injuries is accompanied by property damage. However, contrasting to cost figures of injuries there is no uniform cost figure for valuing property damages. However, the CBA requires being complete in terms of costs and benefits. That means that it is necessary to consider the property damages because the represent a real economic resource loss for the overall society. It would be for the property damages caused by road accidents desirable to have uniform cost-unit rates for the EU, which are differentiated for fatalities, serious injuries, slight injuries and for accidents without personal damages. The suggested cost-unit rates on national level show a considerable span as illustrated in table for selected countries.

Countries	Lower Bound – Upper Bound of Property Damage Costs
Germany	10,000 – 30,000 €
United Kingdom	3,200 – 12,500 €
Sweden	1,500 €
USA	1,000 – 10,000 €

Note: Figures are converted to Euro on basis of 1€ = 1 US$ = 0.67 GB£ = 9 SEK and rounded.

Table 13: National Cost-unit rates for Property Damage Evaluation in Euro per accident (Höhnscheid/Straube 2002; Department for Transport UK 2001; Swedish State Institute for Communication Analysis 1999; U.S. Department of Transportation 2002)

The suggestion is to use a general cost-unit rate for the property damages, which can be assumed as an average value for the EU.

Other Cost-unit rates

Beneath accident cost effects IVSS will have non-accident effects, too. The non-safety effects of IVSS will result in resource cost savings, whereby these cost savings come up from time savings, fuel savings, emission and CO2 savings.

Time Costs

The safety enhancement of IVSS is the actual objective. Therefore, travel time costs seem not so important. However, travel time savings are often the greatest potential benefit of transport improvements (Heggie/Thomas 1982). Time costs and the benefits of time cost savings vary widely depending on factors such as the type of trip, traveller and travel condition. 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 IVSS 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 38 shows the proceeding how time costs are calculated. Vehicle-kilometres 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 IVSS, and also the number of vehicles, which are affected by IVSS, 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.

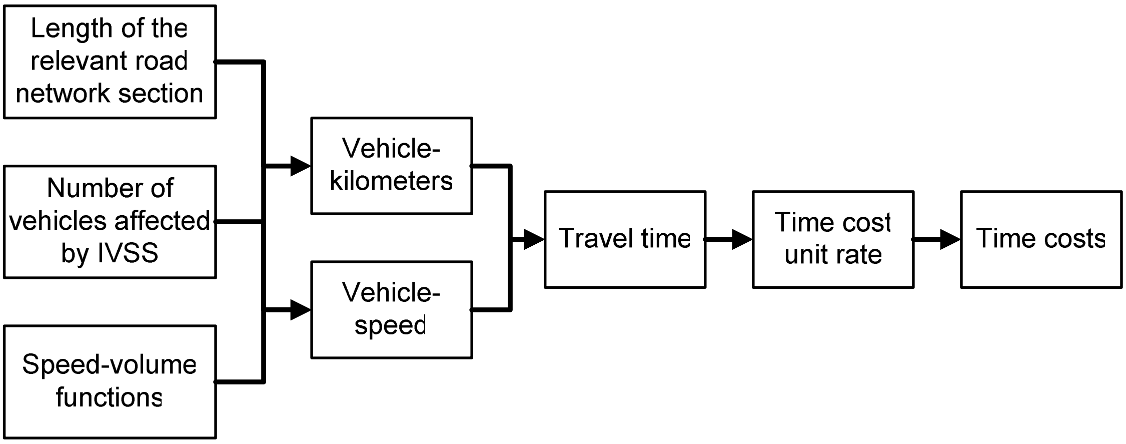

Figure 38: Procedure for Calculating Time Costs (author´s figure)

Table 14 shows the various components, which have been integrated in the calculation of the time cost rates.

Freight transport	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-kilometres)
		Garage
		General costs
Passenger transport	Time costs	Time costs for one labor-hour
		Time costs for one leisure-hour
	Provision costs	Commercially used passenger cars

Table 14: Components of Time Costs (author´s figure)

On the basis of previous table are normally cost-unit rates worked out for the vehicle types. The following table represents 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. Furthermore for an international comparison the time cost-unit rates used by the US Department of Transport are also presented.

Vehicle Category	**Cost-Unit Rates**		
	Germany (Base Year 2000)	United Kingdom (Base Year 2000)	USA (Base Year 1997)
Average Passenger Car	11 €/h	13 €/h	8.9 $/h
Average Truck	32 €/h	14 €/h	16.5 $/h
Average Bus	66 €/h	82 €/h	--

Table 15: Examples for Time Cost-Unit Rates (Planco Consulting GmbH 2000: 15; Baum et.al. 2000: 74; Vickerman 2000: 7-12; Victoria Transport Policy Institute 1998; own calculations)

Table 15 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. Different occupancy assumptions are the main reason for the higher cost-unit rate for buses in the CoBA model.

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-kilometres. The second term is the product of fuel consumption and fuel price. The fuel consumption depends on vehicle-kilometres, 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
Φ_{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 consider following technical relations:

- Fuel consumption increase super proportionally 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 following table) 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**

Table 16: Fixed Operating Costs for Vehicle Types (Forschungsgesellschaft für Straßen- und Verkehrswesen 1997: 13; own calculations)

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.

The following table 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**

Table 17: Fuel Cost-unit rates (Planco Consulting GmbH: 15.; own calculation)

Emission Costs

The estimation of emission quantities is based on emission-vehicle-speed functions for carbon monoxide, carbon hydrogen, nitrogen dioxide, sulphur, soot, and other particles. The different kinds of emissions are transformed by toxic factors to a standardized unity of nitrogen x-oxide.

The air pollution contains two components with different directions of action:

- the direct emissions, which spread spaciously 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/cm3]) 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:

$EF_{FG;j} = c_0 + c_1 * V^2 + c_2 / V$

with

EF	...emission factor (in g/[km*vehicles])
V	...vehicle speed (in km/h)
c_0, c_1, c_2	...parameter depending on vehicle type and emission
FG	...index for the various vehicle types
j	...index for the emission

However, in the most cases the emission factors are calculated by official institutions. For example the following tables show the emission factors for different vehicle types used by the U.K. Department of Transport. Due to the fact that the vehicles within the EU do not differ in their system specification, the U.K. emission factors might be usable for the whole EU.

The following table gives an overview for the NOx-emission factors. The emission factors for PM, VOC and CO are presented at the end of this chapter.

	Emission standard	Urban	Rural single c/way	Rural dual c/way	Motorway
Petrol cars	Pre- ECE	1.99	2.30	2.59	2.85
	ECE 15.00	1.99	2.30	2.59	2.85
	ECE 15.01	1.99	2.30	2.59	2.85
	ECE 15.02	1.70	1.98	2.52	3.69
	ECE 15.03	1.57	1.74	2.07	2.85
	ECE 15.04	1.54	1.83	2.33	3.31
	Euro I (91/441/EEC)	0.292	0.279	0.332	0.622
	Euro II	0.129	0.123	0.146	0.274
Diesel cars	Pre-Euro I	0.653	0.575	0.577	0.757
	Euro I	0.451	0.291	0.210	0.310
	Euro II	0.325	0.209	0.151	0.223
Petrol LGV	Pre-Euro I	1.76	1.97	2.39	3.32
	Euro I	0.326	0.339	0.414	0.648
	Euro II	0.143	0.149	0.182	0.285
Diesel LGV	Pre-Euro I	1.26	1.14	1.17	1.57
	Euro I	0.618	0.399	0.288	0.423
	Euro II	0.469	0.303	0.218	0.321
HGV rigid	Old	11.80	14.40	14.40	14.40
	Pre-Euro I	9.84	6.10	5.53	5.16
	Euro I	6.76	4.41	3.97	3.62
	Euro II	4.86	3.41	3.07	2.71
HGV artic	Old	18.20	24.10	24.10	19.80
	Pre-Euro I	26.19	17.20	15.74	12.20
	Euro I	13.73	10.17	9.30	6.33
	Euro II	9.99	7.63	6.97	5.18
Buses	Old	16.20	14.80	14.80	13.50
	Pre-Euro I	12.22	7.89	6.93	5.45
	Euro I	13.21	6.71	6.04	4.31
	Euro II	9.43	5.03	4.53	3.53
Motorcycles	< 50 cc	0.03	0.03	0.03	0.03
	> 50 cc, 2st	0.03	0.03	0.03	0.03
	> 50 cc, 4st	0.18	0.18	0.18	0.18

Table 18: Emission Factor for Nox in g/km (UK Road Transport Emission Projections 1998)

The different kinds of emissions are transformed by toxic factors to a standardised unit of nitrogen x-oxide (see following table).

Pollutant	**NO_x**	**CO**	**HC**	**SO_2**	**PM**
Toxic factor	**1.0**	**0.003**	**1.5**	**1.0**	**0.342**

Table 19: Toxic Factors for Standardization of Nitrogen X-Oxide

With:

- NOx (oxides of nitrogen): through effects of nitrate aerosols on health and ozone on health and crop production.
- CO (carbon monoxides): an odourless very poisonous gas that is a product of incomplete combustion of carbon.
- HC (hydrocarbon chemicals): A group of chemicals containing hydrogen and carbon that often contribute to air pollution as OC's or VOC's. They are involved in forming ozone, and some hydrocarbons are toxic. Term often used interchangeably with VOCs (Volatile Organic Compounds; Synthetic organic compounds which easily vaporize and are often carcinogenic).
- SO2 (sulphur dioxide): through effects of SO2 and sulphate aerosols on health, and SO2 and acidity on materials.
- PM (particulate matter, focused on PM2.5, particles with an aerodynamic diameter less than 2.5 micrometer): through effects on health.

Table 20 shows the cost-unit rates for SO2, NOx and PM valuated within the European Commission ExternE programme. Due to the given toxic factors SO2 and PM can be transformed to NOx units, which means that as cost-unit rate on European average 4,2000 €/tonne can be used.

	SO2	**NOx**	**PM2.5**
Austria	7,200	6,800	14,000
Belgium	7,900	4,700	22,000
Denmark	3,300	3,300	5,400
Finland	970	1,500	1,400
France	7,400	8,200	15,000
Germany	6,100	4,100	16,000
Greece	4,100	6,000	7,800
Ireland	2,600	2,800	4,100
Italy	5,000	7,100	12,000
Netherlands	7,000	4,000	18,000
Portugal	3,000	4,100	5,800
Spain	3,700	4,700	7,900
Sweden	1,700	2,600	1,700
UK	4,500	2,600	9,700
EU-15 average	5,200	4,200	14,000

Units:
€/tonne SO2
€/tonne NO2
€/tonne PM2.5

Table 20: Marginal External Costs of Emission in Rural Areas, Year 2000 Prices (BeTA Version E1.02 A)

CO_2-Costs

Carbon dioxide (CO_2) is a by-product of combustion with the harmful effect of climate change. The green house effect is considered separately because CO_2 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 (EWS-97). 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 (European Commission, ExternE 1998).

The CO_2-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 CO2 per kg petrol,
- Diesel fuel: 3,15 kg CO2 per kg diesel fuel. ´

Because of the complete-burn assumption the emission factors represent the maximum value of the CO_2-emission.

Congestion Costs

As mentioned above, crashes on motorways are regularly accomplished by congestion leading to time losses, higher fuel consumption, air pollution and carbon-dioxide emissions. These effects can be considered in a general cost unit for crashes differentiated for the impacts on crashes. 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 (ICF Consulting Ltd. 2003, p.13). The high cost-unit rate for crashes with fatalities reflects that on average the duration of a fatality crash is higher than an average congestion by crashes with severe or slight injuries.

Uniform Cost-Unit Rates

Before the background that the economic evaluation is focused on the European level for all States similar cost-unit rates for the monetary evaluation of accident effects should be used. It is clear that each Member State has different costs of goods and services. Some studies use cost-adjustment factors related to the difference in labour costs and car costs. These kinds of adjustment factors keep into account that inhabitants of less wealthy EU-Member States will have smaller and cheaper cars than in other States. Perhaps these inhabitants will use less costly equipment in their cars. That means safety measures in less wealthy EU-Member States will have in terms of monetary values a lower economic benefit than in wealthy EU-Member States.

Here the question arises about the sense and justification of such a proceeding. For an equal judgment on European level of safety measures, which specially aim at the saving of life and avoiding injuries, the proposal of the EU Commission is to use uniform cost-unit rates. Uniform cost-unit rates, furthermore, reflect and support the Community goals of economic and social cohesion.

4.6.2.5 System Costs

The benefits come up as resource savings due to the comparison between the with-case and without-case. The costs of each intelligent vehicle safety system, which have to be confronted with the resource savings, comprise capital outlays (private investment costs, public investment costs), running costs (e.g. operating costs, maintenance costs), and other costs, which could be for example costs for supplemental equipment of road infrastructure, implementation of a traffic guidance centre, training costs. The running costs are normally given as annual figures. The private and public investment costs have to be summed up and then the total sum of costs has to be transformed by the discount rate to one actual value of investment costs for the base year. Then the total annual cost of IVSS is the sum of the annual running costs and the annual capital outlays.

4.6.2.6 Discount Rate

The effects and thus the costs and benefits of Intelligent Vehicle Safety Systems (IVSS) accumulate over the entire useful life of the IVSS. This means that costs and benefits arise at different points in time. For profitability calculations, costs and benefits accumulating over the whole useful life of the IVSS have to be accounted for. In order to be able to compare the effects, which occur at different points in time, the effects have to be applied to a common point in time. Therefore, the starting point of the analysis is determined. The comparability is established by discounting the effects to the same point in time. The costs and benefits occurring in later time periods thereby possess a lower present value. This is justified with the time preference of society: The value of the benefits is the higher, the sooner the benefits arise. Vice versa, the value of the benefits is the lower, the later the benefits arise.

For the establishment of a comparability concerning the time, a decision about the applicable discount rate is required. In the research literature concerning Benefit-cost-Analysis exists an intensive discussion about the choice of the optimum discount rate (Hanusch, 1987, p. 93). The controversy continues to this day. A concrete suggestion about the “right” discount rate does not exist to date:

- Sometimes it is tried to identify a social rate of time preference. The social rate of time preference expresses the willingness of society to abstain from present consume in favour of consume in the future. However, such a social rate of time preference is hardly to determine. It is not corresponding with the time preference of individuals, which is higher. The individual is not prepared to renounce from the consumption of public investments to such an extent, which he is prepared to renounce for private investments.
- As an alternative, the social rate of opportunity costs can be used, which is easier to determine. The social rate of opportunity costs represents the total possible return, which could be achieved, if instead of the planned investment the next best investment alternative would be realized. It can be described with the long-term investment rate, with the interest rate of government loans or with the rate of return for private investments. The use of the social rate of opportunity costs can be seen critically, because it is very difficult to find a representative rate for IVSS.

Thus, there exists no definition of an objective and “true” interest rate for the present value of social costs and benefits. The choice of a social rate is ultimately a normative and political decision. In order to allow for these inevitable uncertainties, the cost and benefit flows can be calculated with different discount rates (e.g. 3%, 5%, 8%). By this means, the sensitivity of the results can be tested and it can be examined, to what extent the IVSS remain beneficial to society or not. The more stable the results are, the more trustworthy are the profitability calculations.

4.6.2.7 Risks and Restriction in the Benefit-Cost Ratio

The cost and benefit flows, which are at the bottom of profitability calculations, are expected outcomes, which might not be realized in the estimated magnitude. Benefit-cost-Analyses are therefore estimations under uncertainty. In calculations of social cost-effectiveness, there is no risk comparable to private investments (e.g. market and competition risks of the entrepreneur, insolvency). Anyhow, also concerning public investments, wrong decisions and surprises occur. Regarding IVSS, these can be for example lower market penetration rates as estimated, changes in the road traffic situation or shortcomings in the technology so that the efficiency in avoiding accidents is diminished. Besides these risks, there can arise reluctance against the application of IVSS. The resulting question is, how such risks and restrictions can be adequately allowed for in Benefit-cost-Analyses and what kind of modifications and supplements can be introduced.

In order to take these risk components into account, different measures can be employed:

- Costs and benefits can be calculated with minimum and maximum values. By this means, an optimistic and pessimistic scenario can be developed.
- The discount rate can be extended with a risk premium (e.g. 0.5 or 1.0 %). This influences the present value of costs and benefits. They become lower, the further they occur in the future. Furthermore, the risks can be considered by calculating with different discount rates.

The implementation of IVSS can be opposed by material, institutional or political restrictions (Eckstein, 1961: 439):

- Technological reasons for obstacles can exist, if for example technical failures or safety problems of the IVSS occur. The introduction of the applications under these circumstances is connected with too much risk. A comprehensive implementation cannot take place.
- Legal constraints can arise, if the legislative framework (including liability issues) for the application is not defined. In this case, the legal deficits are opposed to a market introduction.
- Administrative restraints become effective, if the necessary capacities in the concerned authorities are not available, which are needed for planning, implementation and control.
- Distributional restraints exist, if a measure has socially unbalanced effects. This can lead to significant acceptance problems in the public awareness. This could be the case, if mainly high-income-groups benefit from IVSS and low-income-groups are discriminated. Then, the applications are not enforceable in the political process.
- Financial constraints can occur, if the measures are too expensive compared to the economic benefits they cause. In this case, there would be no significant market penetration.

The above stated restrictions are not immediately integral part of the Benefit-cost-Analysis. However, these restrictions are normally reflected in smaller efficiencies, lower Benefit-Cost-Ratios and reduce the profitability of an application. Political decision-makers, which orientate themselves at Benefit-cost-Results, should be explicitly informed about existing risks and restrictions. This should take place in form of a qualitative comment to the Benefit-cost-Analysis, which should be added to the calculations. This comment should address aspects, which cannot be included in Benefit-cost-Analyses.

4.6.3 Multi-Criteria Analysis (MCA)

4.6.3.1 MCA Technique

The general objective of multi-criteria analysis is to establish preferences between options by reference to an explicit set of objectives. The objectives have to be identified by the decision making institution. Furthermore, it is necessary that measurable criteria are defined to assess the extent to which the objectives have been achieved. Contrary to CBA MCA offers a number of ways of aggregating the data on individual criteria to provide indicators of the overall performance of options. Therefore, a lot of multi-criteria analysis techniques exist.

All different multi-criteria analysis techniques make the options and their contribution to the different criteria explicit, and all require the exercise of judgment. They differ however in how they combine the data. Formal MCA techniques usually provide an explicit relative weighting system for the different criteria.

MCA techniques can be used for following evaluation tasks:

- identification of one single most preferred option,
- ranking of options,
- selection of most promising options for a further detailed assessment of the short-list,
- distinction between acceptable and unacceptable options.

The main limitation of MCA is that the results of the weighting process give no indication of an option adds more to welfare than it detracts. In contrary to CBA there is no rationale, which leads to a final judgment that welfare is improved or not. That means that the best option given as MCA results can be inconsistent with improving welfare. The MCA gives the decision maker the indication that within his assessment scheme an option is preferable, but from an overall societal point of view the option might be not preferable, if welfare is not improved.

Within the MCA the main feature is the performance matrix (consequence table). Each row stands for an option and each column describes the performance of the options against each criterion. The individual performance assessments are often numerical, but may also be expressed as 'bullet point' scores, or color coding.

In a basic form of MCA this performance matrix may be the final product of the analysis. The decision makers are then left with the task of assessing the extent to which their objectives are met by the entries in the matrix. Such intuitive processing of the data can be speedy and effective, but it may also lead to the use of unjustified assumptions, causing incorrect ranking of options. In analytically more sophisticated MCA techniques the information in the basic matrix is usually converted into consistent numerical values. Therefore the weighting and scoring procedures play an important role within the MCA.

Scoring means that the expected consequences of each option have to be assigned to a numerical score. The numerical score reflects the strength of preference for each option for each criterion. The result is that more preferred options have a higher score on the scale than less preferred options. An usual scale is from 0 to 100. With 0 as least preferred option and 100 as most preferred option.

Weighting is assigned to each criterion of an option. The weight of a criterion express how favoured the criterion is. The weighting process can lead to the result that low scores of a criterion become more important if the weight for this criterion is higher than the weight of a criterion with a higher score. That means that with the weighting process compensatory effects are possible.

4.6.3.2 Inclusion of CBA-Results in a MCA-Framework

Due to the evaluation perspective CBA and MCA are evaluation techniques which are appropriate for IVSS.

The advantages of CBA in brief are:

- Gains and losses to all members of society are considered.
- Using monetary terms for evaluating the impacts of a measure can therefore in general point out that introducing IVSS is worthwhile relative to do nothing.
- The monetary values allow a ranking of different technologies.

The main limitations of CBA are:

- Impacts of a technology might exist which cannot readily be quantified in monetary terms (e.g. level-of-service benefits, comfort benefits).
- Distributional impacts of IVSS cannot be assessed. The distribution of costs and benefits among stakeholders is not taken into account.
- There is no distinction between private and public benefits and costs.
- Macro-economic effects (e.g. growth, employment, productivity gains) are not considered.
- The focus on resource savings does not allow incorporating interaction effects. For example, the comfort judgment of users can lead to a preference for a technology which is not justified by CBA.

In these circumstances MCA might be useful. General MCA incorporates the results of CBA. But then the other effects are added. Other effects might be the contribution to other objectives (e.g. user comfort, spatial effects, level-of-service effects). Weight and scores are assigned to the results of CBA and to the other considerable effects. With that a ranking of different measure is possible using an explicit weighting scheme.

However, the main problem of MCA is that a wide variety of techniques for weighting and scoring exist (e.g. direct analysis of the performance matrix, multi-attribute utility theory, linear additive models, hierarchy models, outranking methods, fuzzy set techniques). MCA might produce ranking by considering non-monetary impacts, distributional effects, macro-economic effects and comfort effects, but these effects are incorporated by a weighting scheme, which at least depends on the subjective judgment. Obviously, the limitations of CBA cannot be overcome by MCA in objective, trustworthy and reliable manner.

Comparing CBA and MCA leads to the judgment that CBA is a unified and standardized technique with clear assumptions and assessment rules, whereby MCA covers a wide range of quite distinct approaches.

From an overall evaluation standpoint it can be concluded that CBA is a preferable method for assessing IVSS, because it provides an undisputable methodological background, the absence of a weighting schemes lead to objective results and the calculation procedure within CBA can be used for other evaluation methods. The CBA can provide input to the financial analysis, the cost-effectiveness analysis, the break-even analysis, the business case calculations and also to a multi-criteria analysis.

The overall recommendation is that evaluation of IVSS should be performed by CBA. However, knowing the limitations of CBA, the CBA can be accompanied by additional evaluation procedures, which mainly should focus on following aspects:

- Identification of the benefits and costs for the various stakeholders, because then it is possible to identify those benefits provided in the form of private goods (which should be financed by the individuals) and public goods (which should be financed by the public sector).
- Especially for IVSS evaluation the break-even analysis for system users has to be considered, because the break-even analysis delivers information on the reachable user acceptance. With that also information is provided which can fit into business case calculations.
- Furthermore, to guarantee that CBA will fulfil the criteria of verifiability, efficiency of the evaluation procedure, trustworthiness, representative data, and transparency sensitivity calculations have to be performed and the validity of assessment procedures and results have to be proven.

4.6.4 Evaluation Methods for Stakeholder

4.6.4.1 Objectives of Stakeholder Analysis

The socio-economic assessment of IVSS evaluates the macro-economic cost effectiveness, which results from different costs and benefits of these applications. In order to foster the market introduction of such applications, it is important, to analyse benefits and costs with respect to their distribution between the different stakeholders, which have an interest in the market introduction of IVSS or which are affected by these measures.

There are different stakeholders for IVSS: road users (users of ICC-Applications), manufacturers (OEM) and the society, which is affected by less resource consumption (accidents, environment).

For new technologies like IVSS certain scepticism exists concerning their implementation and diffusion. This can be attributed to uncertainties among the different stakeholder-groups:

- The manufacturers do not know, whether the production of IVSS is profitable for the business. On the one hand, higher production costs result due to IVSS, which can reduce the sales volume. On the other hand, IVSS also mean quality improvements, which can raise the sales quantity. Eventually, cost increases and image losses can occur, for example due to technical defects or possibly necessary call-backs. All in all, IVSS pose an economical risk for the manufacturers.
- Important for the users is the question of the individual profitability. Due to IVSS, higher purchase costs originate. This has to be seen alongside possible cost reductions (e.g. cheaper insurance rates, smaller operational costs of the vehicle) and an improvement in comfort. The question is, whether the individual benefits exceed the costs and therefore profitability for the car user is given.
- The state has to set certain standards for the introduction of IVSS, possibly also authorizations for particular applications or other promotional measures (e.g. tax reductions). In order to be able to make a decision concerning this issue, knowledge about the benefits for society is inevitable. To this benefit components belong the external costs (accidents, carbon dioxide emissions, pollution), which are reduced because of less accidents due to IVSS.

The Benefit-cost-Analysis displays the societal profitability only jointly for all impact components. Which kind of benefits result for the different stakeholder groups is not transparent in a conventional Benefit-cost-Analysis. Such a differentiated display of the benefits for the different stakeholder groups should be carried out in order to improve acceptance of IVSS. For that purpose, a separate breakdown of the Benefit-cost-Analysis is necessary:

- The benefits of the users are the individual savings of internal costs (operational costs of the vehicle, time savings). Likewise, accident costs are relevant for the road users. They possibly overlay with the benefits of the society as a whole. Provided that the accident reductions result in a reduction of insurance rates, the benefits for the user are taken into account.
- The benefits for the society consist of accident reductions (number of accidents and accident severity). These reductions lead to a smaller loss of economic output. Besides that, as a result of the reduction in accidents, less time losses and operational costs of cars emerge.
- The benefits for the manufacturers result from increases in business volume and revenues due to the sale of IVSS. These benefits are not part of the Benefit-cost-Analysis, but must be identified beyond the scope of the Benefit-cost-Analysis in separate calculations. For that purpose, market penetration rates of IVSS, prices for IVSS as well as production costs of IVSS have to be known.

4.6.4.2 Break-Even Analysis

Break-Even Analysis is used to determine the point at which neither profit nor loss is made. This point is called break-even point. BEA contrary to CBA focuses on the private benefits and costs for different stakeholder. The need for BEA is based on the fact 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 IVSS depends at least

- on the general acceptance of the system users and their willingness-to-buy IVSS and further
- on the willingness of OEM to introduce IVSS, whereby the willingness-to-introduce depends on the rentability proof for IVSS.

Although the methodological concept of the break-even analysis for system users and OEM is the same, the proceeding is different.

BEA for System Users

Crucial points for the BEA of system users are

- the identification of the reference base, which determines the realization of benefits coming up from the usage of IVSS and
- the definition for which time period the BEA should be accomplished.

For the identification of the **reference base** it is necessary to identify the user benefits of IVSS.

Similar to the CBA the system users will have benefits due to saving costs. That means the system user compares his situation with IVSS (with-case) to the situation without IVSS (without-case). However, these benefits as result from cost savings are:

- accident cost savings, whereby only the uninsured accident costs has to be considered;
- insurance premium savings, because of the overall positive effect of IVSS on road safety;
- vehicle-operating cost savings, because of better traffic conditions fuel savings might be possible, hereby in contrary to the CBA the savings of fuel tax spendings have to be considered;
- time-cost savings, because of the effects of IVSS on the traffic flow.

Beneath that IVSS induced cost savings the system users will also have additional benefits like comfort benefits. But the total amount of all benefits depend on the frequency a driver will use his vehicle. The best unit to measure this frequency of usage is the number of vehicle-kilometres per year.

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 IVSS costs cover following positions:

- the expenditure for IVSS and
- operating and maintenance costs for IVSS-components.

For the final assessment it is necessary to convert the costs and benefits into present value. At this stage the **definition** for which **time period** the BEA should be accomplished is relevant:

- If the BEA is performed on an annual basis then only the expenditure for IVSS has to be discounted to identify the present value. The other benefits and cost components represent annual values; therefore they have not to be discounted.
- If the BEA is performed for example for the average age of the vehicle fleet, then all future benefits and costs have to be discounted to identify the present value.

Discounting to get the present value 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 IVSS.

The choices of the interest rate and the life-cycle have a decisive influence on the amount of the annual benefits and 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 IVSS. Then, the annual costs for the user of IVSS are the sum between annualised investment costs and discounted operating maintenance costs.

The annual costs of IVSS 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 depending on the number of vehicle-kilometres. Figure 39 gives a schematic overview over the determination of the break-even point. The interpretation of the diagram is as follows:

- For the case that the BEA is done for one year, the diagram gives following indications: A driver with vehicle-kilometres at point A will realize the maximum net savings of IVSS represented by the green triangle. The fixed costs (=expenditure of the system user for IVSS) feed in as discounted values, the variable costs and the benefits are not discounted, because the represent annual values. (Example: With A = 40,000 kilometres as total annual vehicle-kilometres of a driver, the break-even point will be reached within the first year at 10.000 kilometres.)
- If the BEA is performed for the lifetime of a vehicle the point A represents the vehicle-kilometres driven over the whole lifetime of the vehicle. All benefits and costs have to be discounted and feed into the diagram with their present values. (Example: A represents 320,000 kilometres, which will be driven over the whole lifetime of the vehicle. The lifetime is assumed to 8 years. That means the annual average vehicle-kilometres are 40,000 kilometres. The break-even point will be reached at 80,000 kilometres. That means for this example the break-even point will be realized after two years. The maximum of the net savings is reached after 8 years.)

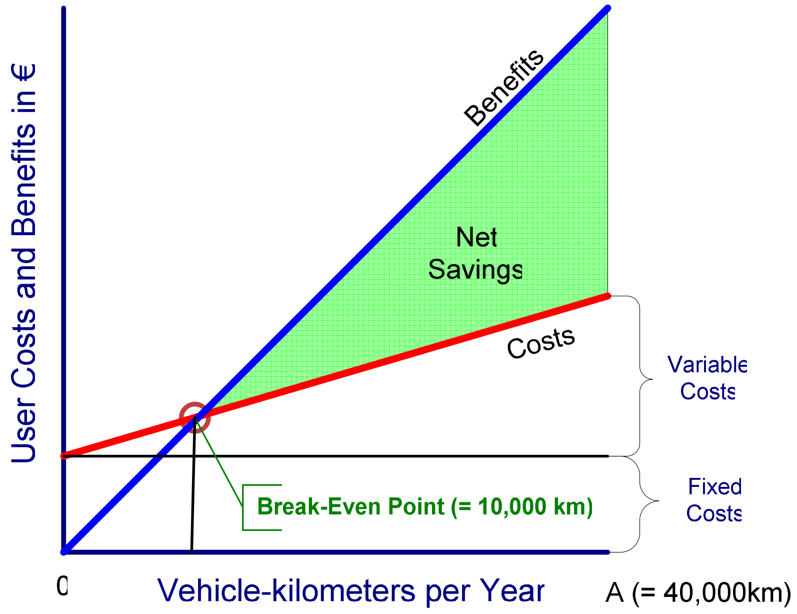

Figure 39: Break-Even Diagram for System Users (author´s presentation)

Break-Even Analysis for OEM

The BEA for OEM is normally used as an internal economic evaluation to prove, if IVSS market introduction can be justified under following objectives:

- Finding a pricing policy to achieve the rentability of IVSS,
- Increasing the market share or sale profits by adding-up the value of car due to IVSS.

Furthermore, determining the break-even point for IVSS can be seen as a starting point for the efforts of OEM to reduce IVSS-production costs. That means that the OEM due to his rentability objective is interested in lowering continuously the break-even point for IVSS.

Like the BEA for the system users the OEM have to confront their benefits with the costs of IVSS. 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 IVSS 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 IVSS,
- Production costs for IVSS,
- Other IVSS related costs.

The research and development costs for IVSS 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 IVSS. Uncertainties definitely exist for the position “Other IVSS related costs”. This cost position covers all kind of expenditures, which are caused by IVSS. The most relevant cost types in this category are following:

- Requirements for compensation of IVSS-users because they suffered from IVSS malfunctions,
- Costs of call-back campaigns because of the technical complexity of IVSS.

Both cost positions are directly linked to the technological complexity of IVSS and the inbound risk of system malfunction. For this background the separate risk evaluation is quite an evident assessment, which can clarify to which extent malfunctioning of IVSS 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 IVSS than requirements for compensation.

The fact that the BEA will be regularly undertaken before the market introduction of IVSS will take place leads also to uncertainties on the side of the potential benefits. The sales profits of IVSS depend on the market acceptance, which is linked to the benefit-cost-effects for IVSS-user. At this stage it is important for the OEM that they know the break-even points of potential IVSS-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 IVSS 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.

The following figure shows a diagram for the break-even analysis of OEM.

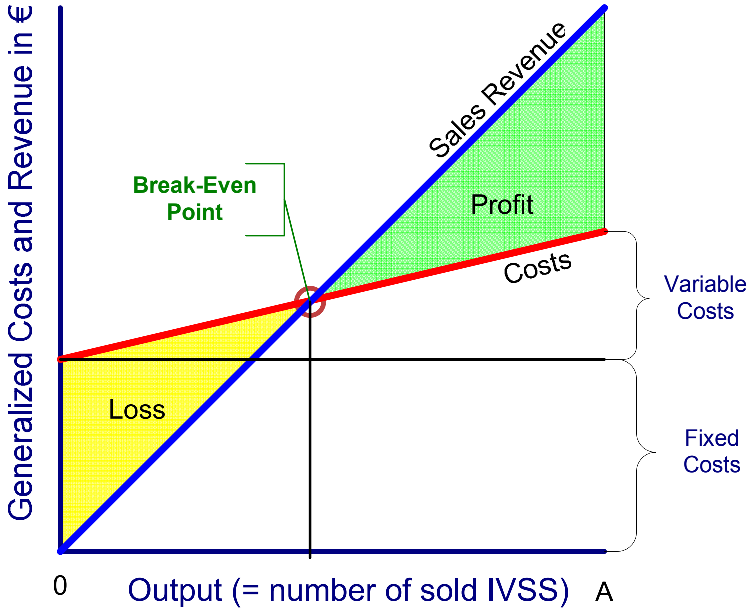

Figure 40: Break-Even Diagram for OEM (author´s presentation)

Fixed costs are those business costs that are not directly related to the level of production or output. In other words, even if the business has a zero output or high output, the level of fixed costs will remain broadly the same. Examples for fixed costs are: rent and rates, depreciation, research and development, marketing costs, administration costs.

Variable costs represent payment output-related inputs such as direct labor costs, raw material costs, maintenance costs, warehousing costs, transport costs.

The sum of fixed costs and variable costs has to be confronted with the revenues, which depend on the number of sold intelligent vehicle safety systems. The break-even point represents that realized revenues are equal to the costs of OEM depending on the number of production output. The break-even point corresponds to a payback period. Therefore, the OEM has to determine the period in which his IVSS production number is equal to the output number determined by the break-even point. If the production of the OEM exceeds the break-even output, the OEM will realize profits. If the OEM is not able to reach the break-even output, the intelligent vehicle safety systems lead to a loss.

4.6.4.3 Financial Analysis

The Financial Analysis (FA) is a technique to measure the impacts on the financial expenditures, revenues and fiscal cash flows of the acting public institution. The Financial Analysis can be seen as decision tool for public institutions. The introduction of IVSS can be supported by the public authorities in different ways, whereby the spectrum of policy intervention lies in between a hands-off approach and strong interventions. Flexible and voluntary measures for IVSS can be voluntary initiatives, codes and standards, letters of commitment, memoranda of understanding. Formal and more command and control instruments can be legal agreements, performance agreements, economic instruments (for example incentives like vehicle tax reductions for vehicles with IVSS or penalties like higher taxes for vehicle without IVSS), and regulations.

Normally, the intensity of public interventions is related to the budget of the relevant public authority. Therefore, the relevant institutions in the field of introducing IVSS need information on the income and expense coming up from policy interventions to support IVSS.

With the FA it is possible to find out the impacts on its own budget and on public expenditure. Within a first step a regulatory impact assessment has to be performed to value the administrative costs of any measure accompanying the introduction of IVSS. With that information is provided if cash outflows due to public supporting measures are kept within the limits of available financial resources.

In a second step possible income effects have to be counted. Contrary to the CBA taxes play now an important role, because the effect of any measure on the public tax budget has to be taken into account. How the tax budget is affected depends on the choice of economic instruments. For example, in the case of incentives by reducing taxes for IVSS-equipped vehicles the tax budget will be lowered. Otherwise penalties will lead to tax increases. The information how the public tax budget is affected can be used as recommendations for the allocation of the tax budget between public institutions.

Additionally, the introduction of IVSS will have price effects for vehicles. These price effects have a further impact on other taxes like the added-value tax (VAT) or taxes on profits. This additional fiscal cash flow has also to be taken into account within the FA.

If the impacts of any supporting measure are spread over future years, the net impacts in each year need to be discounted to a present value. This procedure applies equally to CBA.

FA and CBA together enable the proof if supporting measures are appropriate in terms of welfare. The FA gives information on the expenditure for public interventions. The CBA provides the information on the resource savings. The general rule is that the difference between expenditures and income of any public intervention should not exceed the resource savings. Therefore, the FA can be used also as a decision tool for the choice of the efficient public intervention strategy.

4.6.4.4 Business Case Analysis

The formulation of a Business Case for IVSS should be normally preceded by OEM. Obviously, each OEM might have own concepts and techniques for constructing a good business case. Due to competition reasons the willingness of OEM to publish their business case will be low.

However, to calculate a Business Case within the evaluation of IVSS might be useful to identify possible obstacles and barriers for the introduction of IVSS on the side of the system provider. The purpose is to provide a more comprehensive discussion of the market introduction possibilities for IVSS. These market insights could be helpful for the public authorities for their choice of supporting actions to introduce IVSS.

Within the proposed IVSS assessment methodology a Business Case Analysis can be performed based on the market deployment scenarios, the CBA and the break-even analyses for both system user and OEM.

- The market deployment scenarios show how different market penetration strategies will change the ratio of IVSS-equipped vehicle. On this basis it is possible to determine on average the reachable market shares of OEM for IVSS-equipped vehicle.

- The CBA delivers information on the system costs, which feed into the BEA of OEM and system users, and furthermore the cost savings of system users, which are also an input for BEA of system users, are calculated.
- The break-even analysis for the system users provides information on the break-even points of potential IVSS-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 IVSS 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. With that it is possible to determine the likelihood of different market penetration strategies.
- Within the break-even analysis for the OEM the given information of system costs is used and other risks (for example product liability risks, financial risks of a call-back campaign) were monetarized to determine the payback period.

Based on these information's it is possible to derive different business case scenarios. For each business case scenario it is necessary to calculate the return on invested capital (ROI := return of investments). The ROI can be expressed as a ratio or as a percentage where the return-to-investment ratio is multiplied by 100. Example: a 1.7, or 1.7:1, or 170% ROI are numerically equivalent.

4.6.5 Macro-Economic Effects

Besides cost savings due to improved traffic processes, IVSS affects macro-economic impacts. These impacts are important for the evaluation and political acceptance of IVSS and can serve as an argument in favor of an introduction of IVSS. In a CBA only the savings in resource consumption due to the application of IVSS are determined and compared with the costs of the systems. The macroeconomic impacts are thus not included in a CBA. The macroeconomic impacts have to be analysed in additional calculations and should constitute the basis of the system appraisal together with the CBA. The following macroeconomic impacts are discussed: increase of production value, increase of income, increase of employment.

4.6.5.1 Production Effects

The application of IVSS creates an increase in the production value. This increase results, because the systems are produced and are build in the vehicles. Thereby, an added value is accomplished. Additionally, an increase in production occurs, if infrastructure has to be extended.

The macro-economic production increase due to IVSS is measured with the gross production value. The gross production value includes the turnover of the Original Equipment Manufacturer (OEM) valued at basic price including the purchases, i.e. supplies, of other companies (= inputs). The gross production value includes primary direct and indirect effects, which arise at the OEM and the supplying companies. Furthermore, secondary (= induced) effects occur, which result from the consumption of the increased income of the primarily employed.

The quantification of the impacts on production is carried out on the basis of enquiries about the expenses (= investments and continuous costs) of the OEM. The impacts on the production of the supplying companies can be calculated with the help of Input-Output-Tables. These tables present the integration of goods flows and services flows between the economic sectors of a national economy. For each economic sector it is analysed, which goods and services in which quantity serve as an input to the production of this sector (type and amount of input) and which goods and services in which quantity are produced in this sector (type and amount of output). Input-Output-Tables are provided by official statistical sources for selected years.

4.6.5.2 Income Effects

In order to estimate the impacts of IVSS on economic welfare, the effects on income present a more precise measure than the production effects. The calculations cover income from entrepreneurial activity as well as from dependent personal services. The income effects are deducted from the production effects with several calculation steps:

Production Value

\- Inputs

= Gross Production Value

\- Depreciation

= Net Production Value

\- Taxes

\+ Subsidies

= National Income

The national income is available for the payment of wages from dependent personal services, income from entrepreneurial activity and income from capital. The empirical data for the calculation of income effects have to be identified with the help of inquiries at OEM of IVSS and their suppliers. They are the result of paid wages, calculated interests and business profits.

4.6.5.3 Employment effects

From a political point of view, the most interesting macro-economic impact resulting from the application of IVSS are the employment effects. The employment effects result from production and maintenance of IVSS (including inputs). The employment effects of IVSS can be deducted from the production effects with the help of macro-economic parameters. For a determined gross production value which results from the production of IVSS, the employment effects can be calculated using sectoral labour coefficients. The sectoral labour coefficients for the different economic sectors specify how many employees are needed to generate a certain unit of gross domestic product. The sectoral labour coefficients are published in official statistics. By multiplication of the sectoral labour coefficients with the gross domestic product generated, the number of employees can be calculated.

4.6.5.4 Empirical results

Until now, there exist no systematic studies about the macro-economic impacts of different IVSS. The importance of new technologies for economy and employment is sometimes pointed out in the literature, but mainly with qualitative statements. This applies also for the aspect, that for the production of such systems highly sophisticated jobs are needed.

In a German study, first rough estimations of the employment effects of IVSS (Early Braking and Basic Warning Functions) have been carried out (CarTALK, 2004). In this study a realistic spectrum between worst case and best case has been determined. The worst case has been defined for a Basic Warning-System (market penetration = 10 %) and resulted in 1,800 additional jobs. In the best case of an application of an Early Braking-System (100 % market penetration) 28,000 additional jobs have been calculated for the European Union of 15 member states. The analysis has been based on average parameters. The result does not yet allow for generalization. The empirical research concerning macro-economic impacts of IVSS has to be intensified.

In such analyses, the ambivalence of the employment effects has to be considered. New systems effect additional employment in development and production. However, new solutions in vehicle construction can also make certain conventional vehicle parts disposable, so that a reduction of employment is the consequence. Generally it can be stated, that product innovations show a tendency to affect employment increases, while process innovations show a tendency to cause a decrease in employment.

4.6.6 Distribution of Income

4.6.6.1 Distributional effects in macroeconomic efficiency analyses

For the political acceptance of IVSS and therefore for the implementation chances of IVSS, the social effects possess substantial relevance. The social effects address the fact, that the costs of a measure burden certain social classes, while others benefit from the measures. In such an analysis it is examined, how the effects of IVSS affect the income distribution of the user groups. It should be answered, which income groups – the “rich” or the ”poor” – benefit from IVSS. The political acceptability rises, if the systems contribute to a better social balance and lower income groups derive the larger benefits from such systems.

Such effects on the income distribution are until now largely unexplored for new technologies in the transport sector. Merely on a theoretical basis, it is postulated for macroeconomic profitability analyses, that such distributive impacts are considered in the final conclusions.

The traditional Benefit-cost-Analysis abstains explicitly from the consideration of distributional effects. The question of who is burdened with the costs of implementing the system and who benefits from them is beyond the scope of the approach. Benefits, which accrue to high-income-classes, are rated similar to benefit gains of low-income-classes.

Such an approach is only sufficient, if the existing income distribution in a society is regarded to be optimal. That cannot be assumed. Indeed, inequities in the income distribution have to be determined. Taking this into consideration, the traditional profitability analyses are insufficient, since social aspects are excluded.

Therefore, extended efficiency analyses are required, in which distributional impacts are considered. For this purpose, two questions have to be treated:

- The income effects of an IVSS have to be allocated to individual members (or member groups) of society.
- It has to be determined, how the distribution of incomes among the members of society ought to be, that means which distributional effects are desired or undesired from a society’s viewpoint.

The methods of analysing distributional impacts are examined below. In doing so, first empirical statements about the distributional effects of IVSS are derived.

For the determination of the distributional impacts due to the application of IVSS, the benefit flows and the cost flows have to be allocated to the different income groups. From the balance of benefits and costs of an income group, the effects on the individual income distribution per household results. Depending on type and design of IVSS, different burdens and relieves can arise.

4.6.6.2 Impacts of IVSS

IVSS contribute to an increase in traffic safety and to a reduction of accident costs. This is reflected in a decrease of production losses and social welfare losses due to disability, a decrease of medical treatment costs, property damage costs and administrational costs of insurance companies, costs of jurisdiction and police costs. The increase in traffic safety thus reduces the loss of resources for the economy and the associated decline of productive capacity. A higher social product and thus a larger social income, which can be distributed, are the consequence. These are the benefits of IVSS.

In order to identify the impacts of IVSS on the individual income distribution, knowledge about the total benefit sum and the constituent benefit components is not sufficient. Furthermore, it has to be determined, how the effects, which result from the increased traffic safety, are distributed among the different income groups of households. It has therefore to be examined, which income groups finance the deployment of IVSS and which groups capitalize on the deployment of the systems.

4.6.6.3 Withdrawal effects due to the costs of IVSS

Initially, the effects of financing the IVSS have to be analysed:

> It can be assumed, that mainly automobiles of the upper class (luxury class and upper middle-sized class) are equipped with IVSS. Especially newly developed technologies are initially offered in automobiles belonging to the upper class. In the private passenger car segment, first of all these households will dispose of cars equipped with IVSS, which receive rather high incomes and are therefore able to afford upper class vehicles. The households with higher income thus contribute to the financing costs of IVSS to a large extent.
>
> In commercial road transport respectively goods transport it is questionable, whether the costs of IVSS are borne by the owners of the vehicles. The costs for IVSS first accrue when the vehicle is purchased. In commercial road transport respectively goods transport it is however possible, that the financing is handed on to subsequent groups:

- The financial burden can be allowed for in the final products and services of the companies and can thus raise prices. In this case, the financial burden is spread among the households according to their consumer behaviour.
- The costs of IVSS can also remain at the companies, which use the systems, and can by this way reduce profits. This would reduce the profit distribution to shareholders. There is a general tendency that profits from entrepreneurial activity accrue to private households with higher incomes. This would mean that higher income-groups would in this case contribute more to the financing of IVSS than households with low incomes.
- It is also possible, that the financial burden caused by IVSS is passed on from the companies to the employees with means of wage reductions. In this case, the costs are paid by all income groups according to their occupation, since the income from employment is reduced.

It is indicated, that a substantial part of the financial burden of IVSS is borne by the owners of the vehicles themselves (especially in private transport). However, in commercial road transport respectively goods transport there is the possibility to pass the costs on to private households. To what extent the cost effects will be handed on crucially depends upon the market situation of the companies. If it is a market with active competition, the companies will more probably refrain from a transfer of the costs in order to gain a price advantage compared to competing companies. If it is instead of that a market with low competition, the companies are in a better position to pass the costs on at least partially by increasing the prices for transport and goods.

4.6.6.4 Income relieves due to IVSS

Besides the question, which income groups finance the IVSS, it has to be clarified, how the income relieves (Benefits) resulting from the application of IVSS are distributed among the income groups. In this context, the effects of IVSS on the improvement of traffic safety and the avoidance of accidents come to the fore. The accident costs are composed of personal damage costs (production costs and costs from lost resources) and property damage costs (vehicle and goods damages). From a reduction of accident costs, mainly the owners of those vehicles draw profits, whose vehicles are equipped with IVSS. These vehicles are less affected by accidents and can therefore profit directly from the reduction of accident costs. Beyond, additional benefits account for other groups, who do not possess an IVSS on their own:

The owners of an insured vehicle draw a benefit from a reduced amount of loss, which is borne by the insurance companies. A reduction of the amount of loss can be reflected in a reduction of the insurance rates for the insurance of the vehicle. Thus, the cost reductions can be passed on partially or totally to the insured people. Private as well as commercial transport profit from a reduced insurance rate in equal measure:

- In the case of private transport, the different income groups benefit according to their respective insurance contributions. Since higher income groups normally also pay higher insurance rates (households with more expensive cars or more than one car), the rate relief would benefit them more than the lower income households.
- Concerning commercial road transport (transport of goods and people), the question is – comparable to the situation regarding the costs of IVSS – whether the effects are passed on. Depending on the market situation (e.g. stress of competition), the companies pass on the relieves totally or partially to their customers respectively the end-consumer. Here the different transfer scenarios outlined above are possible.
- It is furthermore possible, that the relieve effects of the insurance companies are only passed on to certain member groups. This is the case, if the insurances grant rate reductions only certain insured people, by granting reductions only for e.g. the insured people, which own vehicles with IVSS. In this case, the total benefits due to avoided property damages of vehicles would accrue to the owner of vehicles equipped with IVSS.
- In goods transport, the transport companies are additionally relieved in case of avoided accidents, because the contributions for the transport insurance decline. Companies involved in goods transport (e.g. forwarding agents) are usually insured against a destruction of the transported goods and consequential damages. If the number of accidents with damages of the transported goods is reduced, the costs for the insurance company decline as well (from the coverage of damages). Depending on the market situation in the insurance sector, the insurance companies pass on these relieves to the insurants (carriers and shipping agents). The transport companies themselves can hand on the relieves partially or totally to the private households.

A large amount of profits from the use of IVSS accumulates directly at the owners of the respective vehicles. But it is evident, that beneficial effects also accrue to third parties (general public, consumers, income recipients, shareholders, insurants etc.), who are not inevitably involved in financing the costs of IVSS (i.e. they are not owners of a vehicle with IVSS). The subsequent table summarizes the distribution of the beneficial effects at third parties due to the application of IVSS:

Beneficial effect	Where do the benefits incur?	Distribution key	Bearer of beneficial effects
Reduction of personal damage	General public	Distribution according to income share of the household group or Per capita distribution of benefit sum	All households according to income share or All households (per capita)
Reduction of property damage	Private transport	Insurance rates	Insured people or certain groups of insured people (high-income groups)
	Commercial transport	Consumer spending of households Share of the company and assets Income from employment	All households Households with higher income All households
	Goods transport	Consumer spending of households Share of the company and assets Income from employment	All households Households with higher income All households

Table 21: Beneficial effects due to application of IVSS (author`s illustration)

4.6.6.5 Who profits – the poor or the rich?

Due to missing empirical data, only qualitative estimations concerning the distributional effects of IVSS can be made. Further statements regarding the effects of the application of IVSS on individual income distribution necessitate the calculation of benefits and costs, which account for the systems as well as the determination of appropriate distribution keys, which allow an allocation of benefits and costs to different reference units (household groups by income).

It can be stated, that the owners of vehicles, which are equipped with IVSS, bear the majority of the costs as well as they receive the majority of benefits. In the case of private transport, it can be assumed that mainly drivers with many travelled kilometres per year and/or households with high income are concerned. These people will most probably afford such rather expensive vehicles with IVSS. In the case of commercial road transport respectively goods transport, the effects will be totally or partially handed on to subsequent bearers of benefits and costs.

Besides that, direct beneficial effects evolve also at third parties, which do not participate at the costs of IVSS. These beneficial effects consist for example of effects from the transfer of cost savings due to accident reductions from the insurance companies to the insured people (reduction of insurance rates). Another benefit for third parties is made up of an increase in productive capacity of the national economy as a consequence of the avoidance of accidents and personal damage. Particularly households, which do not finance the application of IVSS, benefit from these effects. Low-income households thus receive a part of the total benefits without having to bear the financial burden connected with the use of IVSS.

4.6.7 Sensitivity Analysis

The purpose of the sensitivity analysis is to select the “critical” variables and parameters of the assessment model. Critical variable are those whose variations, positive or negative, compared to the value used as the best estimate in the base case, have the greatest effect on the results (e.g. benefit-cost ratio, MCA score, return on invested capital, payback period, break-even points). Normally, according to the specific evaluation method the critical variables have to be identified case by case. However, for the IVSS assessment methodology following critical variables can be identified:

- Model Parameters (e.g. discount rate)
- Demand data (e.g. number of equipped vehicles, willingness-to-pay values, changes in fuel prices, changes in prices of goods and services)
- Traffic Data (e.g. forecast of traffic volume, vehicle-kilometres, accidents)
- IVSS related data (e.g. accident reduction effect of IVSS)
- Price dynamics, which affect cost-unit rates (e.g. accident costs, time costs, vehicle-operating costs, emission costs, carbon-dioxide costs) and system costs (e.g. investment costs, operating costs, maintenance costs.

In a first step it might be useful to carry out a qualitative analysis of the possible impacts of the variables. This qualitative analysis enables the identification of the most significant variables. Significant variables mean that it can be expected that changes of these variables will have a high impact on the results of the evaluation procedure.

In a second step the influence of the most significant variables should be expressed by a quantitative analysis. Which means that for each selected variable the **sensitivity elasticity** has to be calculated? The elasticity is a metric, which measures the sensitivity or responsiveness of changes. The sensitivity elasticity measures the change in one significant variable in response to a change of the results (e.g. benefit-cost ratio, return-to-investment ratio). The definition of the sensitivity analysis is:

$$\text{Sensitivity Elasticity} = \frac{\text{Percentage Change of Result}}{\text{Percentage Change of Critical Variable}}$$

The sensitivity elasticity can take values between zero and infinite. If the value of the sensitivity elasticity of a variable is in between zero and one, the variable has only a marginal effect on the results and therefore this variable does not belong to the critical variables. Larger elasticity values than one indicate that a variable has to be considered as significant critical.

To come up with a general criterion for the identification of critical variables the significant variation above one has to be defined for each final result. This general procedure is given as example for the benefit-cost ratio:

- Previous studies on IVSS are showing a benefit-cost ratio ranging in between 1 and 10.
- A significant change of benefit-cost ratio can be stated for example as a change from 4 to 5. That means that changes in the first decimal place (for example from 4.5 to 4.6) should not to be interpreted as significant change.
- Considering that the result of CBA for a concrete assessment of IVSS lies in between 1 and 10, it is proposed to consider as critical variables those parameters for which a variation of 1 % gives rise to a corresponding variation of 10 % of the benefit-cost ratio. That means that variables with elasticity for changes of the benefit-cost ratio in between zero and ten are not significant and therefore noncritical.
- For benefit-cost ratios, which lie in between 10 and 20, a critical variable is those for which a variation of 1 % gives rise to corresponding variation of 5 %. That means that the variables, which are significant and therefore critical, must have an elasticity value above five.

The advantage of the elasticity concept is that it provides detailed information, how the final results will be affected by critical variables. The weakness of this concept is that it can be complex and time consuming to accurately calculate the elasticity values for each critical variable. Furthermore, interdependencies between critical variables are not addressed.

Beneath the sensitivity analysis by the elasticity concept the **scenario analysis** can be also used to proof the overall sensitivity of the assessment. In general the baseline case should be accompanied by an “optimistic” scenario and a “pessimistic” scenario. In order to define the optimistic and pessimistic scenarios it is necessary to identify for each critical variable the extreme values (minimum values and maximum values) and furthermore to define for the critical assumptions and hypothesis an “optimistic” and a “pessimistic“ view.

The advantage of the scenario technique is that normally both “optimistic” and “pessimistic” scenarios can be easily constructed, because they use the calculation procedure, which is given by the baseline calculation. Furthermore, interdependencies between critical variables can be considered. The usage of the scenario technique is possible without an exactly specified probability distribution. However, that might be also the weakness of this approach because the occurrence probability for the pessimistic and optimistic scenarios is not given.

5 Exemplary Calculations

The objective of this section is to validate and discuss the proposed methodology using several case studies for selected IVSS. The case studies are focused on passenger cars. The key purpose of these case studies is to demonstrate the workability of the assessment procedure. It must be borne in mind that the socio-economic impact assessment must occasionally cope with data limitations - namely on EU-25 level - which also affect the accuracy of its calculations. The proposed SEiSS methodology thus provides a framework for impact assessment which can be filled according to the level of information available.

The general intention when choosing the exemplary calculations was that promising applications with significant expected socio-economic benefits should be selected instead of niche systems with limited application. Based on this principle, the following IVSS were chosen for the exemplary calculations:

- eCall
- Safe Following – Adaptive Cruise Control
- Lane Change Assistant and Lane Departure Warning

The selected IVSS cover different specifics which are relevant in the context of impact assessment. They address diverse crash-related driving phases as well as different accident types. Furthermore, the market deployment plans are dependent on the specific system. The following table provides an overview of the business and traffic environment for the selected IVSS.

IVSS Criteria	eCall	Safe Following (ACC)	Lane Change Assistance and Lane Departure Warning
Safety Objective	Accident severity reduction	Convenience	Accident avoidance and accident severity reduction
Relevant Accident Types	All	Rear end collisions	“Left roadway” accidents, side impacts, head-on collisions
Safety Mechanism	Faster rescue chain	Distance maintenance	Obstacle and lane detection and interaction with driver
Driver Interaction	Manual and Automatic	Semi-Automatic	Driver
Relevant Driving Situations	---	Longitudinal	Lateral
Crash-Related Driving Phase	Post-crash	Driving – Warning – Assistance	Warning – Assistance
Market Deployment	100%, from 2006 onwards	Introduced, innovation cascade	Introduced in HGV, beginning in cars
Reference Years for Socio-Economic Impact Assessment	Based on 2002	2010 / 2020	2010 / 2020
Geographical Coverage	EU-25	EU-25	EU-25

Table 22: Business and Traffic Environment for IVSS Impact Case Studies (author’s table)

5.1 eCall

5.1.1 Objectives

The first case study chosen to illustrate the capabilities of the proposed benefit-cost methodology was the in-vehicle emergency call system (eCall), which can be defined as follows:.

“The in-vehicle eCall is an emergency call generated either manually by vehicle occupants or automatically via activation of in-vehicle sensors. When activated, the in-vehicle eCall system will establish a voice connection directly with the relevant PSAP (Public Safety Answering Point), this being either a public or a private eCall centre operating under the regulation and/or authorisation of a public body. At the same time, a minimum set of incident data (MDS) will be sent to the eCall operator receiving the voice call.” (eCall MoU 2004)

eCall operates differently to other IVSS because it does not alter the vehicle collision probability, but instead affects the severity of the accident by reducing the rescue time. This means that fatalities could be avoided and that the consequences of such accidents might be reduced to severe injuries. In case of severe accidents, the effect of the reduced rescue time might be diminished accident consequences, resulting in only slight injuries. Finally, the faster arrival of emergency medical services on the accident scene could lead to the fact that some slight injuries can be avoided.

The **primary objective** of the eCall case study is to work out the benefits and costs of eCall implementation at a European level. However, the case study also contributes to the following **secondary objectives**:

- Although, compared to other IVSS, eCall has limited effects on road traffic costs, it can be demonstrated that the proposed evaluation framework is appropriate to derive benefit-cost results (**workability proof**).
- Previous benefit estimations for eCall were carried within the E-MERGE project (E-MERGE 2004) and the eSafety Driving Group (eSafety 2004). A major difference exists between the accident cost unit rates used in these studies and in the present case study. It is therefore appropriate to work out the effects of different monetary terms on the benefit-cost result (**sensitivity proof**).

5.1.2 Analytical Framework

The analytical framework of the eCall case study comprises the following issues:

- The socio-economic impact will be calculated for all current member states of the European Union (EU-25).
- Traffic and CARE-based accident data and the cost unit rates used for assigning monetary values to safety and traffic effects reflect the 2002 situation (base year). This means that the costs and benefits to be calculated indicate the socio-economic desirability of eCall when the system would have been implemented to the total European passenger car fleet in this year (which means: 100 % equipment of passenger cars).
- Additionally, it is assumed that the average age of cars in EU-25 is eight years and that the depreciation period for additional equipment in public safety answering points (PSAP) is 20 years.

5.1.3 Accident Cost Savings

Considering the safety benefits the eCall system leads to a higher efficiency of the rescue chain. When medical care for critically (and severely) injured people is available at an earlier time after the accident, the death rate can be significantly lowered. This is known as the Golden Hour Principle of accident medicine. It expresses that, one hour after the accident, the death rate of people with heart or respiratory failure or massive bleeding approaches 100 %. This is why the rapid reaction of rescue services is very important.

Recently, the E-Merge project approached the issue of lowering rescue times carefully. The E-merge impact estimations, which are based on surveys conducted in different Western European countries, will provide the basis for our calculation of the socio-economic impact. According to E-Merge and the eSafety Driving Group, 5 % to 15 % of road fatalities can be reduced to severe injuries and 10 % to 15 % of severe injuries can be reduced to slight injuries. For slight injuries, no positive effect of eCall was foreseen (E-Merge 2004: 49).

Road accidents lead also to congestion. Due to a shorter rescue time, eCall will also reduce the congestion time, because the faster arrival of rescue teams, police and towing firms enables the accident scene to be cleared more quickly. Additionally, there is a reduction in congestion time of 10% in the low-impact case and 20% reduction in the high-impact case, which must also be considered.

It therefore makes sense to perform the economic evaluation for two cases, which refer to the minimum values (low impact of eCall) and the maximum values (high impact of eCall). The benefit-cost results therefore provides a range between the lowest and highest possible effects of eCall. The following table gives an overview of the effects of eCall on accident severity and congestion time.

Effect on Accident Severity	**Low Impact**	**High Impact**
Road Fatalities changed to Severe Injuries	5.0%	15.0%
Severe Injuries changed to Slight Injuries	10.0%	15.0%
Traffic Effect		
Reduction in Congestion Time	10.0%	20.0%

Table 23: Effects of eCall on Accident Severity and Congestion Time – Low and High impact (E-Merge 2004; eSafety 2004)

Table 24 shows the number of road accidents, the fatalities and the severe injuries for each European member state and aggregated for the EU-15, the new EU-10 and the EU-25.

EU-Member States		Number of		
		Accidents	**Killed People (Fatalities)**	**People with Severe Injuries**
Belgium	BE	47,444	1,486	8,949
Denmark	DK	6,856	431	3,946
Germany	DE	362,054	6,842	88,382
Greece	EL	19,671	1,880	3,238
Spain	ES	100,393	5,516	27,272
France	FR	105,470	7,655	24,091
Ireland	IE	6,909	412	1,417
Italy	IT	204,615	6,314	41,138
Luxembourg	LU	1,016	60	440
Netherlands	NL	42,271	1,090	12,388
Austria	AT	43,175	956	8,043

EU-Member States		Number of		
		Accidents	**Killed People (Fatalities)**	**People with Severe Injuries**
Portugal	PT	41,642	1,655	4,690
Finland	FI	6,196	415	8,156
Sweden	SE	157,96	583	4,058
United Kingdom	UK	227,108	3,431	37,514
Total EU 15		1,230,616	38,726	273,722
Czech Republic	CZ	26,586	1,431	5,520
Estonia	EE	2,164	223	470
Cyprus	CY	2,370	98	578
Latvia	LV	5,083	518	1,033
Lithuania	LT	6,090	697	1,217
Hungary	HU	19,686	1,429	3,959
Malta	MT	1,312	16	212
Poland	PL	53,559	5,827	9,276
Slovenia	SI	10,266	269	2,361
Slovakia	SK	7,866	610	1,777
Total New EU-10		134,982	11,118	26,404
Total EU 25		1,365,598	49,844	300,126

Table 24: Number of Road Accidents, Fatalities and Severe Injuries in EU-25 for 2002 (CARE 2004; IRTAD 2004)

The accident effects of eCall at the European level differentiated for the low and high impact-cases are shown in the following table. It is clear that the reduction potential can be determined for every European member state; however, for reasons of clarity the figures for each European member state are not disclosed.

Effect on Accident Severity	Low Impact	High Impact
Road Fatalities changed to Severe Injuries	2,492	7,477
Severe Injuries changed to Slight Injuries	30,013	45,019

Table 25: Reduction in Fatalities and Severe Injuries by eCall for EU-25 in 2002 (absolute numbers, author's calculation)

The safety and traffic impacts can be assigned monetary values using average cost unit rates which reflect the change in accident severity. As proposed before, the cost unit rates in the following table are used in the first step:

Type of Accident	Cost Unit Rate per Accident
With fatalities	1,000,000 €
Severe injuries	135,000 €
Slight injuries	15,000 €

Table 26: European Cost Unit Rates for Accident Evaluation in Euros per accident – eCall

For the monetary evaluation, it is necessary to use the differences between each type of accidents because fatalities will be changed to severe injuries and severe injuries will be changed to slight injuries. That means the avoidance of one fatality leads to cost savings of 865,000 € (the result of the difference: 1,000,000 € minus 135,000 €) and the avoidance of one severely-injured person leads to cost savings of 120,000 € (the result of the difference: 135,000 € minus 15,000 €).

The achievable accident cost savings are shown in the following table:

Benefits	Low Impact of eCall	High Impact of eCall
Accident Cost Savings	5,700 Million €	11,800 Million €

Table 27: Accident Cost Savings With eCall Based on European Cost Unit Rates – EU-25 (author's calculation)

The E-Merge project and the eCall Driving Group suggest the international cost unit rates given in the following table:

Type of Accident	Cost Unit Rate per Accident
With fatalities	977,000 €
Severe injuries	502,109 €
Slight injuries	93,546 €

Table 28: International Cost Unit Rates for Accident Evaluation in Euro per Accident – eCall

That means that the avoidance of one fatality leads to cost savings of 474,891 € (the results of the difference: 977,000 € minus 502,108 €), and the avoidance of one severely-injured person leads to cost savings of 408,563 € (the result of the difference: 502,109 € minus 93,546 €).

The accident cost savings for these cost unit rates are shown in the following table:

Benefits	Low Impact of eCall	High Impact of eCall
Accident Cost Savings	13,400 Million €	21,900 Million €

Table 29: Accident Cost savings of eCall based on International Cost Unit Rates – EU-25 (author's calculation)

Compared with the accident cost savings calculated on the basis of the European cost-unit rates it can be stated that:

- In the low impact case, the benefits based on international cost-unit rates exceed the benefits based on European cost-unit rates by 135.1%
- For the high impact case, the international assessment exceeds the European assessment by 85.6%

For the sensitivity analysis of both results, we need to compare the cost savings due to fatalities and severe injuries avoided (see following table).

Benefit Components	European Cost-Unit Rates	International Cost-Unit Rates	Difference between International Cost-Unit Rate and European Cost-Unit Rate
Avoided Fatality	865,000 €	474,891 €	-45.1%
Avoided Severe Injury	120,000 €	408,563 €	+240.5%
Arithmetic Mean	492,500	441,727	-10.3%

Table 30: Sensitivity analysis for different cost-unit rates (author´s calculation)

The previous table shows that the international cost-unit rates compared to the European cost-unit rates underestimate the benefits of avoiding fatalities and overestimate the benefits of avoiding severe injuries.

Furthermore, it is clear that the overestimation of benefits for avoiding severe injuries dominates the effect on the total accident cost savings, because the number of avoidable severe injuries is higher than the number of avoidable fatalities (for the low-impact case, the number of avoidable severe injuries is twelve times higher than the number of avoidable fatalities; for the high-impact case the number is seven times higher).

For the sensitivity of the European cost-unit rates, the following average conclusions can be drawn:

- In the case of low eCall impact, a 1% increase in the cost-unit rates for avoided severe injuries will lead to an increase in benefits of 0.6%.
- For the high-impact case, a 1% increase in the cost-unit rates for avoided severe injuries results in a 0.4% increase in benefits.

5.1.4 Congestion Cost Savings

In addition to its effect on accidents, eCall will also have an impact on travel time delays due to congestion caused by accidents. The fact that eCall will reach an equipment ratio of 100% in passenger cars leads first to the conclusion that the congestion caused by every single accident could be affected. On this basis a first estimation of congestion cost savings can be performed, based on following steps:

- Estimation of current time delay costs for accidents: With 1,365,598 accidents in 2002 and an average time cost unit rate for each accident of 15,000 €, the total costs of delays are 20 billion €.
- eCall congestion cost savings: on average, the time delay due to accident congestion is 100 minutes. A 10% reduction of congestion time by eCall will lead to time cost savings of 2 billion €, whereas a 20% reduction of congestion time results in time cost savings of 4 billion €.

However, this calculation procedure gives an optimistic evaluation of the achievable congestion cost savings. It might be slightly unrealistic to assume that eCall can be used successfully for each accident. The assessment of the accident impacts is, for example, more conservative, because only some fatalities and severe injuries are seen as avoidable; not all. It therefore makes sense to have an alternative procedure which mirrors the conservative assessment given by the accident impact analysis.

An alternative calculation of congestion cost savings has to overcome the lack of the official accident statistics. There is no evidence which relates the number of accidents to the number of fatalities or severe injuries. For example, 300,126 people have slight injuries, but the number of accidents which caused this number of casualties is undetermined. 300,126 people could have been injured in 300,126 accidents, but they could just as easily have been injured in just 100,000 accidents. Based on the findings of the accident impact analysis, the following impact of eCall on congestion can be derived:

- At low impact, congestion caused by accidents can be reduced by 15%, which leads to congestion cost savings of 170 million €.
- At high impact, congestion caused by accidents is affected by 30%, which leads to congestion cost savings of 469 million €.

5.1.5 Costs of eCall

The benefits determined must be compared with the costs of system implementation (system investment costs, equipment of PSAP, training costs for PSAP staff).

The equipment rate for passenger cars was assumed to be 100%. That means that 210 million passenger cars must be equipped. The costs for the on-board components of eCall are estimated at between 100 € and 150 €. With a depreciation period of 8 years and a discount rate of 3%, the annuity factor is 0.14. That means that annual system costs are between 3 billion € and 4.5 billion €.

PSAP costs range from 30,000 to 50,000 €. The number of actual PSAP in EU-25 is not given. Therefore, an empirical relationship between the number of PSAP and inhabitants is derived for Germany. This calculation shows that one PSAP is required for every 31,000 inhabitants. This takes the total number of PSAP in EU-25 to 1,500. The depreciation period for the PSAP equipment is 20 years. With a discount rate of 3%, the annuity factor is 0.067. The annual costs for PSAP equipment are between 3 million € (= 30,000 € investment costs per PSAP) and 5 million € (=50,000 € investment costs per PSAP). The training costs for PSAP staff are estimated to range from 300 € to 500 € per staff member. The average number of people working at a PSAP is 60. The annual training costs therefore range from between 27 million € to 45 million €.

Table 31 summarises the results of the cost estimations:

Cost Component	**Minimum**	**Maximum**
System Costs (on-board unit)	3,000 Million €	4,500 Million €
PSAP Equipment Costs	3 Million €	5 Million €
Training Costs	27 Million €	45 Million €
Total	3,030 Million €	4,550 Million €

Table 31: Annual Costs of eCall (author´s calculations)

5.1.6 Benefit-Cost Results for eCall

In a final step, the annual benefits have to be confronted with the annual costs. The results are presented in the following table. To obtain the possible range of benefit-cost ratios, the benefits from a low impact of eCall must be compared with the maximum value of costs which can be expected (= Scenario A) and the benefits from a high impact of eCall must to be linked to the minimum value of costs (=Scenario B). This gives us a range of attainable benefit-cost ratios of between 1.3 and 8.5, which represents the combined consideration of the "pessimistic view" and the "optimistic view" for final recommendations of eCall.

The "pessimistic view", with 1.3 as the benefit-cost ratio for eCall, shows that, even with a low success rate and high cost figures, the introduction of eCall is justified, because the resource savings exceed the costs. This means that eCall would, even under pessimistic assumptions and hypotheses, contribute to the welfare of the EU-25.

The "optimistic view" shows that in the best case, which means that system efficiency is reached and costs are minimised due to economies of scale, society can expect to see a benefit of 8.5 € for every 1 € spent on eCall.

Annual Benefits	**Scenario A**	**Scenario B**
Accident Cost Savings	5,700 Million €	21,900 Million €
Congestion Cost Savings	170 Million €	4,000 Million €
Total Benefits	5,870 Million €	25,900 Million €
Annual Costs	**Scenario A**	**Scenario B**
System Costs	4,500 Million €	3,000 Million €
PSAP Equipment Costs	5 Million €	3 Million €
Training Costs	45 Million €	27 Million €
Total Costs	4,550 Million €	3,030 Million €
Benefit-Cost Ratio	1.3	8.5

Table 32: Benefit-Cost Results of eCall (author's calculation)

5.2 Safe Following – ACC

Adaptive Cruise Control (ACC) will enable the vehicle to maintain a driver-defined distance from the preceding vehicle while driving within a maximum speed limit – again set by the driver. Since the system only functions at speeds between 30 km/h and 200 km/h, it is designed primarily for use on motorways and rural roads. If, however, there is a rapid reduction in the vehicle's speed, the system will warn the driver and switch off to let the driver assume control.

In order to carry out a benefit-cost analysis of the safety impacts of ACC, several different pieces of information are needed:

- The costs of ACC and their equipment rates at a given point in time (here: 2010 and 2020)
- The number of relevant accidents (= accidents, which could possibly be avoided using IVSS)
- The efficiency in avoiding these relevant accidents
- The societal costs of accidents.

The **costs and market penetration rates** were forecast based on market analyses from different research institutes. Additionally, expert interviews were carried out in order to verify the data from the different market studies. These interviews were conducted with two suppliers of intelligent vehicle safety systems and one independent expert. Based on this information, it is assumed that 3% of all cars will be ACC-equipped by the year 2010. By 2020, the diffusion rate will have increased to 8%. The costs are forecast at 750 € per unit in 2010 and 400 € per unit in 2020 (see following table).

ACC (EU-25)	**2010**	**2020**
Vehicle Stock (in million cars)	239.1	261.2
Market Diffusion Rate in %	3%	8%
Consumer Price per Unit	750 €	400 €

Table 33: Equipment Rate and Consumer Price per Unit of ACC for 2010 and 2020 (ProgTrans 2004, author's calculation)

These diffusion rates reflect a very slow diffusion process. Although in 2020, more than 20 million cars will be equipped with ACC, the diffusion will still be below 10%. From an economic point of view, it is obvious that implementing ACC is of greatest benefit to those drivers with the highest vehicle kilometres per year. The reason for this is that the statistical risk of an accident is correlated with vehicle kilometres. Drivers with high vehicle kilometres are therefore more exposed to the risk of an accident than those with lower vehicle kilometres. The ACC performance on roads as a function of market penetration can thus be described as a monotonous increasing function with regressive growth. This is shown in Figure 41 by the solid line. For comparison, the dotted line indicates constant growth (which means linear correlation). The functional relationship shows that about 6% of vehicle kilometres can be reached with 3% market diffusion (scenario A). For 15% of vehicle kilometres, market diffusion of 8% is sufficient. The regressive growth becomes apparent with higher equipment rates.

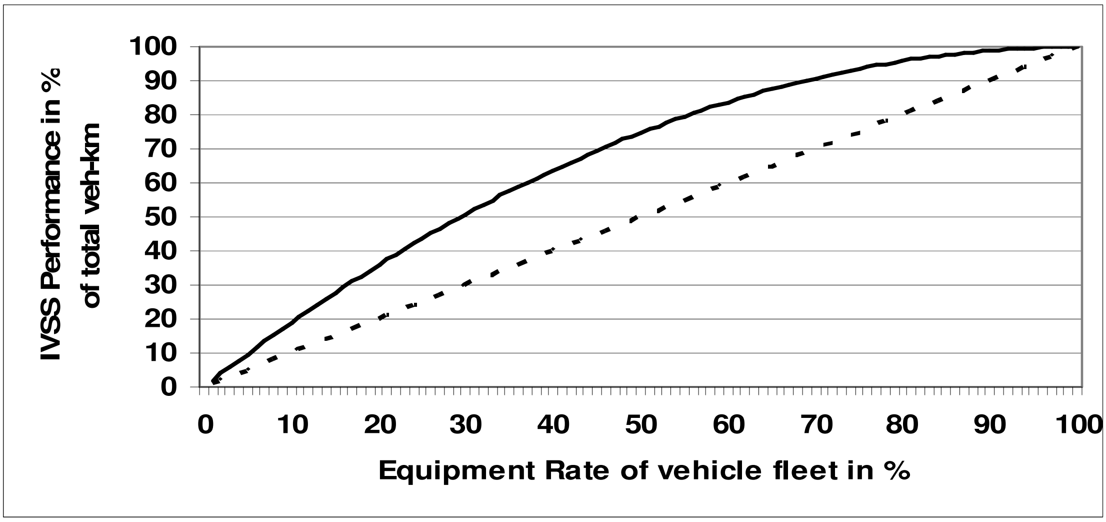

Figure 41: Correlation between Market Diffusion and ACC Performance(author´s figure)

The information on market parameters is now used to estimate the potential socio-economic impact of ACC in EU-25. The impact of using ACC (the "with" case) must be compared with the reference situation not using ACC (the "without" case). The following figure illustrates the forecast **safety performance** for the years 2010 and 2020:

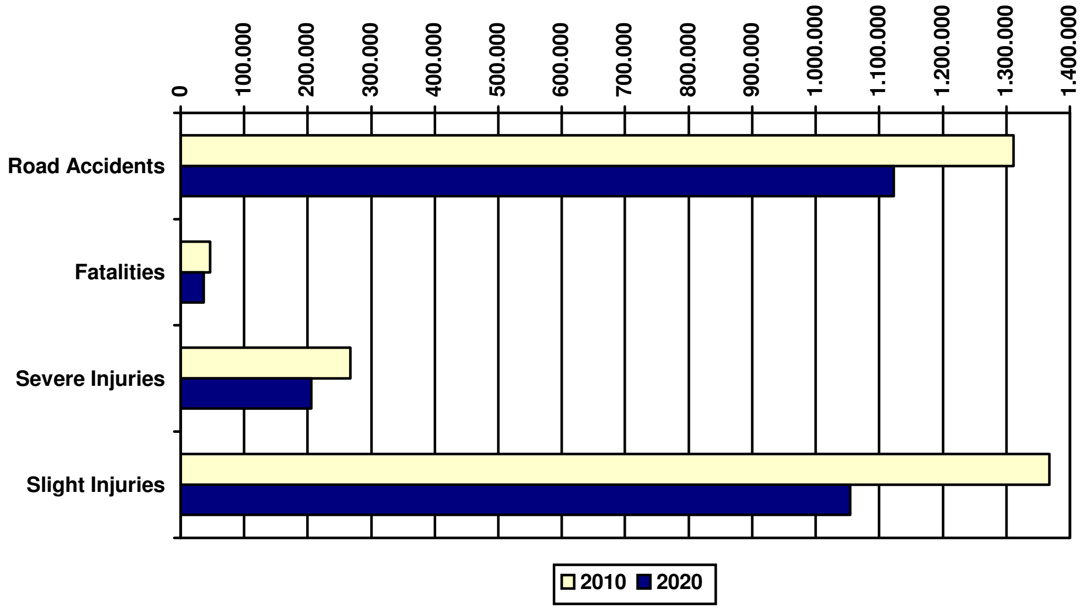

Figure 42: Road Safety Performance Forecast for EU-25 (CARE 2004, ProgTrans 2004, author's calculation).

The improvement in safety is the combined result of two different effects: a reduction in accident numbers and a reduction in accident severity. The reduction in accident severity occurs due to the fact that not all accidents can be avoided entirely through the use of IVSS. The safety improvement is conditioned by several parameters:

- ACC influences rear-end collisions. Rear-end collisions are a frequent type of accident on European roads. An in-depth study of rear-end collisions for ten countries of EU-15 (SWOV 2003) based on CARE data has shown that rear-end collisions account for an average of 13% of all accidents. In this analysis, this average is applied to all the countries which are not covered by the study due to data limitations (Denmark, Luxembourg, Finland and the United Kingdom). Rear-end collisions in Germany account for 13% of all accidents (Statistisches Bundesamt 2003). Due to a lack of data for the new member states, the percentage of rear-end collisions there is also assumed to be 13%.

- The time gains attainable using ACC can reduce rear-end collisions by 25%. ACC operates in the Driving, Warning and Assistance phases; phases in which a faster response to safety-relevant situations is possible. More precisely, this means that there will be a clear time gain in the warning phase since the driver could gain up to 0.5 s due to early warning. This number is a scaled value and would be the result of accident causation analysis. It than has to be considered that the system does not detect all problems and is not permanently used. Hence, the warning phase can be scaled down by 0.2 s. In the assistance phase, there is an additional effect which offers a 0.1 s increase in reaction time. The brake system remains prefilled, which translates to faster brake response. Otherwise, in the driving phase there may be an effect of -0.1 s due to false alarms. The aggregated attainable time saving is 0.2 s. With that, according to the following figure, the collision probability is reduced from 100% to 75%. Therefore, the collision prevention potential for rear-end collisions amounts to 25%.

Figure 43: Rear-End Collision Probability (Enke 1979)

- The time gains also influence the severity of those accidents which cannot be avoided. These time gains can lower vehicle speed and crash impact, leading to a reduction in accident severity. As suggested by the following figure, when speed is reduced by 10 km/h, the probability of severe injuries decreases by 15-20%. It is therefore assumed that 20% of accidents can be shifted down a severity class: 20% of fatalities become severe injuries and 20% of severe injuries become slight injuries. There will be no change from slight injuries to no injuries. The following figure exemplarily shows the correlation of speed and accident severity. Accurate numbers should be derived based on results from accident causation analysis for rear-end collisions.

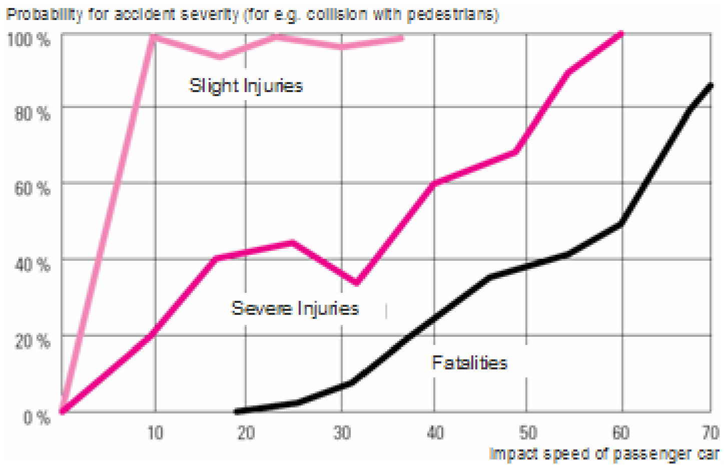

Figure 44: *Accident Impact Speed and Severity of Injuries*

- Since official databases only count reported accidents, they underestimate the number of accidents involving passenger cars. It is estimated that only about 70% of actual accidents in EU-15 are actually recorded in official databases. That implies that three out of ten accidents are not reported in official databases. This structural underreporting must be taken into account in the benefit assessment process. The underestimation factor therefore accounts for 1.3 (CarTALK 2004, ICF 2003) and is applied for EU-25.

Using this assessment framework, the **safety impact of ACC** can be calculated. Table x shows the number of accidents which could be avoided in EU-25 by using ACC. In 2010, the number of accidents could be cut by 3,849 (rear-end) collisions. The related casualty figures show 118 fatalities, 802 severe injuries and 3,987 slight injuries. Since market diffusion is higher by 2020, the avoidance potential should also be higher. It accounts for 8,491 avoided accidents. The related casualties aggregate to 240 fatalities, 1,594 severe injuries and 7,929 slight injuries.

Safe Following (ACC)	Number of Casualties Avoided due to Accident Avoidance (EU-25)	
	2010	**2020**
Number of Accidents	3,849	8,491
Fatalities	118	240
Severe Injuries	802	1,594
Slight Injuries	3,987	7,929

Table 34: *ACC Impact on Accident Avoidance (author`s calculation)*

ACC can also lower the severity of accidents (see previous table). This effect is also important for socio-economic assessment because reducing accident severity also offers reduction potentials for accident costs. In 2010, 95 lives could be saved. In 2020, fatalities could be reduced by 192. As mentioned above, these accidents persist, but at a lower degree of severity. The number of severe injuries thus increases by 95 people (2010) and 192 people (2020). On the other hand, severe injuries can be reduced to slight injuries. This applies for 641 casualties in 2010 and 1,275 casualties in 2020. Therefore, the net reduction of severe injuries aggregates to 546 casualties (= 641-95) in 2010 whereas the reduction in 2020 amounts to 1,083 severe injuries (= 1,275-192). Since there is no severity change for slight injuries, the number of casualties increases by 641(2010) and 1,275 (2020).

Safe Following (ACC)	Reduced Casualties due to Reduced Accident Severity (EU-25)	
	2010	**2020**
Number of Accidents	---	---
Fatalities	95	192
Severe Injuries	546	1,083
Slight Injuries	-641	-1,275

Note: Minus sign = increase in numbers.

Table 35: ACC Impact on Accident Severity (author`s calculation)

Table x gives an overview of the aggregated safety impact of ACC. In total, 213 lives could be saved (2010). In 2020, the number of fatalities could be reduced by 332. The number of severely-injured people could be reduced by 1,348 in 2010 and by 2,677 in 2020. The number of slight injuries could be cut by 3,346 in 2010 and 6,654 in 2020.

Safe Following (ACC)	Aggregated Safety Impact (EU-25)	
	2010	**2020**
Number of Accidents	3,849	8,491
Fatalities	213	332
Severe Injuries	1,348	2,677
Slight Injuries	3,346	6,654

Table 36: Aggregated ACC Safety Impact (*author´s calculation)*

Other, non-safety impacts, such as enlargements in the capacity of road infrastructure are not shown in the forecast ACC diffusion rates. Traffic simulation models have shown that diffusion rates of less than 10-20% show very few changes in traffic characteristics, irrespective of the characteristics of the system or the modelling assumptions made (DIATS 1999).

In order to assess the socio-economic benefits, the safety impact has to be evaluated using **cost unit rates** which represent different levels of severity. As stated in the socio-economic section (see chapter 4.6), standard European cost unit rates are applied. Besides the safety impact on personal injuries, there are also effects on property damage and congestion (see following table for an overview of cost unit rates):

- Since using ACC offers the potential to avoid accidents, not only casualties, but also accident-related property damages can be avoided. Since the range of cost unit rates reflecting property damages is quite considerable (see chapter 4.6), an average rate of 6,000 € per accident is applied. Note that this rate reflects property damages occurring in accidents where there are casualties. The socio-economic benefits of avoiding property damage only (PDO) accidents are not considered in this case study. Although cost unit rates exist for PDO accidents, there is a lack of reliable data on the number of PDO accidents.
- Additionally, accidents are regularly accomplished by congestion leading to time losses, higher fuel consumption, air pollution and carbon-dioxide emissions. These effects are taken into account in a general cost unit rate for different accident severities. According to ICF 2003, average congestion costs caused by fatal accidents amount to 15,000 €, whereas a rate of 5,000 € applies for accidents with personal injuries. The different cost unit rates reflect that, on average, congestion

caused by a fatal accident lasts longer than congestion caused by a crash resulting in severe or slight injuries.

Safe Following (ACC)	Cost Unit Rates for Monetary Assessment (in €)		
	Casualties	**Property Damage (per Accident)**	**Congestion**
Fatalities	1,000,000	6,000	15,000
Severe Injuries	135,000		5,000
Slight Injuries	15,000		5,000

Table 37: Cost Unit Rates for the Socio-Economic Assessment of Safety Impact (EC 2003b, ICF 2003)

The monetary assessment of ACC safety impacts leads to considerable **benefits**. They account for 490 million € in the year 2010. In 2020, the attainable benefits total 990 million €. The following figure shows the distribution of the safety benefits among different components. More than 40% of the total benefits can be attributed to the reduction of fatalities, with a similar contribution being made by the reduction of severe injuries. The remaining 20% of benefits are distributed among the reductions in slight injuries (10%), in property damages (5%) and in congestion (5%).

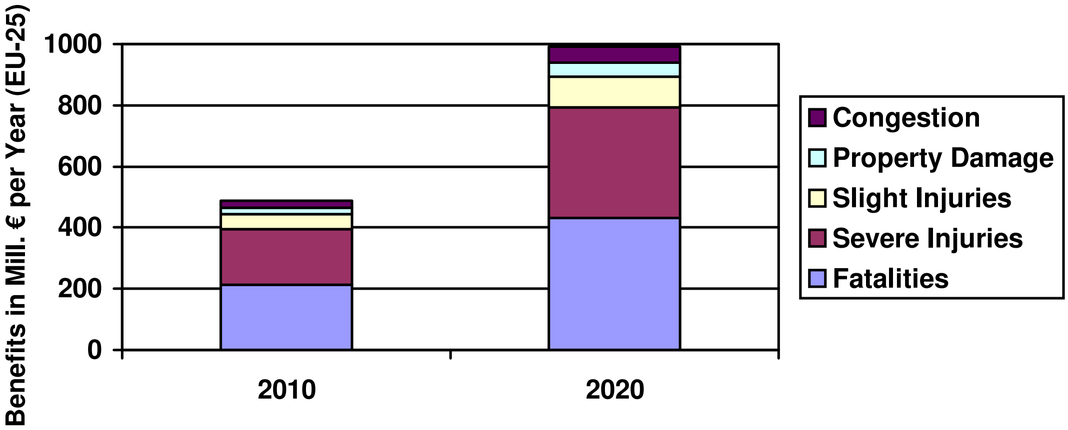

Figure 45: Socio-Economic Benefits of ACC (EU-25; author´s calculation)

Once the benefits have been assessed, **system costs** which represent the denominator of the benefit-cost ratio must be assessed. As stated above, the consumer price per unit equals 750 € in 2010 and 400 € in 2020. The average economic lifetime of a car in EU-15 amounts to 11.4 years (IPTS 2003). Since the average age of the vehicle fleet in the new member states is 50% higher than in EU-15, an average economic lifetime of 12 years is a conservative assumption. Using this figure, the annual costs of equipping vehicles with ACC total 540 million € in 2010 and 840 million € in 2020.

In a final step, the socio-economic benefits must be compared with the annual system costs (see following table). The system costs amount to 540 million € in 2010. Taking the socio-economic benefits to be 490 million €, the **benefit-cost ratio** is 0.9. In 2020, the benefit-cost ratio improves to 1.2. This figure reflects socio-economic benefits of 990 million € and system costs of 840 million €.

Safe Following (ACC)	Benefit-Cost Assessment in Mill. € per year (EU-25)	
	2010	**2020**
Benefits	490	990
Costs	540	840
Benefit-Cost Ratio	0.9	1.2

Table 38: Benefit-Cost Ratio for ACC (EU-25; author´s calculation)

The benefit-cost ratios show that ACC may be a promising IVSS once market diffusion is more advanced. In the short-time perspective, the ACC unit price of 750 € is too high to initiate a more widespread market diffusion. This also means that while the safety benefits are considerable, they are limited because only 3% of the total car fleet is ACC-equipped. The market perspective by 2020 is more optimistic. Because of the higher volume of ACC systems sold (8% market diffusion equates to more than 20 million equipped cars in EU-25) the system costs have been significantly reduced, to 400 €. This is the main reason for the improvement in the benefit-cost ratio to 1.2, which illustrates that market deployment would be beneficial from society's point of view.

However, fostering market penetration will have a substantial impact on the benefit-cost ratios. For sensitivity reasons, the safety benefit is calculated once more to reflect a market diffusion rate of 20% in 2020. Using this rate, the attainable benefits amount to 2,300 million €. Due to economies of scale, the system costs therefore aggregate to 1,680 million €. From these numbers, a benefit-cost ratio of 1.4 can be derived. It must be noted that the benefits of 2,300 million € comprise only the safety benefits and the associated reduction in congestion. Other impacts (e.g. capacity effects) are not included in this figure. As argued above, these effects appear once market diffusion exceeds 10-20%. When these effects are included, the benefit-cost ratio will improve substantially.

The results of other research projects show that the price of the system will have to fall considerably to attain approximate market diffusion rates of 50% across Europe (DIATS 1999: 56f.). Furthermore, unstructured and multi-brand-based production policies may be harmful to ACC success and deter rapid market diffusion (ADVISORS 2003: 82). ACC does, however, possess considerable potential for impact as an enabling function for future ACC enlargements.

5.3 Lane Departure Warning and Lane Change Assistance

Lane Departure Warning (LDW) systems assist drivers in keeping to their lanes by warning drivers when their cars are in danger of leaving their lane unintentionally (mainly due to lack of driver attention). Current systems use either an audible beep or a “rumble strips” noise, which mimics the sound made when a tyre runs over a lane divider. **Lane Change Assistants (LCA)** assist drivers intending to change lanes. The LCA monitors the adjacent lanes and warns the driver if another vehicle is likely to come within colliding distance during the lane change. This occurs, for example, if the other vehicle is located in the LCA-equipped vehicle’s blind spot. In the benefit-cost analysis for this case study, these two systems have been analysed as a single combined system.

In order to carry out a benefit-cost analysis of the safety impacts of LDW and LCA, several different pieces of information are needed:

- The costs of LDW and LCA and their equipment rates at a particular point in time (here: 2010 and 2020)
- The number of relevant accidents (= accidents which could be avoided using LDW and LCA)
- The level of efficiency of LDW and LCA in avoiding these relevant accidents
- The costs of accidents to society.

The **costs and market diffusion rates of LDW and LCA** were predicted using market analyses from various different research institutes. Expert interviews were also carried out in order to verify the data from the different market studies. It is assumed that in the year 2010 just 0.6 % of all vehicles will be equipped with LDW and LCA. By 2020, the diffusion rate will have increased to 7 %. The costs are predicted as € 600 per unit in 2010 (LDW and LCA each cost € 300) and € 400 per unit in 2020. The service life is fixed at 12 years, which is the average lifespan of passenger vehicles in the European Union.

These vehicle equipment rates do not express the percentage of vehicle kilometres driven by vehicles equipped with LDW and LCA. This is due to the fact that drivers who drive a lot (and who thus have a relatively high accident exposure risk) will easier spend money on IVSS. Thus it is assumed that, for example, 3 % market diffusion leads to approx. 6 % of vehicle kilometres being driven with an IVSS-equipped vehicle. The following graph shows the underlying functional relationship. For comparison, the dashed line indicates the linear correlation between equipment rate and system performance:

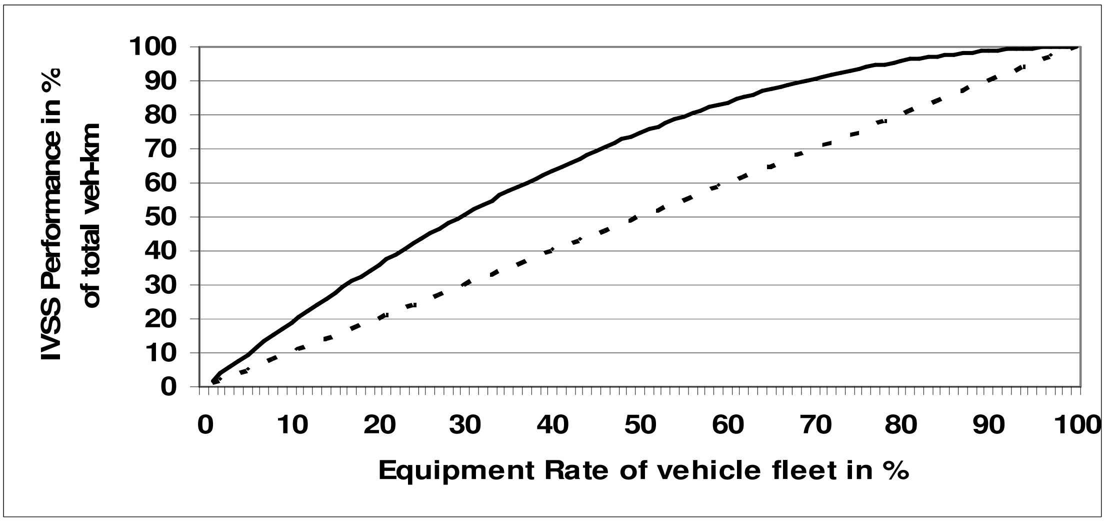

Figure 46: Correlation between Market Diffusion and IVSS Performance (author’s calculations)

The number of relevant accidents can be derived from accident statistics. The next figure shows the total number of road accidents, fatalities and injured people forecast for EU-25 in 2010 and 2020.

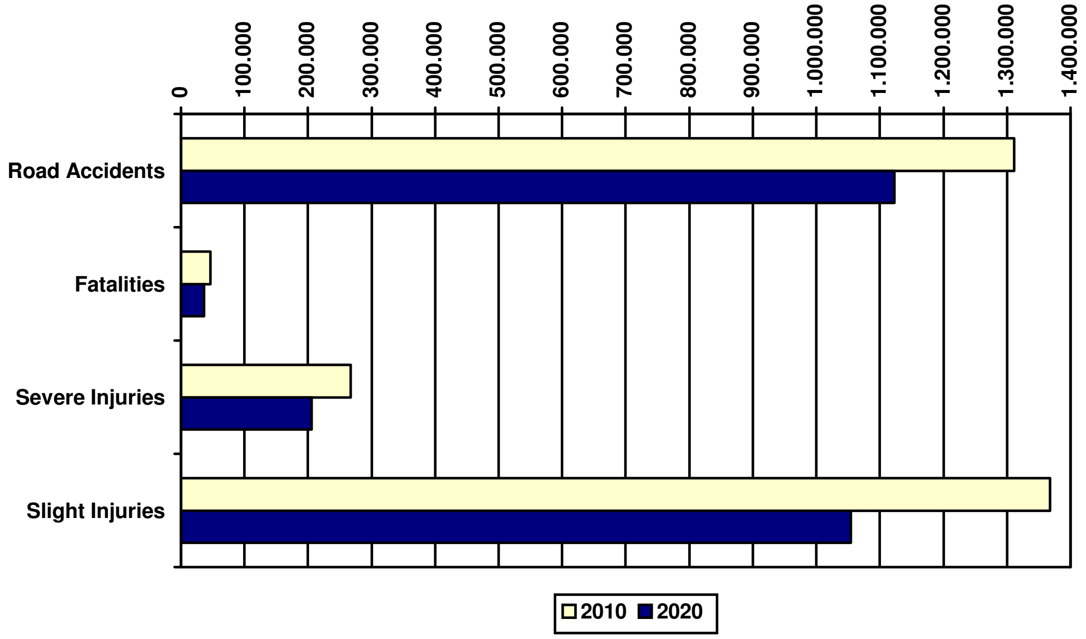

Figure 47: Number of Road Accidents and Casualties Forecast for EU-25 in 2010 and 2020 (CARE 2004, ProgTrans 2004, author's calculation)

The next step involves identifying the percentage of relevant accidents, i.e. the share of accidents which could be avoided due to LDW and LCA. It is assumed that LDW can avoid or reduce the severity of the following two different types of accidents (McKeever 1998):

- Accidents in which two vehicles collide frontally (head-on collision). 2.7 % of all accidents are assumed to be of this type (McKeever 1998).
- Accidents in which a vehicle leaves the road without colliding with another vehicle ("left roadway" accidents). This accident type is more frequent. Referring to all road types (rural, urban and highways), it is assumed that 19.5 % of all accidents belong to this category (McKeever 1998).

Since LCA only supports the lane-change process and does not warn of unintended lane departure, it cannot be assumed that it contributes to the avoidance or mitigation of the types of accidents stated above. However, a further accident type can possibly be avoided or lessened by both the LDW and LCA systems:

- Accidents in which two or more vehicles collide laterally (side-collision accidents) can possibly be avoided by LDW and LCA, depending on the cause of the accident. If the side collision is caused by unintended lane change, LDW can help avoid the crash. If it is due to an intended lane change, LCA could warn the driver in time. In this analysis, it is conservatively assumed that only side-collision accidents between vehicles travelling in the same direction could be avoided. This holds true for an LCA system, whereas an LDW system could possibly also help to avoid accidents in cases where the cars were travelling in opposite directions. It is estimated that 2.5 % of all accidents is made up of side–collision accidents in which the vehicles are travelling in the same direction (McKeever 1998).

These percentage values appear reasonable compared with accident statistics from Germany and other studies analysing the accident avoidance capabilities of LCA and LDW (Statistisches Bundesamt 2003, NHTSA 1996).

The next step estimates the number of relevant accidents which will actually will be avoided or mitigated due to the system functions **(Efficiency of LCA and LDW)**. This estimation differentiates between avoided accidents/fatalities and reduced casualty figures due to mitigation of accident severity. The mitigation is taken into account by shifting the number of casualties in each severity class down a severity class, i.e. from "Fatality" to "Severe injury", and "Severe injury" to "Slight injury". There is no change from "Slight injury" to "No injury", which results in negative values for slight injuries in the table showing the number of accidents and casualties avoided due to reduced accident severity (see below).

It has been shown in various studies that the official accident statistics do not include all accidents which actually occurred. There is a considerable rate of unreported accidents, which varies according to accident severity and member state. In order to assess all benefits of IVSS, these accidents must also be accounted for. In line with enquiries conducted to quantify the amount of unreported accidents (see, for example, ICF Consulting Ltd 2003), it is estimated that accident figures increase by 30 % if unreported accidents are included.

Based on a functional relationship between faster driver reaction and collision probability (Enke 1979, see chapter 4.3), the following assumptions were made about the percentage of accidents avoided and/or mitigated due to LDW and LCA:

- Head-on collisions: It is assumed that LDW warning enables a driver to react, on average, 0.5 seconds earlier than he or she would without the system. This effects a collision reduction of 25 % for all relevant accidents. Furthermore, in 25 % of the accidents, a reduction in accident severity can be assumed.
- "Left roadway" accidents: Time gains of 0.5 seconds can also be assumed for this type of accident using an LDW system. This translates into 25 % accident avoidance and 15 % accident severity reduction.
- Side-collision accidents: Here, both analysed IVSS can contribute to accident avoidance. It is assumed that the aggregate time gain is composed of 0.5 s for the warning phase (LDW and LCA affect different accident causes and therefore the time gains are not combined) and 0.2 s for the assistance phase (LCA with haptic feedback). The cumulated time gain is 0.7 s. This leads us to expect a 60 % reduction in the number of accidents and a 10 % reduction in accident severity.

The accident avoidance potential is calculated based on the information provided above about the number of accidents in the years 2010 and 2020, the percentage values of relevant accidents and system efficiency rates for accident avoidance and mitigation. The first table shows the number of accidents directly avoided. Due to the rather low diffusion rate by 2010, relatively few accidents could be avoided in that year. It is estimated, that 1,442 accidents with 1,848 casualties (51 fatalities, 293 severely-injured people and 1,504 slightly-injured people) could be directly avoided with LDW and LCA in 2010. For 2020, this figure rises to 13,889 accidents with 16,047 casualties.

LDW and LCA	Number of Avoided Accidents/Casualties due to Accident Avoidance	
	2010	**2020**
Number of Accidents	1,442	13,889
Fatalities	51	451
Severe Injuries	293	2,548
Slight Injuries	1,504	13,048

Table 39: Number of Accidents and Casualties Avoided due to Accident Avoidance (author's calculations)

Casualties are also avoided due to accident mitigation. This means that, while the accident cannot be avoided, the level of injuries it causes is shifted down a severity class. As has been mentioned before, since there are no shifts from “slight injuries” to “no injuries”, these values are negative (see table below). This means that accident mitigation results in a greater number of slightly-injured people compared with the reference situation. If the number of directly-avoided slight injuries is also taken into account (1,504 for 2010, see table above), there is still a considerable reduction in slight injuries due to the application of LDW and LCA (1,504 - 160 = 1,344 for 2010).

LDW and LCA	Reduced Casualties due to Lower Accident Severity	
	2010	**2020**
Fatalities	28	246
Severe Injuries	133	1,145
Slight Injuries	- 160	- 1,391

Table 40: Number of Accidents and Casualties Avoided due to Reduced Accident Severity (author’s calculations)

In order to compare the benefits with the costs, the physical effects caused by the use of LDW and LCA in the years 2010 and 2020 must be assigned monetary values. This is done using **accident cost rates**. Accident cost rates vary widely between the different member states of the European Union. As stated in the socio-economic section (see chapter 4.6), standard European cost unit rates are applied (see table below).

The values for casualties do not include costs due to property damage. In order to include these costs in the benefit-cost analysis, an average property damage value of € 6,000 is applied. This figure was derived from the analysis of property damage cost rates in different member states of the European Union (see chapter 4.6). “Property damage only” accidents were not included in the calculations at all due to lack of data.

Congestion costs occur due to the temporary blocking of the road or a temporary reduction in the number of available lanes caused by the accident. The cost rates stated above are used to take these costs into account. The most important congestion costs are due to time losses. These are valued monetarily based on the consideration that the time spend in traffic jams could be used alternatively (e.g. in recreation or work) and thus has an economic value. Additional fuel consumption and increased air pollution and carbon-dioxide emissions are also included in these values. The different cost units for the congestion costs take into account the fact that more severe accidents lead to longer traffic hold-ups.

	Cost Unit Rates for Monetary Assessment (in €)		
	Casualties	**Property Damage (per Accident)**	**Congestion**
Fatalities	1,000,000	6,000	15,000
Severe Injuries	135,000		5,000
Slight Injuries	15,000		5,000

Table 41: Cost Unit Rates for Monetary Assessment (in €; European Commission; author´s calculation)

Using the information stated above, the following benefits and costs can be calculated for the years 2010 and 2020:

LDW and LCA	Benefit-Cost Assessment in Million € per year (EU-25)	
	2010	**2020**
Benefits	173	1,529
Costs	86	735
Benefit-Cost Ratio	2.0	2.1

Table 42: Benefit-Cost Assessment in Million € per year (EU-25; author`s calculation)

As can be seen, the benefits resulting from the employment of LDW and LCA are roughly twice as high as the costs. Since the market diffusion in 2010 is only 0.6 %, the absolute values are rather low compared to the costs and benefits for 2020 (7 % equipment rate). The benefit-cost ratio increases slightly over time, mainly due to sinking unit costs for the systems.

The distribution of benefits according to their physical causes is shown in the next figure. It can be seen that the large majority of cost savings can be ascribed to personal damage costs (approx. 90 % of total costs). Fatalities account for nearly half of the total accident costs. Congestion and property damage costs each account for approx. 5 % of all costs. Costs due to slight injuries constitute approx. 10 % of all costs.

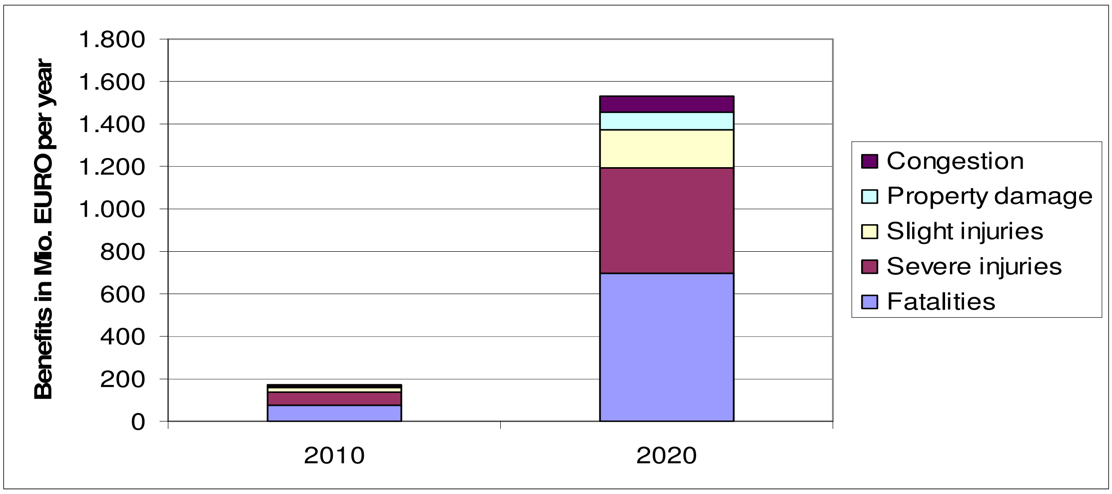

Figure 48: Distribution of Benefits According to Physical Causes in 2010 and 2020 (author's calculation)

This case study shows that the introduction of LDW and LCA could be beneficial to society. Support from public authorities to promote the development and use of LDW and LCA can be justified on the grounds of economic considerations.

Summing up, the overall results of the exemplary calculations indicate the socio-economic favourability to deploy IVSS. From the methodological point of view, the exemplary calculations have demonstrated that the proposed assessment framework is workable with different IVSS (workability proof). According to the system specification the calculation is based on different levels of detail regarding system parameters, impact channels, input data scenarios (pessimistic/optimistic scenario) and market penetration, e.g. assumption of full penetration (sensitivity proof). Obviously, the socio-economic impact assessment has to cope with data limitations which also influence the calculation results. In this context, the proposed SEiSS methodology provides a framework for impact assessment which can be filled according to the level of available information. With that, the data input for the exemplary calculations should be reviewed and refined in a further step in order to carry out more detailed impact calculations.

Annex Emission Factors

	Emission standard	Urban	Rural single c/way	Rural dual c/way	Motorway
Diesel cars	Pre-Euro I	0.180	0.151	0.146	0.195
	Euro I	0.045	0.026	0.024	0.062
	Euro II	0.027	0.016	0.015	0.037
Diesel LGV	Pre-Euro I	0.378	0.310	0.299	0.458
	Euro I	0.119	0.084	0.083	0.161
	Euro II	0.072	0.050	0.050	0.097
HGV rigid	Old	1.593	0.982	0.899	0.899
	Pre-Euro I	0.779	0.470	0.427	0.352
	Euro I	0.512	0.313	0.279	0.191
	Euro II	0.270	0.164	0.147	0.101
HGV artic	Old	1.322	0.792	0.618	0.618
	Pre-Euro I	1.128	0.694	0.628	0.472
	Euro I	0.775	0.479	0.428	0.296
	Euro II	0.298	0.184	0.164	0.114
Buses	Old	1.392	1.218	1.218	0.618
	Pre-Euro I	0.738	0.425	0.378	0.268
	Euro I	0.490	0.346	0.307	0.208
	Euro II	0.302	0.133	0.118	0.080
Motorcycles	< 50 cc	0.04	0.04	0.04	0.04
	> 50 cc, 2st	0.04	0.04	0.04	0.04
	> 50 cc, 4st	0.12	0.12	0.12	0.12

Petrol vehicles

g/km	Leaded	Unleaded without TWC	Unleaded with TWC
Cars	0.06	0.02	0.01
LGVs	0.08	0.04	0.02

Table 43: Emission Factor for PM10 in g/km (UK Road Transport Emission Projections 1998)

	Emission standard	Urban	Rural single c/way	Rural dual c/way	Motorway
Petrol cars	Pre- ECE	2.53	1.86	1.46	1.25
	ECE 15.00	2.01	1.35	1.20	1.07
	ECE 15.01	2.01	1.35	1.20	1.07
	ECE 15.02	1.99	1.45	1.01	0.96
	ECE 15.03	1.99	1.45	1.01	0.96
	ECE 15.04	1.67	1.19	0.87	0.81
	Euro I (91/441/EEC)	0.16	0.10	0.08	0.15
	Euro II	0.069	0.043	0.035	0.065
Diesel cars	Pre-Euro I	0.173	0.113	0.080	0.059
	Euro I	0.069	0.044	0.023	0.015
	Euro II	0.048	0.030	0.016	0.010
Petrol LGV	Pre-Euro I	2.01	1.17	0.69	1.21
	Euro I	0.09	0.07	0.10	0.19
	Euro II	0.04	0.03	0.04	0.09
Diesel LGV	Pre-Euro I	0.346	0.223	0.146	0.194
	Euro I	0.255	0.181	0.123	0.100
	Euro II	0.153	0.108	0.074	0.060
HGV rigid	Old	6.42	3.21	3.21	3.21
	Pre-Euro I	3.21	1.85	1.68	1.40
	Euro I	1.89	1.12	0.97	0.64
	Euro II	1.75	1.04	0.91	0.58
HGV artic	Old	6.78	3.21	3.21	3.21
	Pre-Euro I	3.07	1.67	1.46	0.94
	Euro I	1.45	1.02	0.89	0.64
	Euro II	1.30	0.95	0.82	0.56
Buses	Old	5.80	2.60	2.60	2.30
	Pre-Euro I	1.39	0.70	0.63	0.51
	Euro I	1.50	1.09	0.94	0.68
	Euro II	1.40	0.94	0.81	0.59
Motorcycles	< 50 cc	9.75	9.75	9.75	9.75
	> 50 cc, 2st	9.76	9.76	9.76	9.76
	> 50 cc, 4st	1.76	1.76	1.76	1.76

Table 44: Emission Factor for NMVOC in g/km (UK Road Transport Emission Projections 1998)

	Emission standard	Urban	Rural single c/way	Rural dual c/way	Motorway
Petrol cars	Pre- ECE	29.4	22.3	17.8	17.2
	ECE 15.00	20.5	14.5	15.2	22.9
	ECE 15.01	20.5	14.5	15.2	22.9
	ECE 15.02	17.2	12.1	7.70	10.0
	ECE 15.03	18.3	11.7	7.65	9.58
	ECE 15.04	11.4	7.81	6.10	8.33
	Euro I (91/441/EEC)	1.68	0.97	1.42	4.60
	Euro II	1.17	0.68	0.99	3.22
Diesel cars	Pre-Euro I	0.760	0.545	0.437	0.429
	Euro I	0.451	0.295	0.214	0.301
	Euro II	0.316	0.207	0.150	0.211
Petrol LGV	Pre-Euro I	17.2	9.34	9.64	39.0
	Euro I	3.42	1.71	1.47	4.70
	Euro II	2.40	1.19	1.03	3.29
Diesel LGV	Pre-Euro I	1.192	0.910	0.845	1.416
	Euro I	0.916	0.658	0.560	0.829
	Euro II	0.641	0.461	0.392	0.581
HGV rigid	Old	6.00	2.90	2.90	2.90
	Pre-Euro I	4.32	2.65	2.45	2.04
	Euro I	2.42	1.73	1.54	1.05
	Euro II	1.95	1.53	1.36	0.99
HGV artic	Old	7.30	3.70	3.70	3.10
	Pre-Euro I	5.00	3.08	2.83	2.44
	Euro I	2.56	1.73	1.54	1.16
	Euro II	2.09	1.44	1.29	1.16
Buses	Old	18.8	7.30	7.30	1.76
	Pre-Euro I	7.15	3.89	3.50	3.50
	Euro I	3.17	1.73	1.51	1.05
	Euro II	2.54	1.44	1.26	1.05
Motorcycles	< 50 cc	18.6	18.6	18.6	18.6
	> 50 cc, 2st	23.1	23.1	23.1	23.1
	> 50 cc, 4st	18.9	18.9	18.9	18.9

Table 45: Emission Factor for Co in g/km (UK Road Transport Emission Projections 1998)

6 Appendix

6.1 Abbreviations

ABS	Automatic Braking Systems
ACC	Advanced Cruise Control
ACEA	European Automobile Manufacturers Association
ADAS	Advanced Driver Assistances
AIS	Abbreviated Injury Scale
ATT	Advanced Transport Telematics
AVCSS	Advanced Vehicle Control and Systems
AVG	Automated Vehicle Guidance
BASt	Bundesanstalt für Straßenwesen
BEA	Break-Even Analysis
BCC	Business Case Calculations
CBA	Benefit-cost Analysis
CEA	Cost-Effectiveness Analysis
DSRC	Dedicated Short Range Communications
EAS	Electric Power Assisted Steering
EBS	Emergency Braking System
EC	European Commission
EMB	Electromechanical Braking
ERTICO	European Road Transport Telematics Implementation Coordination Organisation
ESP	Electronic Stability Programme
EU	European Union
EU-15	European Union (15 member states)
EU-25	European Union (25 member states, since 01.05.2004)
FA	Financial Analysis
GIDAS	German In-Depth Accident Study
GDP	Gross Domestic Product
GDV	Gesamtverband der Deutschen Versicherungsindustrie
GPS	Global Positioning System
GSM	Global System for Mobile Communications
HGV	Heavy Goods (Duty) Vehicle
HMI	Human Machine Interface
IfMO	Institut für Mobilitätsforschung

ILS	Institut für Land- und Seeverkehr an der Technischen Universität Berlin
IP	Integrated Project
ISA	Intelligent Speed Adaptation
IST	Information Society Technology Programme
IT	Information Technology
ITS	Intelligent Transport Systems and Services
IVSS	Intelligent Vehicle Safety Systems
LCA	Lane Change Assistant
LDA & LDW	Lane Departure Warning
LOC	Loss of Control
LSF	Low Speed Functionality
MCA	Multi-Criteria Analysis
MSD	Minimum Set of Data
MPV	Multi-purpose Vehicles
OECD	Organisation for Economic Cooperation and Development
OEM	Original Equipment Manufacturer
PDO	Property Damage Only
PSAP	Public Safety Answering Point
ROI	Return on Investment
R&D	Research & Development
S&G	Stop & Go
SUV	Sport-utility Vehicle
UPR	Unprotected Road User
VGS	Vehicle Guidance Systems
VRU	Vulnerable Road User
WP	Working Package

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6.5 Relevant EU Projects and Studies Profile

ADASE I+II

ADASE (Project start/end: 01.01.98 - 30.06.99), Public Deliverables (D2, D5.2, D6.3), 1999

Advanced Driver Assistance Systems in Europe

also Automated Highway Systems – European Analysis

Partners: DaimlerChrysler (DE); BMW (DE); COFIROUTE (FR); CRF (IT); Renault (FR); RWS (NL); VW (DE) (Key partners)

Funded by European Commission, 4th Framework Program, TAP

Project Reference: AHSEA IA 1101

http://www.cordis.lu/telematics/tap_transport/research/projects/ahsea.html

Main objectives:	- Adoption of broad US and Japanese programmes to set up the technological base for intelligent vehicles and intelligent infrastructure - Formation of an interdisciplinary system harmonisation platform in order to bring ITS-related products and services to the European market (ADASE roadmap) - Special attention to European boundary conditions
Work packages:	- Interdisciplinary approach with strong focus on a series of workshops (user needs, legal aspects, policy and decision makers)
Technology:	- All major technologies covered, but no technological development itself - Roadmap for ADAS development - Technical requirements for business development (system architecture and functional requirements, D5.2)
Market:	- ADAS product development strategies based on marketability levels (high, medium, low), levels are declared by potential of a technology to become a product, expected safety/efficiency/comfort effects, realisation perspective (near-term/mid-term), usability and required training on the system, user and public acceptance - Global analysis of US market projections and consequences for Europe based on principal transport indicators - Market analysis for navigation systems as example for emerging systems - Market introduction strategies for ADAS products such as early product launch/system development strategy, strategic product launch strategy (fast follower), technology leadership, skimming, penetration pricing - results are resumed in D6.3
Traffic:	- Traffic aspects were not addressed specifically - Reference to German Shell study on motorisation trends
Socio-economic impact:	- Workshop with policy and decision makers (D2.3): expected benefits from stakeholder perspective (automotive industry, public authorities, road provider) - The socio-economic impact was not addressed from a general social point of view

ADASE II (Project start/end: 01.08.2001- 31.07.2004)

Advanced Driver Assistance Systems in Europe

Partners: DaimlerChrysler AG (Coordinator) (DE); AW Transport Research Centre of Rijkswaterstraat (NL); BMW AG (DE); C.R.F. Societa Consortile per Azioni (I); Centre d'Etudes Techniques de l'Equipement-Mediterranee (F); Clepa-European Association of Automotive Suppliers (BE); Compagnie Financière et Industrielle des Autoroutes (F); Jaguar Cars Limited (UK); Peugeot Citroen Automobiles SA (F); Regienov (F)

Funded by the European Union DG VII Fifth Framework, Thematic Network

Project Reference: IST-2000-28010

http://www.adase2.net/

Main objectives:	Advanced Driver Assistance Systems improve road transport safety, efficiency and comfort. ADASE II provides the communication and dissemination platform between experts in the field, authorities and the public. It requires involvement of all major players. Transport authorities, road providers, E&S and automotive industry will organise expert workshops on the key areas of importance in the development of Advanced Driver Assistance systems. Telematics links to connect new vehicle technology to traffic management centres, other vehicles and service providers are used. ADASE II is a thematic network which integrates international, national and regional activities in the field of Active Safety and Advanced Driver Assistant Systems. ADASE II investigates new paths for European transport systems. Advanced Driver Assistance Systems (ADAS) are concepts to improve transport safety, efficiency and comfort without placing additional strain on resources (energy and land use), on the environment and on quality of life. ADASE II combines new vehicle technologies (including innovative vehicle control) with Telematics links to traffic management centres, other vehicles and service providers. The vehicle acquires information about both the immediate driving environment and the situation ahead and informs the driver, warning him or her about hazardous situations or even reacting by releasing him or her from certain driving tasks. In addition to safety-related functions, ADASE II will provide the basis for improved interfaces to other modes of transport and profitable applications and services such as smart travel advice, tele-commerce, in-car entertainment, mobile office support etc.
Work description:	- The preparation of the market introduction of ADA systems requires a holistic approach; all major players in the ADASE II environment therefore had to be involved. Transport authorities (CETE; RWS), road providers (Cofiroute), E&S (CLEPA) and the automotive industry, were involved in the organisation of five workshops covering the key areas of importance in the deployment of Advanced Driver Assistance Systems. - Milestones: - Major project milestones coincided with the expert workshops on: - legal aspects & human machine interface; - architecture & technology roadmap; - road infrastructure design & road-vehicle, vehicle-vehicle communication systems & applications; - sensor technologies; - effects on safety, throughput & comfort.
Technology:	- Roadmap for ADAS development, sensor workshop - ADAS community, ADAS as a brand name, cluster meetings to enforce standardisation - Overview: market introduction of systems

Market:	Overview: market introduction of systems (manufacturer, product, function, supplier, market segment, vehicle model, availability, geographical market area, price), Annex to D2.1
Traffic:	Traffic aspects were not specifically addressed
Socio-economic impact:	The socio-economic impacts was not specifically addressed

ADVISORS

ADVISORS (Project start/end: 01.04.2000-31.12.2002), Final Report April 2003

Action for advanced Driver assistance and Vehicle control systems Implementation, Standardisation, Optimum use of the Road network and Safety

Partners: SWOV Institute for Road Safety Research (coordinator) (NL); JAN DE RIJK BV (NL); ACHMEA Holding (NL); Delft University of Technology - TRAIL (NL); Belgisch Instituut voor de Verkeerveiligheid (BE); Aristotle University of Thessaloniki (GR); Swedish National Road and Transport Research Institute VTI (SE); University of Groningen (NL); CRF - Fiat Research Center (IT); Siemens Automotive SA (FR); University of Stuttgart (DE); Bundesanstalt fur Straßenwesen (DE); National Technical University of Athens (GR); Centrum Dopravniho Vyzkumu (CZ); Technical Research Centre of Finland (FIN); Transport Research Foundation TRL (GB)

Funded by the European Community under the Competitive and Sustainable Growth Programme (1998-2002)

Project Reference: GRD1 2000 10047

http://www.advisors.iao.fraunhofer.de/

Main objectives:	Based on test site demonstrations, ADVISORS developed a methodology for assessing the impact of different types and different levels of penetration of ADAS in terms of the safety, efficiency and environmental performance of the road transport system. ADVISORS also developed implementation scenarios to help introduce appropriate ADAS. ADVISORS' approach was problem-focused rather than technology-driven. Appropriate ADAS were selected based on a problem analysis of the European Road network and analysed using a multidisciplinary approach in order to gain new policy insights. All the stages for a potential breakthrough of ADAS were investigated: the market conditions, the impacts on driving behaviour, road safety and environment, the role of regulatory authorities, public acceptance, implementation strategies etc. Assessment methodologies were developed and applied to deliver empirical evidence. This evidence, together with questionnaire results, was then fitted into a pre-developed decision scheme. This approach led to the creation of an integrated framework for designing road safety policies to help implement suitable ADAS. Policy recommendations and guidelines were put forward during the last stage.
Work packages:	- WP1: Problem identification and inventory of ADAS - WP2: Actor interests, acceptance, responsibilities and users' awareness enhancement - WP3: Risk analysis and liability issues - WP4: Development of multi-parameter criteria & a common impact assessment methodology - WP5: Pilot evaluations - WP6: Cost-effectiveness analysis of ADAS - WP7: Development of priority implementation scenarios for ADA systems - WP8: Market analysis and exploitation - WP9: Project management

Technology:	- Because of the strong methodological project focus, ADVISORS did not aim to develop safety-related technologies itself. Instead, the project provided a broad overview of ADA systems which are already available or currently under development. - Information on technologies was gathered during the ADAS inventory (D1). Each system was described briefly from a technological viewpoint. - Concerning the technology implementation path it was expressed - based on stakeholder interviews - which IVSS are most likely to be implemented by 2010 (D2: Actor interests, acceptance, responsibilities and users' awareness enhancement). - Several systems underwent a multidimensional risk analysis (technology, driver behaviour, legal and insurance issues). Results were documented in D3.
Market:	- The ADAS inventory (D1) did also specify – where available – basic assumptions concerning readiness to market and market diffusion as well as system costs. - The project also used the results of driver interviews to provide information on current market diffusion for selected systems in six EU member states (D, NL, FIN, I, GR, CZ).
Traffic:	- Not specifically addressed
Socio-economic impact:	- A system impact assessment was carried out based on a common assessment methodology using multi-criteria analysis (D6). This was used with expert ratings to determine the most important factors involved in ADAS testing and implementation strategies. The most important factors are driver safety (weight: 0.203), third-party safety (0.183), environmental impact (0.108) and travel time reduction (0.107). - Demonstrating the analytical capabilities of benefit-cost analyses, an exemplary calculation of ACC costs and benefits was performed in D6.

AIDE

<table>
<tr><td colspan="2">AIDE (Project start/end: 01.02.2004-31.01.2008), Presentation
Adaptive Integrated Driver-Vehicle Interface
Partners: 28 partners, equally distributed between industry (car manufacturers and suppliers) and research institutions
Funded by the European Commission DG INFSO, Integrated Project within FP 6
http://europa.eu.int/information_society/programmes/esafety/forum/rtd_projects/text_en.htm</td></tr>
<tr><td>Main objectives:</td><td>Develop the HMI (Human-Machine Interface) concepts required for the safe and efficient integration of ADAS and IVIS into the driving environment</td></tr>
<tr><td>(Work packages) Organisation:</td><td>- Behavioural Effects and DVE Modelling (SP 1)
- Evaluation and Assessment Methods (SP 2)
- Design and Development of AIDE Interface (SP 3)
- Horizontal activities (SP 4)</td></tr>
<tr><td>Technology:</td><td>- Three prototype vehicles demonstrating, evaluating and testing the AIDE concept and the adaptive and integrated HMI (expected)
- General design guidelines and proposal for standards for Adaptive Integrated Interfaces (expected)
- Too early for results, monitoring will be continued</td></tr>
<tr><td>Market:</td><td>- Model and simulations of behavioural effects of ADAS and IVIS (expected)
- Too early for results, monitoring will be continued</td></tr>
<tr><td>Traffic:</td><td>- Not specifically addressed</td></tr>
<tr><td>Socio-economic impact:</td><td>- Generic methodology for the evaluation of Adaptive integrated Interfaces with respect to safety (expected)
- Too early for results, monitoring will be continued</td></tr>
</table>

ARCOS

<table>
<tr><td colspan="2">ARCOS (Project start/end: 2001-2004), ARCOS Programme Results, October 2004
Action de recherche pour une conduite sécurisée
Partners: 60 French partners (public and private)
Funded by the French Programme PREDIT
http://www.arcos2004.com/</td></tr>
<tr><td>Main objectives:</td><td>- The project aimed to enhance driving safety on the basis of four safety functions:
- controlling inter-vehicle distances
- avoiding collisions with fixed or slow-moving obstacles
- avoiding lane departure
- alerting other vehicles of accidents</td></tr>
</table>

Work packages:	- WP1 detection and perception techniques - WP2 other measurement techniques : visibility and adhesion - WP3 telecommunications - WP4 information processing & action design - WP5 simulation, a priori assessment, accidentology - WP6 man-machine cooperation - WP7 individual and societal acceptability - WP8 socio-economy, liability, regulation - WP9 experiments - WP10 management - WP11 application for heavy duty vehicles
Technology:	- ARCOS functions: - Managing distances between vehicles - Avoiding and mitigating collisions - Alerting vehicles ahead - Avoiding lane departure
Market:	- Social acceptability of driver assistance systems based on 2,000 interviews in France: systems which reduce the impression of driver's control over the vehicle are judged less acceptable, IVSS would, on the one hand, increase the level of driving comfort, confidence in one's own driving skills and the perceived feeling of safety within the vehicle, but on the other hand would considerably reduce the enjoyment of driving - User survey (currently under progress within PREDIT) - Market diffusion rates as fixed elements of assessment procedures
Traffic:	- Strong focus on accidentology: in-depth analyses of accidents as a road safety research tool based on 500 reports of fatal accidents (France, 2001-2002) - Overview/ranking of important accident situations: 19 generic categories with 165 subcategories - Safety impact estimations by linking ARCOS functions and fatal accidents: preventing "left roadway" accidents was the most promising function (61%, which means that 61% of fatal accidents would be affected by the function), other functions: Collision avoidance and mitigation (40%), alerting vehicles ahead (9%), Management of inter-vehicle distances (1%)
Socio-economic impact:	- Socio-economic benefits of improved road traffic safety - Scenario approach – benefits depending from safety development in the future (different annual reduction rates, time horizon 2015) - Overall annual safety benefits for France estimated in a range between 1.4 billion euros and 2.6 billion euros with 1.8 billion euros reflecting a trend-like development of road safety - Breakdown of benefits by systems shows that more than half of the benefits can be attributed to preventing "left roadway" accidents - Economic considerations on public authorities' willingness to invest in road safety

CarTALK 2000

CarTALK 2000 (Project start/end: 01.08.2001-31.07.2004), Final Report September 2004

Partners: Daimler Chrysler AG (DE); Centro Ricerche Fiat (I); Robert Bosch GmbH (DE); Siemens (DE); Netherlands Organisation for Applied Scientific Research (TNO) (NL); University Cologne; Institut für Verkehrswissenschaft (DE); University of Stuttgart; Institute of Parallel and Distributed High-Performance Systems (IPVS) (DE)

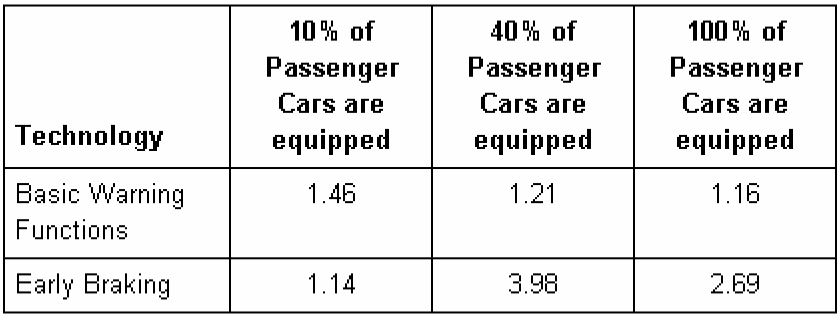
IST Cluster of the 5th Framework Program of the European Commission

Project Reference: IST-2000-28185

http://www.cartalk2000.net

Main objectives:	The European Project CarTALK 2000 focused on the new driver assistance systems which are based upon inter-vehicle communication. The main objectives were the development of co-operative driver assistance systems and the development of a self-organising ad-hoc radio network as a communication basis with the aim of preparing a future standard. As for the assistance system, the main issues were: - the assessment of current and future applications for co-operative driver assistance systems, - the development of software structures and algorithms, i.e. new fusion techniques, - the testing and demonstration of assistance functions in test vehicles in real or reconstructed traffic scenarios. To achieve a suitable communication system, algorithms for radio ad-hoc networks with extremely high dynamic network topologies were developed and prototypes were tested. In addition to its technological goals, CarTALK 2000 actively addressed market introduction strategies including cost/ benefit analyses and legal aspects, and eventually aimed at a standardisation to bring these systems to the European market.
Work packages:	- Enabling research and socio-economic feasibility - System architecture - Communication system - Applications – assistance systems and infotainment - Standardisation and market introduction
Technology:	- Passenger Car Technology with following application cluster: - Information and warning functions (e.g. Basic Warning Functions) - Communication-based longitudinal control systems (e.g. Early Braking) - Co-operative assistance systems (e.g. Highway Merging)
Market:	Market diffusion rates are reflecting different levels of penetration rates are not derived from market projections
Traffic:	Traffic simulations (based on TNO Mixic model) for applications selected for socio-economic assessment (Basic Warning, Early Braking)

Socio-economic impact:	Benefit-cost Analyses were worked out at a European (EU-15) level for the effects of Basic Warning Functions and Early Braking for different equipment ratios. The maximum of the benefit-cost ratio was not reached at 100 % equipment rate.



Technology	10% of Passenger Cars are equipped	40% of Passenger Cars are equipped	100% of Passenger Cars are equipped
Basic Warning Functions	1.46	1.21	1.16
Early Braking	1.14	3.98	2.69

CHAMELEON

CHAMELEON (Project start/end: 01.01.2000-31.03.2003)

Pre-crash application all around the vehicle

Partners: Centro Ricerche Fiat S.C.p.A. (I) (Coordinator); PSA Peugeot Citroen Automobile (F); Temic Telefunken Microelectronic GmbH (DE); Thomson-CSF Detexis (F); Volvo Car Corporation (SE); Porsche AG (DE); Regienov Renault Recherche Innovation (F); IBEO Lasertechnik Hipp KG (DE); SAAB Borfors (SE); EICAS Automazione S.p.A. (I); Institut für Kraftfahrwesen Aachen (ika) (DE); Centro Studi sui Sistemi di Trasporto (CSST) (I); Israel Aircraft Industries – TAMAN, RAMOT (Tel Aviv) University Authority for Applied Research and Industrial Development Ltd. (ISR)

Funded by the European Commission DG INFSO Fifth Framework

Project Reference: IST-1999-10108

http://www.chameleon-eu.org (service unavailable)

Main objectives:	CHAMELEON was a project which considered the link between preventative and passive safety. The main objective of the project was the development of an innovative pre-crash system which is able to identify an impending collision. This information can then be distributed to different passenger protection systems to improve their safety. Obstacle detection technologies were assembled using the defined requirements of pre-crash applications to guarantee secure target detection in all road scenarios. An essential part of the project was the development of suitable test methods for the assessment and further development of the system.
Technology:	The CHAMELEON system was basically composed of a sensor module for obstacle detection (vision system, medium range radar, laser scanner, laser, short range radar) and a processing module for crash prediction (control unit). Output was intended to be used by an advanced passive safety system on board.
Market:	not addressed
Traffic:	not addressed
Socio-economic impact:	not addressed

CHAUFFEUR

PROMOTE CHAUFFEUR 1 (Project start/end: 01.01.1996- 31.12.1998), Final Report December 1998

Partners: Daimler Benz AG (DE); Alpen Straßen AG; ARCESE Transporti S.p.A (I); Benz Consult (DE); Willi Betz GmbH & Co. KG (DE); Robert Bosch GmbH (DE); Cavewood Transport Ltd. (GB); Centro Ricerche Fiat (I); Central Research Laboratories Ltd. (GB); Centro Studi sui Sistemi di Trasporto (I); ELTRAC s.r.l. (I); IVECO SpA (I); MIZAR Automazione SpA (I); Pünder, Vohard, Weber & Axster (DE); TÜV Rheinland e.V. (DE); WABCO Westinghouse Fahrzeugbremsen (DE); ZF Friedrichshafen AG (DE)

Funded by the European Union DG VII Fourth Framework

Project Reference: TR 1009

http://www.cordis.lu/telematics/tap_transport/research/projects/chauffeur.htm

Main objectives:	- Develop two fully operative prototypes of CHAUFFEUR heavy duty vehicles incorporating Tow-Bar functions. - Demonstrate and test the Tow-Bar application under real traffic conditions. - Socio-economic assessment of Tow-Bar application. - Implication strategies considering legal issues.
Work packages:	- Tow-Bar components: sensor modules, data transceivers, and vehicle controllers were implemented to provide and process the information required by the towed vehicle needs to perform its driving task. - Vehicle base: intelligent controls for engine, driveline, brakes and steering system were developed. They were linked together by a vehicle base network and an overall control concept. - Installation and functional tests: development of hardware and software components. - Test, evaluation and support issues: risk and safety analysis for Tow-Bar system performed. Impacts on traffic, infrastructure, traffic organisation and drivers are investigated and legal aspects considered. Benefit-cost analysis for Tow-Bar was done. - Feasibility study of platooning and automated platooning: the feasibility of developed systems was tested using simulations, and additional technical requirements for such systems were identified.
Technology:	The Tow-Bar System consists of following technology components: Monocular Vision System and infrared system. Pattern-based approach, requires preceding trailer to have CHAUFFEUR equipment, designed to follow other heavy duty vehicles at a close distance.
Market:	Workshops with freight forwarders to improve system design based on user needs
Traffic:	- Precondition for socio-economic impact assessment - Modelling of traffic situation on German motorways (base year: 1994)
Socio-economic impact:	The work of CHAUFFEUR 1 has proved that electronic coupling of trucks is technically feasible, economically viable, and operationally acceptable. However, more operational flexibility is needed to make maximum use of the system capabilities (see PROMOTE CHAUFFEUR 2)

PROMOTE CHAUFFEUR 2 (Project start/end: 2000-2003), Final Report May 2003

Partners: DaimlerChrysler AG (DE); Centro Ricerche Fiat (I); IVECO S.p.A. (I); REGIENOV, Renault V.I. SA (F); Robert Bosch GmbH (DE); Central Research Laboratories Ltd. (GB); WABCO Vehicle Control System (DE); ZF Lenksystem GmbH (DE); TÜV Kraftfahrt GmbH (DE); Centro Studi Sistemi Transporta (I); PTV Planung Transport Verkehr AG (DE); Clifford Chance Pünder (GB)

Funded by the European Commission DG INFSO Fifth Framework

Project Reference: IST-1999-10448

http://www.chauffeur2.net/

Main objectives:	- Extension of the CHAUFFEUR 1 project with following goals: - developing the CHAUFFEUR-Assistant as an extension of the Tow Bar System of CHAUFFEUR 1 by adding interoperable system functions which allow following of any other heavy duty vehicle. - Platooning: Realisation of three heavy duty vehicles platoon and demonstration of typical platooning manoeuvres in test environment. - Horizontal support function as human machine interface, system evaluation and system concepts, scenarios and traffic simulation, concepts for freight logistics, benefit-cost analysis for the system, user acceptance, legal and liability implications
Work packages:	- CHAUFFEUR Assistant: Development of system technology. - Platooning: extension of the electronic Tow Bar from 2 to 3 trucks, automatic following at short distance, following vehicles like trailers, coupling and de-coupling manoeuvres. - Demonstration vehicles: adding new environment sensing system on serial standard truck from three different OEM, using new sensing system vehicle base sub system, integration of a by-wire drivetrain, definition of safety requirements. - System assessment: traffic impacts, socio-economic evaluation, legal issues. - Demonstration scenarios
Technology:	CHAUFFEUR-Assistant functions as a combination of Adaptive Cruise Control over the whole dynamic range and vision-based lane keeping. The CHAUFFEUR Assistant consists of two subsystems, a lane-keeping system (LK) and an intelligent (smart) distance-keeping system (SDK). Technology components are: two cameras, stereo vision approach, radar, sensor fusion of video and radar data.
Market:	- Hazard analysis: since the hazard analysis of the CHAUFFEUR assistant function did not bring up any insurmountable safety problems, it was concluded that CHAUFFEUR 2 was on the right path and could continue as planned. - Legal implications: the procedure for the investigation of the legal and liability implications of the two CHAUFFEUR 2 applications were investigated. Conclusion was that no major hurdles will come up.
Traffic:	Traffic effects: traffic simulations proved that CHAUFFEUR Assistant systems will cause an improvement in traffic flow of up to 4.7 % depending on the number of CHAUFFEUR-Assistant-equipped vehicles on the motorway and the number of lanes.
Socio-economic impact:	Costs vs. benefits: the results of the cost/benefit analysis conducted for the CHAUFFEUR Assistant function proved that CHAUFFEUR Assistant will bring considerable benefits from a political and economic point of view. Depending on the equipment rate, a benefit cost ratio of up to 4.5 can be expected.

COMUNICAR

COMUNICAR (Project start/end: 01.01.2000-31.12.2002) Communication multimedia unit inside car Partners: C.R.F. Societa Consortile per Azioni (Coordinator) (I); Bundesanstalt für Straßenwesen (DE); Borg Instruments GmbH (DE); DaimlerChrysler AG (DE); Fraunhofer Gesellschaft zur Förderung der Angewandten Forschung e.V. (DE); Metravib (F); Netherlands Organisation for Applied Scientific Research - TNO (NL); The National Technical University of Athens (GR); Universita degli Studi di Genova (I); Universita degli Studi di Siena (I); Volvo Car Corporation (SE) Funded by the European Commission DG INFSO Fifth Framework Project Reference: IST-1999-11595 http://www.comunicar-eu.org/	
Main objectives:	Development of an appropriate HMI able to manage all simultaneous input/output messages, thus improving the driver's comfort and safety by increasing alertness and reducing the workload involved in the driving task
Work packages:	- WP1: Project management - WP2: User needs and state of the art - WP3: Function specifications - WP4: Multimedia HMI virtual prototyping - WP5: Multimedia HMI development and in-vehicle integration and verification - WP6: Testing. demonstration and pilot validation - WP7: Dissemination and implementation - WP8: Project assessment and evaluation
Technology:	Audio, video and haptic feed back systems, their combination and the use of an information manager were used
Market:	User acceptance
Traffic:	None
Socio-economic impact:	None

DIATS

DIATS (Project start/end: 01.04.1996-31.03.1999), Final Report May 1999

Deployment of Interurban ATT Test Scenarios (Advanced Transport Telematics)

Partners: Transportation Research Group, University of Southampton (Co-ordinator) (GB); Transport Research Laboratory (GB); Department of Law, University of Southampton (GB) INRETS (FR); INRIA (FR); Heusch Boesefeldt GmbH (DE); Technical University of Hamburg (DE); SINTEF (NO); STRATEC (BE)

Funded by the European Union DG VII Fourth Framework

Project Reference: RO-96-SC.0301

http://www.trg.soton.ac.uk/diats/diats.htm

Main objectives:	- Identification of options currently available and likely to become available in the short and medium terms for implementing “co-operative driving”, based upon ATT systems for motorway-type roads. - Development of scenarios of “highest potential impact” for each of the systems identified. - Identification of the key elements required to successfully deploy these ATT measures in field tests and to create awareness of the potential of this area of Traffic, Transport and Information Management.
Work packages:	- Identification of ATT systems - Development of implementation scenarios - Definition of testing and evaluation methods - Simulation modelling - Assessment of behavioural response and user issues - Evaluation of safety issues - Identification of strategies for ATT implementation - Liaison with owners and user groups
Technology:	- The following ATT systems were identified as being a first priority option for development up to 2002: automatic incident detection; ramp metering; AID, ramp metering and VMS; COMPANION/Intelligent Road Studs; adaptive cruise control (ACC). ACC with dialogue management was identified as second priority, automated highway as third priority.

Market:	- The highest deployment potential for fixed-infrastructure systems was determined for a combination of systems consisting of AID operating with VSL and other warning systems, such as variable message signs or warning lights. The vast majority of operators considered the linking of AID and VMS systems to be necessary to provide information to the drivers about incidents ahead and potential routing options. - Deployment potential for in-vehicle – fixed infrastructure combinations: The rate at which consumers will buy the new systems and use them depends greatly on the individual system characteristics. First-stage driver assistance devices will operate independent of the infrastructure, although the possibility exists for systems to be controlled by the infrastructure. Government and network operators can influence the rate at which new driver assistance technologies reach the market through fiscal incentives and by assisting in the removal of potential legislative barriers to deployment. - There was a desire to see the potential for the automated highway concept unlocked which will offer increased capacity. However, the path to reaching this goal was not clear and this explains the focus of national administrations on driver assistance systems, driver information and fixed control systems in the run up to 2002. - Deployment barriers: All of the systems, with exception of the Automated Highway concept, have been implemented in Europe. From this point of view it was argued that there were no insurmountable barriers to the deployment of these technologies. Several additional considerations for successful deployment were outlined for each technology.
Traffic:	- The benefits of AID systems, both in improving network efficiency and in reducing the number of unsafe situations leading to an incident were confirmed. The impact of the AID system depends on three main factors: traffic demand, distribution of accident types, and reduction in incident duration. - Ramp metering was shown to be extremely effective in reducing congestion which occurred under the same conditions without the system, particularly at highest demand levels. - The main benefit of VSL was perceived to be a harmonisation of speed between motorway lanes. - Warning lights were found to reduce accidents by reductions in short time headways and average deceleration of vehicles. - ACC has been shown to provide support to the driver in the control of the longitudinal driving task, with reductions in the variation of acceleration of around 46%.
Socio-economic impact:	- ADAS Assessment Guidelines have been developed. These consist of 7 stages: 1. Preliminary Assessment, 2. Scenario Analysis, 3. Human Factors Investigation, 4. Stated/Revealed Preference Surveys, 5. Microscopic Assessment, 6. Link Assessment, 7. Field Trials.

E-Merge

E-Merge (Project start/end: 01.04.2002-31.03.2004), Final Report June 2004

Pan-European Harmonisation of Vehicle Emergency Call Service Chain

Partners: ERTICO (B); Opel (D); GDV (D); Telmacon (D); Volvo Technological Development (S); SOS Alarm Sverige (S); Comuni di Milano (I); Peugeot Citroen Automobiles (F); ACASERVI (E); SEAT (E); Mizar Automazione (I); CRF (I); Office of the Deputy Prime Minister (GB); Association of Chief Police Officers United Kingdom (GB); Cap Gemini Ernst & Young (NL)

Funded by the European Commission DG INFSO, Fifth Framework

Project Reference: IST-2001-34061

http://www.e-merge.org

Main objectives:	- Establish a harmonised in-vehicle emergency call service which works throughout Europe and which is not limited to any particular service provider in a country - Deliver and demonstrate the concept for in-vehicle eCall - Extend availability of eCall services in European countries - Enhance rescue chain efficiency
Work packages:	- WP 1: Project Management - WP 2: User Needs - WP 3: Specification of System - WP 4: System Development - WP 5: Trials - WP 6: Validation - WP 7: Dissemination & Exploitation
Technology:	- Tested and validated specifications for the interface between in-vehicle eCall system and Public Safety Answering Points (PSAP) at pan-European level - Tested and validated specifications for the interface between PSAP and Service Provider at pan-European level - Specifications for the Minimum Set of Data (MSD) - Specifications on how to transmit MSD as data over the 112 voice channel - Recommendations on related issues such as in-vehicle system design, PSAP system design, SP design and Full Set of Data
Market:	Deployment considerations: introducing eCall in 1-2 “advanced” EU member states and collect experiences; then large-scale deployment, also small implementation in one of the new member states for referential values
Traffic:	- Emphasised the Golden Hour Principle of Accident Medicine, which means that lower rescue times will improve survival chances of accident victims with severe injuries - Assessed the safety impact of eCall by experts (questionnaire): fatalities and severe injuries can both be reduced by an average of between 5 % and 10 %

Socio-economic impact:	- Safety improvements converted to monetary values lead to annual savings of between 5 and 10 billion euros (depending on the cost unit rates used) - Benefit-cost assessment was carried out as business case evaluation for different stakeholders, no aggregate assessment on society level (D6.3) - Stakeholders addressed: vehicle manufacturers, member states incl. PSAP and emergency dispatchers and operators, mobile telecom operators, private service providers incl. automobile clubs, insurance companies, equipment manufacturers, individual drivers - Exemplified benefits for equipment manufacturers: new market for all vehicles in Europe (17 billion euros), additional margin when deployment enforced by public authorities or insurance companies (170 million euros), replacement speeded up, whereas costs are limited to those involved in launching a new product (= standard business risk)

EDEL

EDEL (Project start/end: 01.03.2002- 28.02.2005)

Enhance driver's perception in poor visibility

Partners: Centro Ricerche Fiat Societa Consortile per Azioni (Coordinator) (I); Hella KG Hueck & Co. (DE); Jaguar Cars Limited (UK); Osram Opto Semicondustors GmbH & Co. OHG (DE); Robert Bosch GmbH (DE); Universita degli Studi di Genova (I); Universita degli Studi di Siena (I); Universität Karlsruhe (DE)

Funded by the European Commission DG INFSO, Fifth Framework

Project Reference: IST-2001-34076

http://www.edel-eu.org

Main objectives:	Development of an advanced vision enhancement system for night vision application based on near infrared sensor, a novel illumination system and an adaptive HIM
Technology:	Active infrared
Market:	none
Traffic:	none
Socio-economic impact:	Impact assessment of proposed technology, data not yet available

GST

GST (Project start/end: 01.03.2004-28.02.2007), Presentation

A global system for telematics enabling on-line safety services

Partners: ERTICO (Coordinator) (BE); MECEL AB (SE); Telediffusion de France (F); Centro Ricerche FIAT Societa Consortile per Azioni (I); Netherlands Organisation for Applied Scientific Research – TNO (NL); Telecom Italia SPA (I); FORD Forschungszentrum Aachen GmbH (DE); Regienov (F); Technische Universität München (DE); Trusted Logic (F); Q-Free ASA (N); Adam Opel AG (DE); PTV Planung Transport Verkehr AG (DE); Tele Atlas N.V. (NL); European Broadcasting Union (CH); Trialog (F); France Telecom (F); Katholieke Universiteit Leuven (BE); Telematics Cluster VZW (BE); Vialis Verkeer & Mobiliteit BV (NL); TUEV Inter Traffic GmbH (DE); Prosyst Software AG (DE); Kreis Offenbach, Eigenbetrieb Rettungsdienst (DE); Gewi Hard- und Software Entwicklungsgesellschaft mbH (DE); AVE Verkehrs- und Informationstechnik GmbH (DE); ALLIANZ Zentrum für Technik GmbH (DE); Motorola Electronics S.P.A. (I); Aircraft Development and Systems Engineering (ADSE) B.V. (NL); Pendragon Medical AG (CH); RSA Security Ireland Limited (IRL); Interconnect Communications Limited (UK); ORANGE (F); Petards Mobile Intelligence A/S (DEN); Sussex Police Authority (UK); Gatespace AB (SE); Wirelesscar Sweden AB (SE); IT-Forskningsinstitutet Viktoria AB (SE); Telmacon GmbH (DE); Siemens VDO Automotive AG (DE); Istituto Superiore Mario Boella Sulle Tecnologie dell'Informazione e delle Telecomunicazioni (I); Swedish National Road Administration (SE); SES ASTRA (LU); VOLVO Technology AB (SE); BMW Forschung und Technik GmbH (DE); DaimlerChrysler AG (DE); MIZAR Automazione S.P.A (I).; Robert Bosch GmbH (DE); Navigation Technologies B.V. (NL); T-Systems Nova GmbH (DE)

Funded by the European Commission DG INFSO, FP 6, Integrated Project

Project Reference: 507033

http://europa.eu.int/information_society/programmes/esafety/forum/rtd_projects/text_en.htm

Main objectives:	- Create an open market for telematics services (create horizontal market for on-line services, bring key safety and market-enabling services to market) - Provide a common framework for the deployment of co-operative systems
(Work packages) Organisation:	- Technology-oriented subprojects - Service-oriented subprojects - Field trials in eight cities - Validation results
Technology:	- Open systems: enabling co-operation and infrastructure sharing between all modes (expected) - System and data protection, privacy and reliability (expected) - Common approach for service payment and billing (expected) - eCall as standard feature in future cars (expected) - Enhanced floating Car Data uploads and safety channel broadcasts to allow wide range of safety-enhancing and added-value services (expected) - Too early for results, monitoring will be continued
Market:	- Certification in order to promote rapid service deployment (expected) - too early stage of project for results, monitoring will be continued
Traffic:	- not specifically addressed
Socio-economic impact:	- not specifically addressed

HUMANIST

HUMANIST (Project start/end: 01.03.2004-29.02.2008), Presentation

Human-centred design for information society technology

Partners: Europe Recherche Transport (Coordinator) (F); Institut National de Recherche sur les Transports et leur Sécurité (F); Bundesanstalt für Straßenwesen (DE); Centrum Dopravniho Vyzkumu (CZ); Technische Universität Chemnitz (DE); Danish Transport Research Institute (DK); Eurisco International (F); Factum OHG (A); Centre for Research & Technology Hellas/Hellenic Institute of Transport (GR); BIVV Belgisch Instituut voor de Verkeersveiligheid VZW (BE); Institute of Communication and Computer Systems (GR); European Commission - Joint Research Centre (BE); National Technical University of Athens (GR); SWOV Institute for Road Safety Research (NL); TNO Human Factors (NL); Institute of Transport Economics; TRL Limited (GB); Universidad Politecnica de Madrid (E); Universidade Técnica de Lisboa, Faculdade de Motricidade Humana (P); Statens Vag- Och Transportforskningsinstitut (SE); Technical Research Centre of Finland (FIN); Institute for Occupational Physiology at the University of Dortmund (DE)

Funded by the European Commission DG INFSO, FP 6, Network of Excellence

Project Reference: 507420

http://europa.eu.int/information_society/programmes/esafety/forum/rtd_projects/text_en.htm

http://www.noehumanist.org/

Main objectives:	- Promotion of road safety and mobility through road/vehicle telematics and communication technology with research in HMI - Federate the research in the domain of user/system interactions and their applications on road telematics and driver assistance systems and create a European Virtual Centre of Excellence on HUMAN-centred design for Information Society Technologies applied to road transport.
(Work packages) Organisation:	- Research Task Forces (Driver needs and ITS, ITS potential benefits, cognitive engineering and human-centred design, ITS driving behaviour, methodologies for ITS safety, education and training for ITS, ITS to train and educate) - Integration Task Forces (Mobility Improvement, Research infrastructure Sharing, Electronic Means) - Dissemination Task Forces (Transfer of knowledge, Training programme, Diffusion of knowledge)
Technology:	- Knowledge database on system design criteria (expected) - Too early for results, monitoring will be continued
Market:	- Too early for results, monitoring will be continued
Traffic:	- Too early for results, monitoring will be continued
Socio-economic impact:	- Too early for results, monitoring will be continued

INVENT

INVENT (Project start/end: 01.06.2001-31.05.2005), INVENT brochure (“Mobile With Eight Senses”) and supplements

Intelligent traffic and user-oriented technology

Partners: Adam Opel AG; AUDI AG; BMW Group; DaimlerChrysler AG; Deutsches Zentrum für Luft- und Raumfahrt e.V. (DLR); Ericsson Eurolab; Deutschland GmbH; Ford Forschungszentrum Aachen GmbH; Forschungsgesellschaft Kraftfahrwesen mbH Aachen (fka); Hella KG Hueck & Co.; Hermes Versand Service GmbH; IBM Deutschland GmbH; Institut für Automation und Kommunikation e.V. Magdeburg (ifak); MAN Nutzfahrzeuge AG; Navigation Technologies NAVTEQ GmbH; PTV Planung Transport Verkehr AG; Rechtsanwälte Vogt und Kollegen; Robert Bosch GmbH; Siemens AG; Siemens Restraint Systems GmbH; Siemens VDO Automotive AG; TRANSVER GmbH; TÜV Kraftfahrt GmbH, Universität zu Köln; Volkswagen AG (all DE)

Funded by the German Federal Ministry of Education and Research, research initiative

http://www.invent-online.de/

Main objectives:	- Improvements in traffic safety - Optimisation of traffic flow - Synthesis of individual and community goals in routing and traffic management - Self-organisation of traffic using information in the traffic network - User-friendly technology
(Work packages) Organisation:	- Driver Assistance / Active Safety with five subprojects (two ADAS applications projects: Anticipatory Active Safety, Congestion Assistance, three horizontal projects dealing with driver behaviour and HMI, detection and interpretation of the driving environment, traffic impact, legal issues and acceptance), assessment activities are concentrated within horizontal subproject (traffic impact, legal issues and acceptance) - Traffic Management 2010 - Traffic Management in Transport and Logistics
Technology:	- Enlargement of ACC functionality to stop+go situations - Systems and components supporting lane changing and turning manoeuvres (e.g. lateral control assistance, intersection assistance, pedestrian and cyclist protection, predictive control of vehicle dynamics) - Applications concerning merging of intelligent vehicles and intelligent infrastructure - Demonstration of systems in April 2005
Market:	- Functionality and acceptance of assistance systems to be developed is tested - in order to optimise system design - with traffic simulation algorithms and surveyed according to user acceptance and willingness-to-buy - Workshop on market deployment of driver assistance systems, documentation available in spring 2005
Traffic:	- Integrated traffic simulation platform (bringing together several traffic simulation programmes) to optimise ADAS system specification
Socio-economic impact:	- Socio-economic assessment of the ADAS applications developed (CBA for society, individual break-even-calculations, social impacts), results available in spring 2005

PREVENT

PREVENT (Project start/end: 01.02.2004-2008)

Preventive and active safety applications

Partners: DaimlerChrysler AG (DE) (IP Coordinator); IP Core Group: BMW AG (DE); Robert Bosch GmbH (DE); CRF (I); Ford (DE); PSA (F); Rgionev (F); Sagem (F); Siemens VDO (DE); VolvoTEC (SE); Inrets (F); etc. (more than 50 partners including OEMs, suppliers, SMEs and organisations)

Funded by the European Commission DG INFSO, Sixth Framework, IP

http://europa.eu.int/information_society/programmes/esafety/forum/rtd_projects/text_en.htm

Main objectives:	PReVENT will develop, test and evaluate safety-related applications, which use existing advanced sensors and communications devices integrated into on-board systems for driver assistance. In short, PReVENT will help drivers to avoid accidents. Depending on the significance and timing of the hazard detected, the types of systems examined in PReVENT will alert drivers as early as possible, warn them, and if there are no reactions from the driver, actively assist and intervene accordingly as far as possible.
Work packages:	- Vertical, application-oriented fields of research: - Safe Speed and Safe Following - Lateral Support and Driver Monitoring - Intersection Safety - Vulnerable Road Users and Collision Mitigation - Horizontal issues relevant to all PReVENT activities were also identified and include sensor and sensor data fusion, digital map-related issues, and common impact assessment, as well as a sub-project centred around a “liability-risk mitigation” strategy.
Technology:	- Use of existing technology - Development of 3D camera system, but based on existing technology - Development and integration of several intelligent vehicle safety systems (functions)
Market:	- Work packages address impact assessment and liability strategies
Traffic:	- Not relevant
Socio-economic impact:	- Assessment requested

PROMETHEUS

PROMETHEUS (Project start/end: 01.01.1987- 31.03.1995) Programme for European traffic and high efficiency and unprecedented safety Partners: DaimlerChrysler (Coordinator) (DE); e.g. Porsche AG (DE); Siemens Automotive S.A. (DE); SNR (F); Ford Motor Car Company Limited (UK); Mecel (SE); VolvoCar Corporation (SE); MAN Nutzfahrzeuge AG (DE); different universities and research institutes from 11 European countries (total: approx. 230) EUREKA Project E!45 Project Reference:	
Main objectives:	Creation of concepts and solutions which would point the way to a road traffic system with greater efficiency economy and with reduced impact on the environment combined with a degree of unprecedented safety
Technology:	Definition of needed technologies for requested safety functions
Market:	Not covered
Traffic:	Not covered
Socio-economic impact:	Expert meaning

PROTECTOR

PROTECTOR (Project start/end: 01.01.2000-31.03.2003), Final Report October 2003 Preventive safety for unprotected road user Partners: Centro Ricerche Fiat S.C.p.A. (Coordinator) (I); DaimlerChrysler AG (DE); MAN Nutzfahrzeuge AG (DE); IBEO Lasertechnik Hipp KG (DE); Siemens VDO (DE); TÜV Kraftfahrt GmbH (DE); Università die Pavia (I); Institut für Kraftfahrwesen Aachen (DE); Centro Studi sui Sistemi di Trasporto (I) Funded by the European Commission DG INFSO, Fifth Framework Project Reference: IST - 1999-10107 http://www.crfproject-eu.org/	
Main objectives:	The general objective was the improvement of the safety of vulnerable road users (pedestrians, cyclists, motorcyclists) in urban and rural areas, through the interaction of enhanced autonomous on-vehicle sensors (based on laser, microwave and computer vision technologies) with corresponding components carried by the road users themselves (transponders, microwave/optical reflectors, etc.). The operative objectives of the project were the development, evaluation and validation of these autonomous and/or cooperative detection methods, either in a real environment or in an "ad hoc" established test site for the most critical scenarios, at both automobile and commercial vehicle level.
Work packages:	- Definition of the PROTECTOR concept - HMI definition and development of warning and control strategies - Sensing system analysis to identify sensors to be adapted for the application - Building and validation of the demonstrator vehicles - Testing in commercial vehicles and automobiles, parallel evaluation at simulation level - Cost/benefit analysis of the PROTECTOR implementation - Exploitation of the results

Technology:	- The project developed three demonstrator vehicles equipped with VRU detection systems, risk assessment modules and HMI devices to achieve the VRU protection application. - All sensor systems were successfully able to demonstrate a proof of concept for VRU detection/classification. For the first time, VRU detection systems were exposed to the very complex urban scenario, with promising results. The main technical challenge ahead is to reduce the number of false detections while maintaining the correct detection rate at a reasonable level. The field tests suggested that the strengths of the radar and laser-scanner lie more in the area of VRU obstacle detection, whereas the stereo vision sensor is quite suitable for VRU object classification. The introduction of the risk assessment module showed a relevant reduction in false warnings, thanks to the probability functions developed for this application. - A significant outcome was that the EU guidelines used in the design and evaluation phases received a relevant contribution so that the general test methodology followed in the project can be taken as a reference for future work in this area. - Sensor fusion is an appealing option for increasing the robustness of classification, and there is reason to be optimistic about VRU detection/classification progress.
Market:	- The evaluation of user acceptance on test tracks and on public roads involved gathering data at three different levels: cognitive, emotional and motivational. We also requested a general assessment of the system and a forecast of future developments. The idea and the approach of the system made a good impression on most subjects; however the amount of false alarms was unacceptable.
Traffic:	- Not addressed
Socio-economic impact:	- Not addressed

RADARNET

RADARNET (Project start/end: 01.01.2000-30.10.2004) Multifunctional automotive radar network Partners: Siemens AG (Coordinator) (DE); AB Volvo (SE); BMW AG (DE); C.R.F. Societa Consortile per Azioni (I); DaimlerChrysler AG (DE); Infineon Technologies AG (DE); Institut National Polytechnique de Toulouse (F); Jaguar Cars Limited (GB); The University of Birmingham (GB); Technische Universität Hamburg-Harburg (DE) Funded by the European Commission DG INFSO, Fifth Framework Project Reference: IST-1999-14031 http://www.radarnet.org/start.htm	
Main objectives:	Development of a new type of multifunctional, low-cost radar network. Within this project, new safety-related intelligent vehicle functions which required radar network functionality were to be developed.
Work packages:	- Development of vehicle safety functions - Development of a new 77 GHz GaAs radar system - Development of a multifunctional radar network - Creation of prototypes
Technology:	- 77 GHz GaAs radar systems - Sensor and data fusion concepts
Market:	- Not covered
Traffic:	- Not covered
Socio-economic impact:	- Not covered

RESPONSE

RESPONSE 1 (Project start/end: 1998-2000), Final Report December 2001

Vehicle Automation – Driver Responsibility – Provider Liability: Legal and Institutional Consequences

Partners: TÜV Kraftfahrt GmbH (DE); Barlow Lyde & Gilbert (GB); Bayerische Motorenwerke AG (DE); Alain Bensoussan – Avocats (F); Robert Bosch GmbH (DE); Clifford Chance Pünder (GB); DaimlerChrysler AG (DE); Centro Ricerche Fiat S.C.p.A (I); Ford Forschungszentrum Aachen GmbH (DE); Jaguar Cars Limited (GB); Studio Legale Macchi di Cellere e Gangemi (I); Motor Industry Research Association (GB); PSA Peugeot Citroen (F); Renault Recherche Innovation (F); Estudio Juridico Sanchez Calero (ES); Setterwalls Advokatbryå, Autocruise S.A. (F); Transport Research Foundation (GB); Volkswagen AG (DE); Volvo Technological Development Corporation (S); Swedish National Road and Transport Research Institute (S)

Project Reference: Fourth Framework Telematics Applications Programme Transport Sector Contract TR 4022 of the European Community

http://www.adase2.net/response

Main objectives:	The relevant areas for market introduction of Advanced Driver Assistance Systems were analysed and structured from a non-technical point of view.
Work packages:	- System Safety, user perspective, and legal concerns - Overview on Advanced Driver Assistance Systems and their Classification - The average driver and Driver-System Interaction - Technical Safety and Risk Analysis - Assessment of ADAS - Legal Aspects of Testing - Legal Aspects of Market Introduction
Technology:	The focus was the market introduction of all kinds of Advanced Driver Assistance Systems.
Market:	The outcome of the project for the market introduction of ADAS included: - A concept concerning the interaction between system safety, safety of usage and (product) liability, - An analysis of the legal aspects of the testing and market introduction of ADAS resulting in recommendations for manufacturers, suppliers and public authorities, - A conceptual checklist for the translation of user needs into product design, - Validation procedures for the user-centred assessment of ADAS, - Recommendations for functional specifications, standardisation, and type approval. RESPONSE concluded that ADAS systems remain “unproblematic” from the legal and user’s viewpoint only as long as they can be controlled and/or overridden by the driver at any time.
Traffic:	Not specifically addressed
Socio-economic impact:	Not specifically addressed

RESPONSE 2

RESPONSE 2 (Project start/end: 01.09.2002-30.04.2004), Final Report May 2004 Advanced Driver Assistance Systems (ADAS): From Introduction Scenarios towards a Code of Practice for Development and Testing Partners: Daimler Chrysler AG (DE); Centro Ricerche Fiat (I); Netherlands Organisation for Applied Scientific Research (TNO) (NL); Peugeot Citroen Automobiles Sa France (F); European Road Transport Telematics Implementation Co-ordination Organisation (ERTICO) (B); Audi AG (DE); Robert Bosch GmbH (DE); BMW AG (DE); Thomas Miller &CO (GB); Ford-Werke AG (DE); University of Cologne (DE) Project Reference: IST-2001-37528 http://response.adase2.net/	
Main objectives:	RESPONSE 2 was conceived as an intermediate step between the 5th and 6th Framework Programmes. Together with the ADASE 2 cluster project, Response 2 prepared the ground for a big e-Europe initiative for market introduction of ADAS and, especially, active safety systems. Its main objectives, therefore, were: - To start with the legal requirements of “reasonable safety” and “duty of care” and define them in an agreement of industry and beyond - To move towards a code of practice for the development and testing of ADAS from an integrated system safety and human factor perspective
Work packages:	- Market Introduction Scenarios - Risk Benefit Analysis - Towards a Code of Practice
Technology:	The focus was the market introduction of all kinds of Advanced Driver Assistance Systems.
Market:	- The technology “Scenario Management” of work package 2 “Market Introduction Scenarios” provided a deep understanding of the development possibilities of the ADAS market situation into the year 2010. The market scenarios consisted of the following steps: - In the first step, the analysis of future influential Enablers/Disablers led to the determination of two key factors which will significantly determine the future market situation of ADAS. The first one is the “Usability of ADAS”; the second is the “Financial Risk for OEM”. - The next step provided a development of these key factors with an extreme projection into the year 2010. The combination of these projections resulted in four future scenarios supplying a description of a possible future. Identified key factors are the “Usability of ADAS” and the “Financial risk for OEM”. - Both influencing factors “Usability of ADAS” and “Financial risk for OEM” therefore dominate the development and the question of whether and how ADAS will be introduced to and established in the market. Success will only be achieved if both influencing factors lead to “adequate development”: i.e. “high usability” and “low financial risk”.
Traffic:	Not specifically addressed
Socio-economic impact:	The socio-economic considerations were the subject of WP 2 and are analysed from a market perspective.

SAVE-U

SAVE-U (01.03.2002-28.02.2005)

Sensors and system architecture for the protection of vulnerable road users

Partners: Faurecia Industries (Coordinator) (F); Commissariat a l'Energie Atomique (F); DaimlerChrysler AG (DE); Mira Ltd. (GB); Siemens VDO Automotive AG (DE); VW AG (DE)

Funded by the European Union DG VII Fifth Framework

http://www.save-u.org/file_html/library.htm

Main objective:	The main objective of SAVE-U is to develop an integrated system for the active protection of unprotected road users (UPR) such as pedestrians and cyclists. The target set by the EU was to reduce pedestrian fatalities by 30 % and severe injuries by 17 % by 2010. The project deals with 3 different stages: - The detection of the UPR at sufficient distance (up to 30 metres in an urban environment) covering the largest range of scenarios; - The definition and implementation of driver warning and vehicle control strategies in order to avoid a crash; - The definition of strategies for the active protection of UPRs if a collision cannot be avoided.
Work packages:	- WP1: Scenario analysis and data collection - WP2: Analysis of dressed human body characteristics - WP3: Identification of system concepts for the protection of VRUs - WP4: Specification of sensor platform and ECUs - WP5: Definition of detection strategy and design of sensor platform - WP6: Development of Image sensor and image processing - WP7: Development of radar network, sensors and ECUs - WP10: Building of prototypes and fitting on cars - WP11: Development of test methods, evaluation - WP12: Project management - WP13: Assessment and evaluation of project progress - WP14: Dissemination and implementation
Technology:	A new SAVE-U sensor platform will be created. This platform will operate three different technologies and will combine data for optimised UPR detection (e.g. 24 GHz radar sensors, multi-sensor processing algorithms; IR/video cameras; image segmentation algorithms; image processing platform; multi-cue detection algorithms, closed-loop tracking strategies, high- and low-level data fusion, exchange of sensor raw data): At the end of the project, two experimental vehicles will be equipped with prototypes of the innovative sensor platform and with the novel driver warning and vehicle control strategies.
Market:	- Not covered
Traffic:	- Not covered
Socio-economic impact:	Deliverable 6: matrix for the evaluation of actuators relying on the following indicators: reversible/irreversible; passive/crash-active/preventive methods; protection of UPR of car occupants; protection potential from an accident statistic point of view; avoidance/reduction of first impact; avoidance/reduction of second impact.

STARDUST

STARDUST (Project start/end: 01.03.2001-31.05.2004), Final Report July 2004

Towards sustainable town development: a study of the deployment of sustainable urban transport systems

Partners: University of Southampton (Coordinator) (GB); Stratec S.A. (BE); The Foundation for Scientific and Industrial Research at the Norwegian Institute of Technology (NO); French National Institute for Transport and Safety Research (F); French National Institute for Research in Computer Science and Control (F); University of California-Berkeley (USA)

Funded by the European Union DG VII Fifth Framework

Project Reference: EVK4-CT-2000-00024

http://www.trg.soton.ac.uk/stardust/index.htm

Main objectives:	- The objective of the STARDUST project was to assess the extent to which ADAS (Advanced Driver Assistance Systems) and AVG (Automated Vehicle Guidance) systems can contribute to sustainable development in an urban environment. - An impact assessment of ADAS and AVG application was carried out with respect to traffic efficiency, safety and environmental impacts.
Work packages:	- WP 10: Critical analysis of ADAS and AVG options in 2010 - WP 20: Definitions and scenarios for the deployment of ADAS/AVG systems and related evaluation framework - WP 30: Assessment of behavioural acceptance of ADAS/AVG systems - WP 40: Human factor investigation of ADAS and AVG systems - WP 50: Towards assignment tools through micro-simulation - WP 60: Assessment of large-scale deployment of ADAS and AVG by simulation - WP 70: Legal and institutional aspects of the deployment of ADAS/AVG: review and synthesis of existing analysis - WP 80: Systems evaluation - WP 90: User group liaison - WP 100: Dissemination activities - WP 110: Project management
Technology:	- Investigated systems: adaptive cruise control and stop+go control, lane departure warning (incl. lane-keeping assistance), intelligent speed adaptation (ISA), fully-automated driving (cybercars), forward vehicle collision warning system, side-obstacle warning systems (lane change assistance), parking assistance, night vision enhancement systems, driver monitoring
Market:	- Impact assessment comprises user acceptance (based on questionnaires), microscopic traffic simulations (with predefined penetration and use rates), environmental impact and traffic safety
Traffic:	- Traffic simulation for different European cities: Brussels, Paris, Oslo, Southampton - Results show significant reductions in journey times and network queuing times in scenarios with widespread use of systems (e.g. 80% penetration); detailed results are compiled in D10
Socio-economic impact:	- Research on impact channels

TRL Report

TRL Report 220, Report published 1996 Review of the potential benefits of road transport telematics Prepared for Department of Transport (GB) http://www.trl.co.uk	
Main objectives:	- Develop a methodology for the socio-economic assessment of transport telematics systems - Provide likely benefit-cost calculations for a great variety of proposed transport telematics applications (groups: inter-urban, urban, monitoring and enforcement, public transport trip planning, driver information, navigation and guidance, freight and fleet management, automated vehicles, vulnerable road users) - Provide guidance for GB transport policy decisions
Work packages:	- Not relevant
Technology:	- Description of individual systems - System characteristics - Test scenarios
Market:	- Policy context - Existing uses of the application (deployment/penetration)
Traffic:	- Analysis of underlying traffic effects for socio-economic impact assessment - Expected impact per system - Indicators to be used (e.g. travel time savings, vehicle operating costs) - Assumed effects on selected indicators
Socio-economic impact:	- Clear methodology based on ERTICO guidelines - Compilation of impact indicators and used monetary values - Benefit-cost analyses for a great variety of systems, base year 1994 - Examples for results: - Automatic Speed Control – Benefit-Cost Ratio: 1 - Autonomous Intelligent Cruise Control – Benefit-Cost Ratio < 1 (negative benefit-cost flow in the period considered (1998-2007)), results are strongly influenced by the considered benefits (= perceived time savings due to better quality of driving, but no safety impact) - Basic considerations on distributional effects - Sensitivity of the CBA results

6.6 Description of Partners

VDI/VDE Innovation + Technik GmbH

The VDI/VDE Innovation + Technik GmbH (VDI/VDE-IT) is an independent organisation founded by two of Europe’s major scientific and technical organisations, VDI - Association of German Engineers and VDE - Association for Electrical, Electronic & Information Technologies. VDI/VDE-IT employs about one hundred highly qualified people. The professional spectrum of our team includes engineers, natural scientists, business managers, economists and political- as well as social scientists.

VDI/VDE-IT supports industry and science in exploiting and transforming R&D results into innovative products, industrial processes and services. One major industry focus relies on the automotive industry. Our mission focuses not only on technological developments but also on related economic and social implications. Additionally, many years of experience have made us experts in the foundation and the development of technology-oriented companies.

VDI/VDE-IT operates at regional, national and European levels. It participates in the design and is responsible for the implementation and management of innovation support programmes run by the Federal Ministry of Education and Research and the Federal Ministry of Economics and Labour. At international level VDI/VDE-IT undertakes studies and disseminates research results on behalf of the European Commission and the OECD. Since its foundation 1978 in Berlin, VDI/VDE-IT has carried out and supervised more than 6.600 innovative projects and supported more than 1.100 business start-ups.

Further, VDI/VDE-IT is involved in various networks on the national and international level (e.g. the European Foresight Process, Tafti, Europractice, Eurimus Board, Adhesives, Idmap, Nexus, Elsnet).

We support

- foundations of new technology based firms
- development of new products and processes
- introduction of new technologies
- the design of finance, organisation, marketing and distribution conceptions

We organise

- European technology co-operation
- pre-competitive co-operative/joint projects
- seminars, workshops and publications
- concepts of technological politics
- technology networks

We analyse

- trends of technologies
- sociological conditions and structures
- competition, markets and innovation mechanisms

We inform about

- public support programmes
- international dissemination of results

IfV Köln

The Institute's research focuses on transport planning and transport economics. The research covers traffic safety analyses, benefit-cost analysis, break-even analysis, market analyses, competition and integration of transport systems, evaluation tools of assessment, methods of forecasting and evaluation of transport developments, telematics, passenger and freight transport, demand analysis (elasticities, conjoint analysis, stated preference methods, and new econometric approaches), road pricing and fiscal matters of transport. The overall economic analyses are extended by economical analyses and the estimations for the private rentability (e.g. break-even analyses, acceptance analyses). Thereby the research work reaches from the European level over studies with national and regional focus up to the local level. A strong research objective is the efficiency assessment of new Intelligent Transport Systems. In the past, the Institute has completed research projects for a variety of clients, for example

- the German Ministry of Transport,
- the German Ministry of Science and Technology,
- the Federal Highway Research Institute (BASt),
- the European Conference of Ministers of Transport (ECMT),
- the German Transport Forum,

various associations, i. a. road haulage, automobile industry, public transport firms, German Railway (Deutsche Bahn AG).

The Institute is engaged in co-operatives and interdisciplinary research work with planning and engineering expertise (e.g. BASt, TÜV Rheinland). Since the last years, the Institute for Transport Economics is engaged in several European Research Projects covering a broad spectrum of transport topics:

- CANTIQUE – Concerted Action on Non-technical Measures and their Impact on Air Quality and Emissions,
- CHAUFFEUR I and II,
- EUROSIL – European Strategic Intermodal Links,
- EUROTOLL – European Project for Toll Effects and Pricing Strategies,
- MINIMISE – Managing Interoperability by Improvements in Transport System Organisation in Europe,
- PAV-ECO – Economic Evaluation of Pavement Maintenance,
- TENASSESS – Policy Assessment of Trans-European Networks and Common Policy,
- ROSEBUD - Road Safety and Environmental Benefit-Cost and Cost-Effectiveness Analysis for Use in Decision-Making.,
- RESPONSE 2 – Advanced Driver Assistant Systems: from introduction scenarios to a code of practice
- Cartalk 2000 - Safe and comfortable driving based upon inter-vehicle communication