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Master thesis

Scenario analysis for speed assistance

Development and application of a scenario model for the deployment of speed assistance systems

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Abstract

Speed assistance systems have a strong potential to contribute to solving road traffic problems regarding congestion, energy consumption and safety. However, most speed assistance systems are not yet commercially available, and when they are, large-scale deployment takes a long period of time due to several problems. These problems were analysed by means of scenario analysis and the construction and application of a scenario model. Four scenarios were considered varying in the level of demand for speed assistance and the level of market organisation. The analysis and the scenarios indicated that the deployment of speed assistance can lead to penetration rates of up to 50 percent in 2025 in the case of high demand and strong market organisation. Cooperation among stakeholders is therefore the first and most important step towards a new traffic situation, which is smarter, safer and cleaner than today.

Preface

This document is the final report of the scenario analysis I performed within the scope of my graduation in the master Civil Engineering and Management at the University of Twente, main subject Traffic and Transport. The research originated from the knowledge centre Applications of Integrated Driver Assistance (AIDA), which is realised by TNO and the University of Twente. The research took place from February till September 2006 at TNO Mobility and Logistics in Delft as part of the SUMMITS[1] programme.

About a year ago my intention was to perform a research in the field of Intelligent Transport Systems and Advanced Driver Assistance System in particular. A number of interesting research projects were available at the university, but I preferred to work at TNO because I wanted to get acquainted with their working environment. After a while, Bart van Arem defined a research project which I could perform at TNO, which had something to do with ‘scenarios’, a ‘scenario model’, ‘deployment’ and ‘roadmaps’. The next few months I was overloaded with new information, ideas and views from other perspectives and I often didn’t have a clue what we were talking about. Now, seven months later, I can say I (mostly) enjoyed performing this scenario analysis. I have learned a lot and finally understand what we were talking about seven months ago. Better late than never….

What I liked most about my research were the interviews with experts and stakeholders. It was difficult and a bit exciting to discuss with someone who knew much more about the subject then I did. I was glad to find that all respondents were very enthusiastic and happy to receive me at short notice. In a reasonable short period of time I learned very much about deployment, stakeholders and ADA systems and was given the opportunity to visit meetings and workshops and experience driving with Adaptive Cruise Control, Lane Departure Warning and Stop & Go. I would like to thank all the respondents for making this possible.

I would like to take this opportunity to thank a few people. First of all I would like to thank Bart van Arem for creating the possibility to perform an assignment in the field of Advanced Driver Assistance System at TNO. Along with Bart, I would like to thank Cornelie van Driel and Kerry Malone for their useful feedback on my work, their motivation in times my enthusiasm decreased and giving me the freedom to form my work. I would also like to thank Vincent Marchau and Leonie Walta for their comments on my work.

Next, I would like to thank Petie en Kees Zantvoort for accommodating me for seven months. Your care and hospitality made your place feel like home. These seven months, I was happy to have one specific person close to me. Marlies, without your support this period would have been much tougher.

Last but not least I would like to thank my parents for giving me the opportunity to study at a university and supporting me for the years of being a student. Mom, dad, without your support I wouldn’t be where I am standing today.

Delft, September 2006

Jaap Vreeswijk

[1] SUstainable Mobility Methodologies for Intelligent Transport Systems

Executive summary

It is believed that Information and Communication Technologies, which enable the building of intelligent vehicles and infrastructures, provide new advanced solutions that can contribute to solving the transport related societal challenges congestion, energy consumption and safety. Unfortunately, despite their potential, most intelligent systems are not yet on the market, and when they are, large-scale deployment takes a very long period of time due to several problems.

Clearly, there is a need to identify these problems and define a strategy for large-scale deployment. As a result, the objective of this research was to obtain insight into the mechanisms of deployment by *formulating plausible deployment scenarios for Speed Assistance systems by means of scenario analysis and the development of a scenario model.* The focus of this research is on Speed Assistance systems, because the transport problems discussed above are mostly speed related. ‘Speed Assistance (SA) systems’ is a generic term for the three IRSA[2] system variants (Advisory, Intervening and Controlling) and the Congestion Assistant together. SA systems assist the driver in their longitudinal driving tasks by providing speed advice or speed warnings and cruise control-like functionalities. The primary aim of these systems is to calmly reduce the speed of the traffic flow to prevent the formation of shock waves due to abrupt braking manoeuvres and increase the traffic safety. Secondary benefits are expected with regard to throughput, vehicle emissions and driving comfort.

Scenarios are an integrated description of a future state of society or special parts of it, and a plausible sequence of events leading to this future state, without the necessity of including statements on the probability of those events. Exploring the future is a very complex task involving a considerable level of uncertainty. Scenarios are used to address this uncertainty and describe future developments based on explicit assumptions. It has to be noted that there is a clear difference between probable *versus* possible developments. At its best, forecasting gives the reader a hint of what *will happen*. This very markedly differs from scenarios that usually are developed to describe what *can happen* under a certain set of circumstances and assumptions. Giving the reader a number of scenarios leaves him with the impression that the scenarios represent the outer limits of what realistically *can happen*. The reader is left with an option to judge and choose for himself the most plausible path of events within those limits set by the scenarios.

To guarantee the feasibility of this research, the scope of the research was limited to the *most critical* factors with regard to the deployment of SA systems. These factors could be identified by means of interviews among experts and stakeholders. Additionally, the results of the interviews were validated and expanded by means of a literature review. Together, the interviews and literature review identified awareness and acceptance, vision and strategy and coordination and cooperation as the most critical deployment factors. For further analysis these factors were summarised by two overall deployment factors: market development (the development of market demand as the result of awareness and acceptance factors) and market organisation (market structure as the result of cooperation, coordination, vision and strategy).

To indicate the outer limits of probable future developments a scenario landscape was constructed. Market development and market organisation represent the two dimensions of the landscape and the four quadrants represent four scenarios. Extreme projection of the dimensions indicated that market organisation can range from ‘individual’ to ‘collective’ and that market development can range from ‘stable’ to ‘growth’. Stability and growth represent the state of factors that generate market demand such as system acceptance, social need and purchasing power. These factors are low in a stable situation and high in a growing situation. Market organisation indicates the structure of the supply side

[2] Integrated full-Range Speed Assistance

of the market in terms of coordination, cooperation and commitment of stakeholders. 'Collective' represents a situation in which stakeholders have a progressive attitude towards the deployment of SA systems and stimulate the market. When the market is individual the reverse of the above mentioned is true. The four quadrants of the scenario landscape represent the four deployment scenarios Conservative, Regulation, Free market and Progressive, which are characterised by six themes (see figure 1).

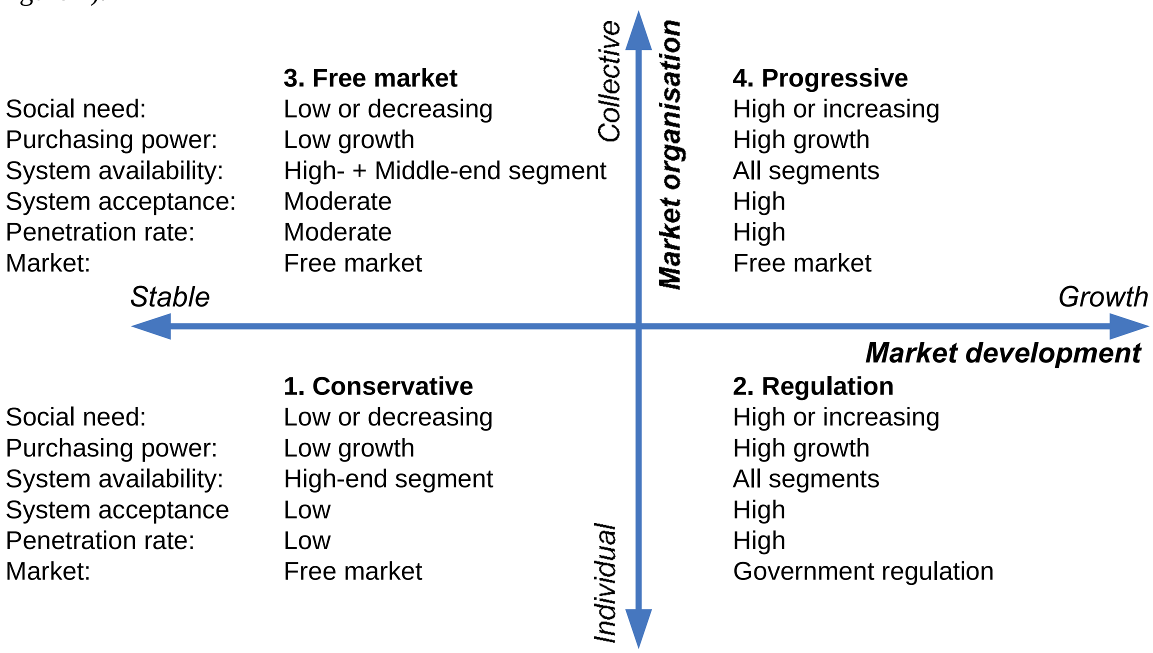


Figure 1: four scenarios for the deployment of SA systems

In this analysis, the development of the deployment of SA systems is measured by the penetration rate of SA systems. Penetration rate is the percentage of vehicles equipped with a particular system. A number of scenario variables and sub-variables are defined, which are likely to induce values for the penetration rate of the system. A schematic presentation of these variables and the relations between them form the basis of the scenario model and present the mechanisms of deployment (see figure 2). The schematic presentation of the scenario model was used to describe the four deployment scenarios theoretically. The scenarios were described as follows:

- *Scenario 1 – Conservative*. This scenario is characterised by a stable market involving low social need, low growth of the purchasing power and low system acceptance. Due to the lack of a technology push there is neither a strong demand nor a strong supply, which results in poor development of the deployment of SA systems.

- *Scenario 2 – Regulation*. This scenario is characterised by a growing market involving high social need, high growth of the purchasing power and high system acceptance. Due to the lack of a technology push, the government acts as the manager of the social interest and regulates the market, which results in a strong development of the deployment of SA systems.

- *Scenario 3 – Free market*. This scenario is characterised by a stable market involving low social need, low growth of the purchasing power and initially, low system acceptance. Due to cooperation between the government and car manufacturers a strong technology push arises. As the result of promotion and pricing strategies the system acceptance increases and the deployment of SA systems starts to develop moderately.

- *Scenario 4 – Progressive.* This scenario is characterised by a growing market involving high social need, high growth of the purchasing power and high system acceptance. Due to cooperation between the government and car manufacturers a strong technology push arises. The combination of strong demand and strong supply result in a strong development of the deployment of SA systems.

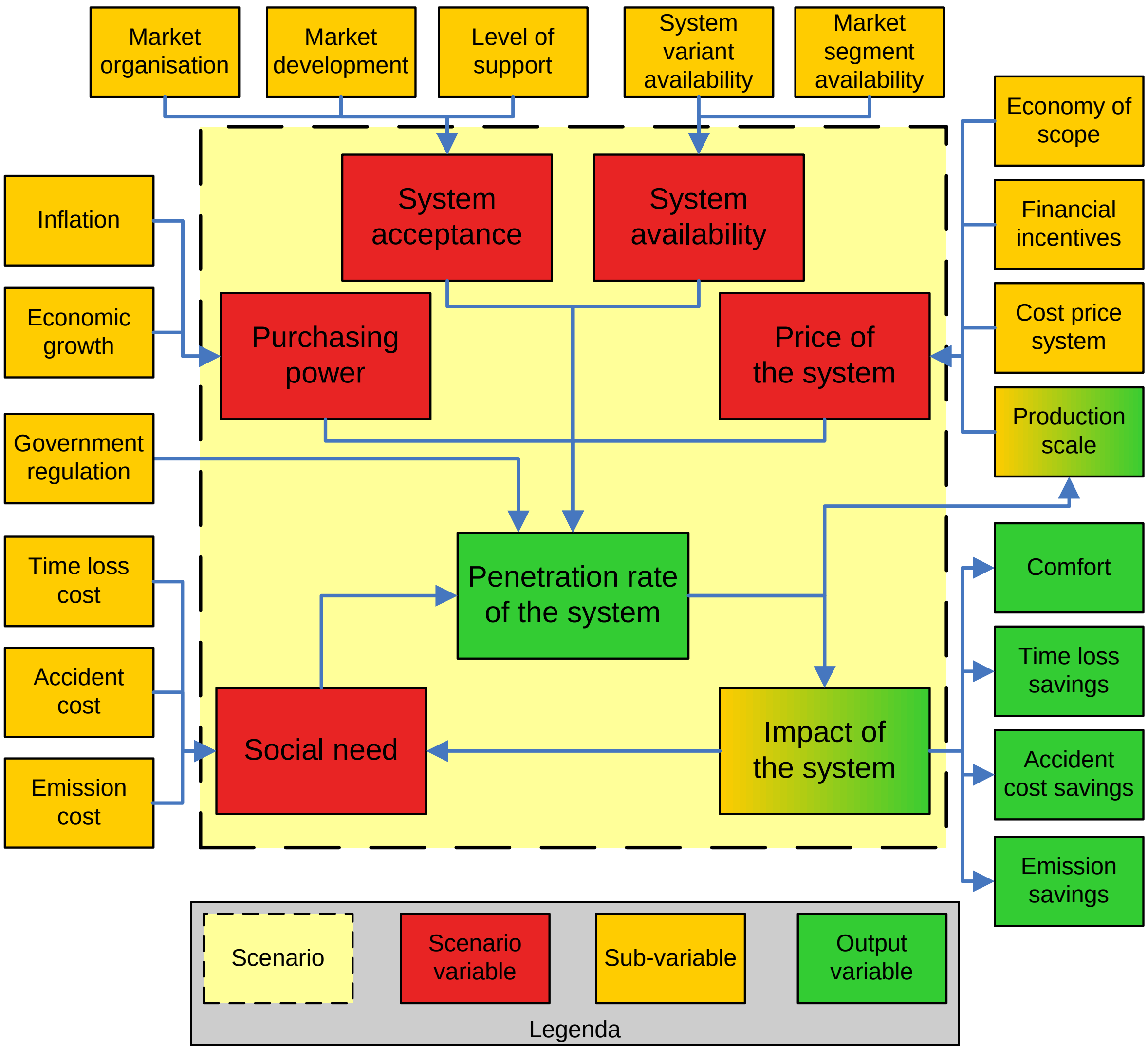


Figure 2: schematic presentation of scenario model

To evaluate the consequences of the scenarios a scenario model was applied. First the scenario variables and sub-variables were quantified and mathematical equations were formulated for the relations between the variables. In the end, the four deployment scenarios were quantified and the expected penetration rates were calculated for each scenario.

The results showed that the penetration rate of SA systems increases most in the scenarios 2 and 4, that the penetration rate of SA systems develops the least in scenario 1, and that scenario 3 is a hybrid between the scenarios 1 and 4. From these results it can be concluded that the deployment of SA systems is subject to two key drivers: government regulation (scenario 2) and cooperation between the government and car manufacturers (scenarios 3 and 4). Additionally, with regard to the users, system acceptance, social need and financial factors like purchasing power and financial incentives can make a significant difference. In general it can be concluded that under specific market conditions penetration rates of up to 50 percent can be reached in 2025. Specifically, the penetration rates of the IRSA Advisory and IRSA Intervening variants can develop fast, but the penetration rates of the IRSA Controlling variant and the Congestion Assistant develop much slower. . These differences can easily be explained because the IRSA Controlling variant and the CA are more expensive, less accepted and available at a later stage. On the basis of the findings from the interviews, literature review and scenario development it can be concluded that the scenarios 3 and 4 are most likely. Although these scenarios seem most plausible, it is likely to suggest that scenario 4 is too opportunistic and scenario 3 too conservative. Most plausible seems a hybrid between both scenarios, making the scenarios 3 and 4 the two outer limits of what realistically can happen.

Finally, a possible plausible path of events was suggested in terms of a deployment strategy. In summary, the necessary steps of the deployment strategy should successively be: formulation of a clear vision, bring together all the stakeholders involved, clarify the benefits of the stakeholders, develop a Code-of-Practice on which all stakeholders agree, raise public and political awareness and acceptance and finally guide the take-up of systems with subsidies or mandatory introduction.

In conclusion, scenario analysis and the development of a scenario model to formulate plausible deployment scenarios for Speed Assistance showed that the deployment of SA systems can be successful if specific scenario conditions are created. Much effort is necessary to create the desired scenario conditions, starting with bringing all stakeholders together. It is likely that cooperation among stakeholders is the first, and most necessary step towards a new traffic situation, which is smarter, safer and cleaner than that of today.

Management samenvatting

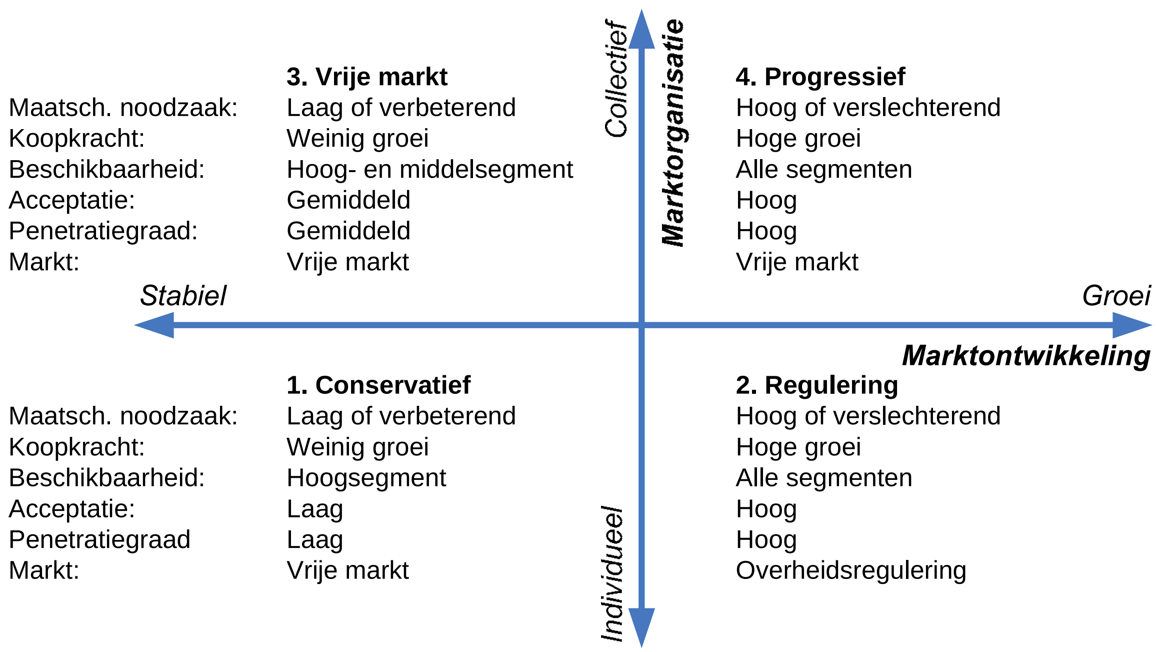
Het is de verwachting dat Informatie en Communicatie Technologieën, die de ontwikkeling van intelligente voertuigen en infrastructuur mogelijk maken, nieuwe geavanceerd oplossingen kunnen bieden die bijdragen aan het oplossen van maatschappelijke uitdagingen zoals files, energieverbruik en veiligheid. Ondanks hun potentie zijn de meeste intelligente systemen helaas nog niet op de markt en als ze dat zijn, heeft invoering op grote schaal lang geduurd als het geval van een aantal problemen.

Uit bovenstaande blijkt dat er een behoefte is om deze problemen te identificeren en een strategie te bepalen voor invoering op grote schaal. De doelstelling van dit onderzoek is derhalve om inzicht te krijgen in de invoeringmechanismen door *plausibele invoeringscenario's te formuleren voor snelheidsondersteunende systemen op basis van een scenario analyse en de ontwikkeling van een scenariomodel.* Dit onderzoek focust op Snelheidsondersteunende systemen, ondermeer omdat bovengenoemde verkeersproblemen veelal een verband hebben met de snelheid van voertuigen. 'Snelheidsondersteunende systemen' is gebruikt als een verzamelnaam voor de drie IRSA systeemvarianten (Adviserend, Intervererend en Controlerend) en de Fileassistent samen. Snelheidsondersteunende systemen ondersteunen autobestuurders in hun longitudinale rijtaak door snelheidsadviezen of snelheidswaarschuwingen en cruis control-achtige functionaliteiten aan te bieden. Het voornaamste doel van deze systemen is om de snelheid van een verkeerstroom geleidelijk te reduceren om de vorming van schokgolven als gevolg van abrupte remmanoeuvres te voorkomen en daarmee de verkeersveiligheid te verhogen. Bijkomende voordelen worden verwacht met betrekking tot doorstroming, uitstoot en rijcomfort.

Scenario's zijn een geïntegreerde beschrijving van de toekomstige staat van (een deel van) de samenleving en een aannemelijke opeenvolging van gebeurtenissen die leiden tot deze toekomstige staat, zonder de noodzaak om een uitspraak te doen over de waarschijnlijkheid van deze gebeurtenissen. Toekomstverkenning is een zeer lastige taak die gepaard gaat met een aanzienlijke mate van onderzekerheid. Scenario's worden gebruikt om deze onderzekerheid te benoemen en toekomstige ontwikkelingen te beschrijven op basis van expliciete aannames. Het moet opgemerkt worden dat er een verschil is tussen waarschijnlijke *versus* mogelijke ontwikkelingen. Toekomstbeschrijving geeft de lezer op zijn best een indicatie van wat er *zal gebeuren.* Dit is een duidelijk verschil met scenario's die normaal gesproken worden ontwikkeld om te beschrijven wat er *kan gebeuren* als gevolg van bepaalde omstandigheden en aannames. Door de lezer een overzicht te geven van meerdere scenario's, krijgt de lezer het idee dat de scenario's een voorstelling zijn van de uiterste grenzen van wat realistisch gezien *kan gebeuren.* Hierdoor krijgt de lezer de mogelijkheid om zelf te beoordelen welk pad van gebeurtenissen het meest aannemelijk is binnen die uiterste grenzen opgelegd door de scenario's.

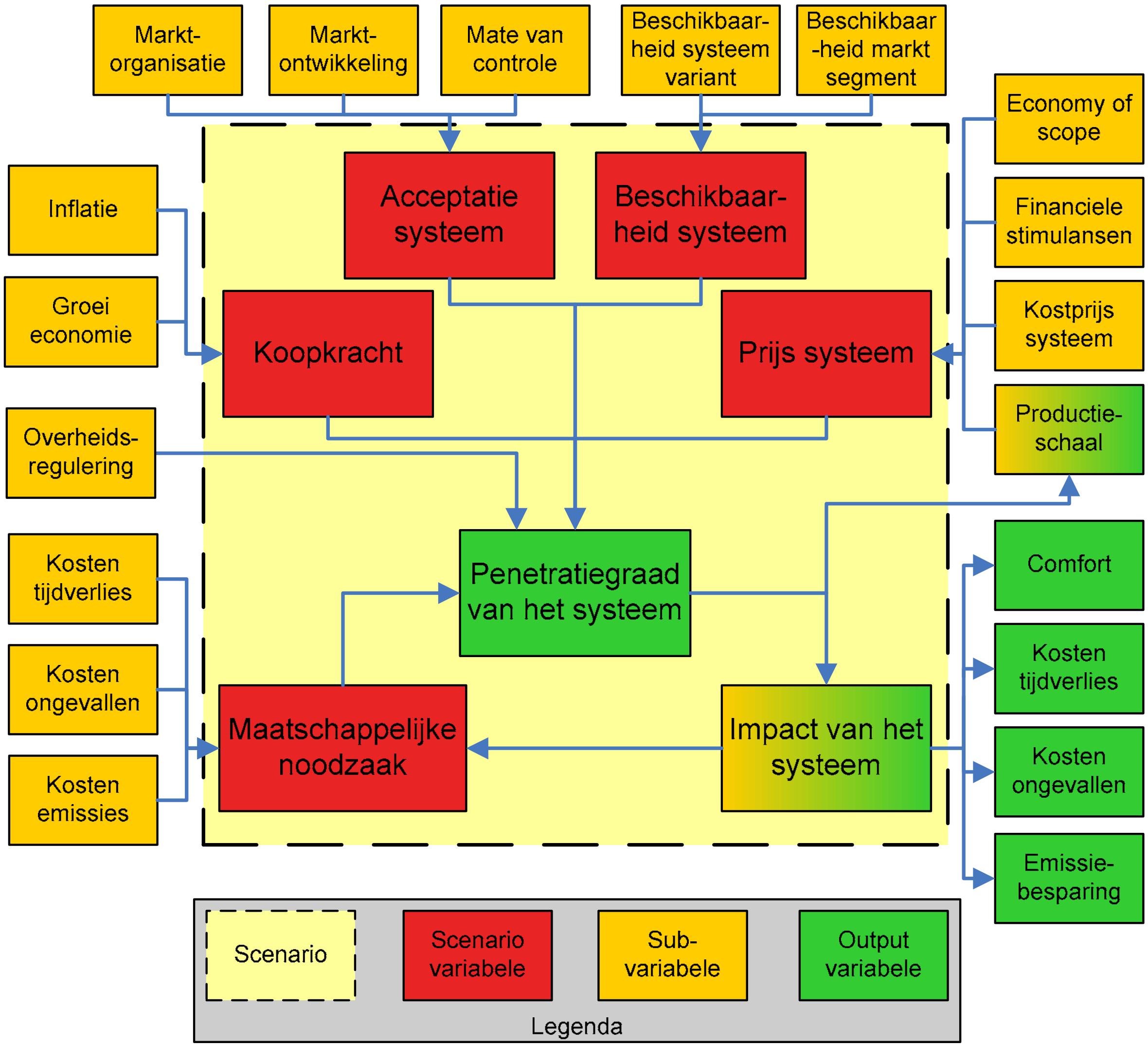
Om de realiseerbaarheid van het onderzoek te garanderen is het onderzoekskader begrenst tot de *meest kritische* factoren met betrekking tot de invoering van Snelheidsondersteunende systemen. Deze factoren zijn geïdentificeerd op basis van interviews onder experts en betrokken partijen. De resultaten van de interviews zijn gevalideerd en aangevuld aan de hand van een literatuurstudie. Samen identificeerden de interviews en literatuurstudie bewustzijn en acceptatie, visie en strategie en coördinatie en samenwerking als de meest kritische invoeringfactoren. Voor het vervolg van het onderzoek zijn deze factoren samengevat onder twee overkoepelende factoren: marktontwikkeling (de ontwikkeling van de marktvraag als het gevolg van bewustzijn- en acceptatiefactoren) en marktorganisatie (de gestructureerdheid van de markt als gevolg van coördinatie, samenwerking, visie en strategie).

Om de uiterste grenzen van mogelijke toekomstige ontwikkelingen aan te duiden is een scenariolandschap geconstrueerd. Marktontwikkeling en marktorganisatie representeren de twee dimensies van het landschap en de vier kwadranten beschrijven vier scenario's. Extreme projectie van de dimensies heeft bepaald dat marktorganisatie kan reiken van 'individueel' tot 'collectief' en dat marktontwikkeling kan reiken van 'stabiel' tot 'groei'. Stabiel en groei representeren de staat van de factoren die marktvraag genereren, zoals systeemacceptatie, maatschappelijke behoefte en koopkracht. Deze factoren zijn laag in een stabiele markt en hoog in een groeiende markt. Marktorganisatie duidt op de structuur van de aanbodzijde van de markt in termen van coördinatie, samenwerking en de mate van betrokkenheid van belanghebbenden. 'Collectief' representeert een situatie waarin de belanghebbenden een progressieve houding hebben met betrekking tot de invoering van Snelheidsondersteunende systemen en de markt stimuleren. In het geval van een individuele markt is exact het tegenovergestelde het geval. De vier kwadranten van het scenariolandschap beschrijven de vier scenario's Conservatief, Regulering, Vrije markt en Progressief. De scenario's worden gekarakteriseerd door zes thema's (zie figuur 1).



Figuur 1: vier invoeringscenario's voor Snelheidsondersteunende systemen.

In deze analyse is de penetratiegraad van Snelheidsondersteunende systemen gebruikt als maat voor de ontwikkeling van de invoering van deze systemen. Penetratiegraad is het percentage auto's uitgerust met een bepaald systeem. Vervolgens zijn een aantal scenariovariabelen en subvariabelen gedefinieerd waarvan wordt verwacht dat ze leiden tot waarschijnlijke waarden voor de penetratiegraad van Snelheidsondersteunende systemen. Een schematische weergave van deze variabelen en de relaties daartussen vormt de basis voor het scenariomodel en beschrijft de invoeringmechanismen (zie figuur 2). Deze schematische weergave van het scenariomodel is gebruikt om een theoretische beschrijving van de vier invoeringscenario's te maken. De scenario's zijn als volgt beschreven:



Figuur 2: schematische weergave van scenariomodel

- *Scenario 1 – Conservatief*. Dit scenario wordt gekenmerkt door een stabiele markt, wat gepaard gaat met een lage maatschappelijke noodzaak, kleine groei van de koopkracht en lage acceptatie voor het systeem. Mede als gevolg van het uitblijven van een technologiepush is er noch een sterke marktvraag noch een sterk marktaanbod. Het resultaat is een summiere ontwikkeling van de invoering van Snelheidsondersteunende systemen.

- *Scenario 2 – Regulering*. Dit scenario wordt gekenmerkt door een groeiende markt, wat gepaard gaat met een hoge maatschappelijke noodzaak, grote groei van de koopkracht en hoge acceptatie voor het systeem. Als gevolg van het uitblijven van een technologiepush treedt te overheid op als behartiger van het maatschappelijke belang en reguleert de markt. Het resultaat is een sterke ontwikkeling van de invoering van Snelheidsondersteunende systemen.

- *Scenario 3 – Vrije markt*. Dit scenario wordt gekenmerkt door een stabiele markt, wat gepaard gaat met een lage maatschappelijke noodzaak, kleine groei van de koopkracht en lage acceptatie van het systeem. Als gevolg van samenwerking tussen de overheid en automobielfabrikanten ontstaat er een sterke technologiepush. Daarnaast leiden promotie- en prijsstrategieën ertoe dat de acceptatie van de systemen stijgt en de invoering van Snelheidsondersteunende systemen gematigd ontwikkeld.

- *Scenario 4 – Progressief*. Dit scenario wordt gekenmerkt door een groeiende markt, wat gepaard gaat met een hoge maatschappelijke noodzaak, grote groei van de koopkracht en hoge acceptatie van het systeem. Als gevolg van samenwerking tussen de overheid en automobielfabrikanten ontstaat er een sterke technologiepush. De combinatie van een sterke marktvraag en een sterk marktaanbod leidt tot een sterke ontwikkeling van de invoering van Snelheidsondersteunende systemen.

Om de gevolgen van de scenario's te evalueren is het scenariomodel toegepast. Eerst zijn de scenariovariabelen en subvariabelen gekwantificeerd en zijn wiskundige vergelijkingen gedefinieerd voor de relaties tussen de variabelen. Uiteindelijk zijn de vier invoeringscenario's gekwantificeerd en konden de verwachte penetratiegraden worden berekend voor alle scenario's.

Uit de resultaten viel op te maken dat; de penetratiegraad van Snelheidsondersteunende systemen het meest ontwikkeld in de scenario's 2 en 4, dat de penetratiegraad van snelheidsondersteunende systemen het minst ontwikkeld in scenario 1 en dat scenario 3 kan worden beschreven als een kruising tussen de scenario's 1 en 4. In het algemeen kan worden geconcludeerd dat bij bepaalde marktcondities penetratiegraden tot 50 procent kunnen worden bereikt in 2025. Met name de penetratiegraden van de IRSA Adviserende en IRSA Interverende varianten kunnen snel ontwikkelen. De penetratiegraden van de IRSA Controlerende variant en de Fileassistent ontwikkelen aanzienlijk langzamer. Op basis van de bevindingen van de interviews, literatuuronderzoek en scenario-ontwikkeling kan worden geconcludeerd dat de scenario's 3 en 4 het meest waarschijnlijk zijn. Hoewel deze scenario's het meest aannemelijk lijken, kan worden gesuggereerd dat scenario 4 te optimistisch is en scenario 3 te terughoudend. Het meest waarschijnlijke scenario lijkt een kruising tussen beide scenario's, waardoor de scenario's 3 en 4 kunnen worden gezien als de uiterste grenzen van wat realistisch gezien het meest waarschijnlijk is.

Tenslotte is een suggestie gedaan voor een mogelijke opeenvolging van gebeurtenissen in termen van een invoeringsstrategie. Samengevat zouden de stappen van een invoeringsstrategie achtereenvolgens moeten zijn: formuleren van een duidelijke visie, samenbrengen van alle betrokken partijen, verduidelijken van de baten van alle betrokken partijen, ontwikkelen van een 'Code-of-Practice' waarin alle betrokken partijen zich kunnen vinden, verhogen van het publieke en politieke bewustzijn en acceptatie en uiteindelijk de invoering van systemen begeleiden door het verstrekken van subsidies of het verplicht stellen van gebruik.

Samengevat kan er worden geconcludeerd dat de uitvoering van een scenarioanalyse en de ontwikkeling van een scenariomodel om te komen tot de formulering van aannemelijke invoeringscenario's voor Snelheidsondersteunende systemen, heeft laten zien dat de invoering van deze systemen kan leiden tot hoge penetratiegraden wanneer bepaalde scenariocondities kunnen worden gecreëerd. Er zal veel werk moeten worden verzet om de gewenste scenariocondities te creëren, te beginnen bij het samenbrengen van alle betrokken partijen. Het is waarschijnlijk dat samenwerking tussen de betrokken partijen de eerste en belangrijkste noodzakelijke stap is naar een nieuwe verkeerssituatie die slimmer, veiliger en schoner is dan de huidige.

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1 Introduction

1.1 Background

Last February (2006), a few weeks after this research was started, European commissioner Mrs. Viviane Reding launched the Intelligent Car Initiative by means of a speech in Brussels. This initiative attempts to move towards a new traffic situation which is smarter, safer and cleaner than today (Reding, 2006). It is believed that Information and Communication Technologies, which enable the building of intelligent vehicles and infrastructures, provide new advance solutions that can contribute to solving the key societal challenges congestion, energy consumption and safety. Unfortunately, despite their potential, most intelligent systems are not yet on the market, and when they are, large-scale deployment takes a long period of time due to several problems. The main reasons for slow take up are legal and institutional barriers, the extremely competitive situation of the automotive sector, the relatively high cost of intelligent systems, the consequent lack of customer demand, and, most of all, the lack of information, throughout society, about the use and potential benefits of these systems.

The Intelligent Car Initiative is a policy framework to guide the efforts of stakeholders in the area of Information and Communication Technologies (ICT), aiming at accelerating the deployment of intelligent vehicle systems on the European and other markets through clearly defined actions such as:

- Coordinating and supporting the work of the relevant stakeholders, the citizens, the Member States and the industry.
- Supporting research and development in the area of smarter, cleaner and safer vehicles and facilitate the take-up and use of the research results.
- Creating awareness of ICT-based solutions to stimulate users' demand for these systems and create socio-economic acceptance.

Currently, the main problem is the uncertainty in how the deployment of intelligent vehicle systems takes place as a function of different conditions. In this research, a scenario analysis is performed to address this uncertainty and identify factors which accelerate and decelerate deployment. With regard to intelligent vehicle systems the scope of this research is limited to 'Speed Assistance systems', which is a generic term for IRSA[3] systems (Versteegt, 2005) and the Congestion Assistant (Van Driel and Van Arem, 2006). The aim of both systems is similar; assist drivers in their longitudinal driving tasks by providing speed advice or speed warning and cruise control like functionalities.

1.2 Objective

Slow take-up and uncertainty about the deployment of SA systems indicate the need of insight into the mechanisms which are the basis of deployment. It is assumed that once these insights are obtained, plausible deployment scenarios can be formulated, which can be useful for the definition of a deployment strategy. A scenario model is assumed to be a useful tool to evaluate scenarios by means of calculations. Considering this, the objective of this research can be formulated as follows:

Formulating plausible deployment scenarios for Speed Assistance systems by means of scenario analysis and the development of a scenario model.

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1.3 Research model

The research is structured as presented in Figure 1.1 and can be explained as follows: Interviews with experts and stakeholders in the field of Speed Assistance system were used to limit the scope of the literature study. Based on the interviews and literature the most critical factors with regard to the deployment of SA systems were identified (A). The deployment factors were used to formulate plausible scenarios (B) which subsequently were modelled in a scenario model (C). Finally, conclusions were drawn from the findings on plausible deployment scenarios (D).

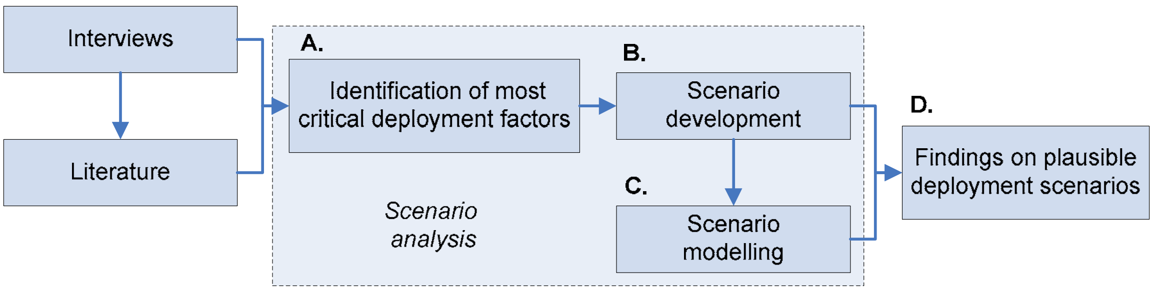


Figure 1.1: research model

To achieve the research objective a number of research questions are formulated. The research questions are linked alphabetically with the research model.

- **A.** What are the most critical factors with regard to the deployment of SA systems?
- **B.** How can deployment scenarios be developed on the basis of the critical deployment factors?
- **C.** How can the mechanisms of deployment and the deployment scenarios be modelled?
- **D.** What can be learned from the findings on plausible deployment scenarios?

1.4 Definitions

Deployment (or implementation)	The whole of the initial market phase of the development of a product-market combination and the development of market penetration.
Deployment factor	Barriers or stimulants with regard to the development of deployment.
Deployment strategy	A sequence of events and necessary actions to create a desired future state defining the roles, tasks and responsibilities of all stakeholders involved.
Scenario	An integrated description of a future state of society or special parts of it, and a plausible sequence of events leading to this future state, without the necessity of including statements on the probability of those events (Van Arem, 1996).
Scenario analysis	Method to address uncertainty about the future and describe possible future developments based on explicit assumptions (Masser et al., 1991).
Scenario model	Schematic or mathematical presentation of a scenario. A mathematical presentation enables calculations.

1.5 Contents of the report

Following on this introduction, chapter 2 provides a general introduction into Advanced Driver Assistance Systems and Speed Assistance systems in particular. Chapter 3 is a methodological chapter discussing scenario analysis and defining a research approach for this research. In chapter 4 the results of the interviews and literature reviews are presented and the most critical deployment factors are identified. Next, four deployment scenarios are developed in chapter 5, followed by the construction of a scenario model, which is discussed in chapter 6. Evaluation of the application of the model and a presentation of the research results can be found in chapter 7. The research results, the validity of the model and the research approach are evaluated and discussed in chapter 8. Based on the judgments of the author, this chapter concludes with ideas for a deployment strategy. Finally, the conclusions and recommendations for further research are presented in chapter 9.

2 Speed Assistance systems

2.1 Introduction

This chapter presents an introduction into Advanced Driver Assistance systems (ADA systems), and Speed Assistance systems in particular. The objective of this chapter is to provide the reader with insights in the dynamics, continuous developments and numerous interests of driver assistance.

The structure of this section is as follows. Section 2.2 introduces Advanced Driver Assistance systems followed by the introduction of Speed Assistance systems in section 2.3. The (expected) availability of Speed Assistance systems, now and in the future, is discussed in section 2.4. In section 2.5 the multi-stakeholder environment with regard to ADA systems is analysed. Finally, this chapter is summarised in section 2.6.

2.2 Advanced Driver Assistance Systems

Simply put, ADA systems sense the driving environment and provide information or vehicle control to assist the driver in optimal vehicle operation. These systems can operate at the tactical level of driving (throttle, brakes, steering) as contrasted with strategic decisions such as route choice, which might be supported by an on-board navigation system (Bishop, 2005). ADA systems have a great potential for improving the safety, comfort and efficiency of driving (Van Arem et al., 2002). In Figure 2.1 the possible traffic impacts of ADA systems are presented schematically.

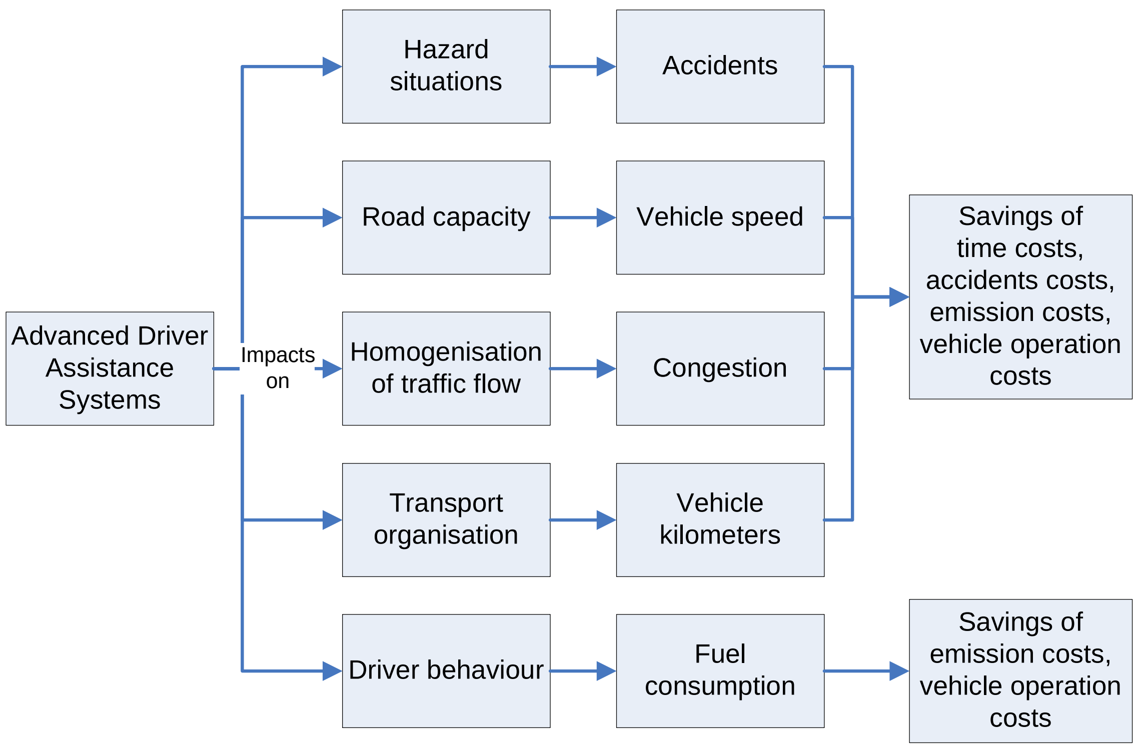


Figure 2.1: possible traffic impacts of ADA systems (source: Abele et al., 2005)

Operating a vehicle consists of four driving tasks that ADA systems aim to support (Visser, 2004):

- Navigation (finding and following a route from A to B);
- Manoeuvring (lane change, turning);
- Operational (speed, headway), and
- Emergency manoeuvres.

ADA systems can be used in different ways, with different levels of support. A system can either be a pure advisory system, a system that partly intervenes in the vehicle control, or a fully controlling system that completely takes over one or more of the driving tasks. When all driving task are taken over by a system one speaks of automatic driving. A more detailed explanation of the different levels of support is given in Table 2.1.

Table 2.1: overview of levels of support

Level of support	Explanation
Advisory	Information and warning - optic[1] - acoustic[2]
Intervening	Information and warning - besides optic and acoustic - haptic[3] ➢ vibrating chair ➢ active throttle ➢ active steering wheel ➢ active braking
Controlling	Active system support: (partly) taking over one or more of the driving tasks ➢ automated speed adaptation ➢ automated headway keeping

[1] Optic: concerning the sense of sight, [2] Acoustic: concerning the sense of hearing, [3] Haptic: concerning the sense of touch

More general, ADA systems are seen as a next generation systems beyond current active safety systems, which provide relatively basic control but do not sense the environment or assess risk. Antilock braking systems, traction control and electronic stability control are examples of such systems (Bishop, 2005).

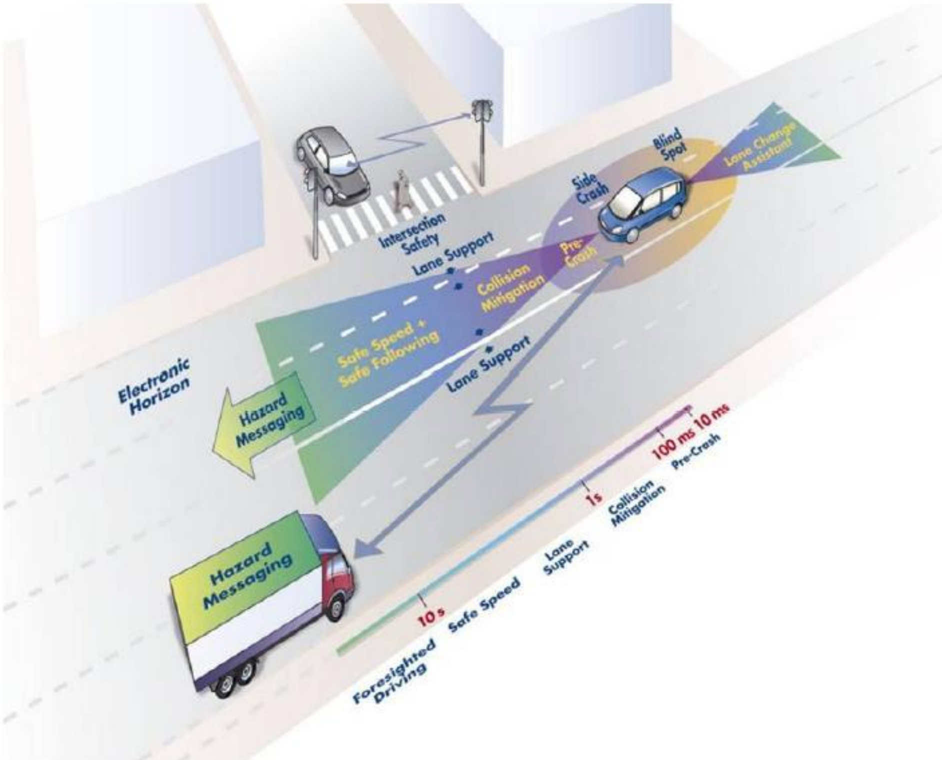


Figure 2.2: vision of safety zone around a vehicle (source: PReVENT, 2005)

As suggested above, ADA systems are often referred to as 'safety systems', mostly because the current focus is aimed at traffic safety by both the government and the industry[4]. The vision with regard to these safety systems is to create a safety zone around a vehicle by developing and realising a set of complementary safety functions (or ADA system functionalities). It is expected that this approach will strongly contribute towards the realisation of essentially safer (and more comfortable and more efficient) road traffic in the future. As can be seen in Figure 2.2, the safety zone is divided in several layers based on the so called 'time-to-collision', which ranges from 'foresighted driving' to 'pre-crash'. Several projects like CVIS, SAFESPOT, PReVENT and ARPOSYS focus on the different layers. This research particularly focuses on the layer 'safe speed + safe following'.

2.3 Speed Assistance systems

Speed Assistance systems support the driver in their longitudinal driving task, in particular in operating a vehicle. In this research two systems are under investigation; Intelligent full-Range Speed Assistance (IRSA) systems and the Congestion Assistant (CA). Both are described in this section.

2.3.1 Integrated full-Range Speed Assistance systems

The aim of IRSA systems is to assist drivers in their longitudinal driving tasks by providing speed advice or speed warnings and cruise control-like functionalities. Headway advice is added to make sure the IRSA systems will smooth traffic flow near merging and weaving locations.

IRSA systems can be used in different ways, either as a pure advisory system, as a system that partly intervenes in the vehicle controls, or as a controlling system that fully controls the longitudinal speed

[4] Although the industry aims at safety, they prefer to refer to the current systems as comfort systems to avoid liability claims.

of the vehicle. The driver determines in which way he will use the IRSA system by selecting a mode of operation. Basically, the only difference between the advisory and intervening modes and the controlling mode of IRSA is the presence of a human driver which 'distorts' the optimal desired acceleration computed by the IRSA system in the controlling mode.

Most speed advices and/or warnings which IRSA systems present to the driver are based on object warnings. Dynamic warning of objects requires communication via either Infrastructure-Vehicle (I-V) communication or Vehicle-Vehicle (V-V) communication. In the SUMMITS project it is assumed that these communication technologies are available in 2015. Each of the objects warnings and their aims are shortly summarized below. All these object warnings are integrated in the IRSA system.

- *(Reduced) speed limit warning*. The primary aim of these warnings is to calmly reduce the traffic speed to prevent the formation of shock waves due to abrupt braking manoeuvres.

Figure 2.3: speed limit warning

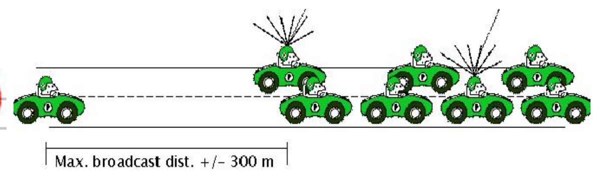


Figure 2.4: vehicle-based speed warning

- *Vehicle-based speed warning.* Broadcast of messages containing the location and speed of a vehicle when its speed drops below a certain threshold, or when it has to brake hard. The primary aim of this early breaking-like functionality is to increase traffic safety.

- *Curved road segments*. The aim of these warnings is to increase safety by alerting drivers for sharp curves and to calmly reduce the speed of the traffic flow to prevent the formations of shock waves due to abrupt braking manoeuvres.

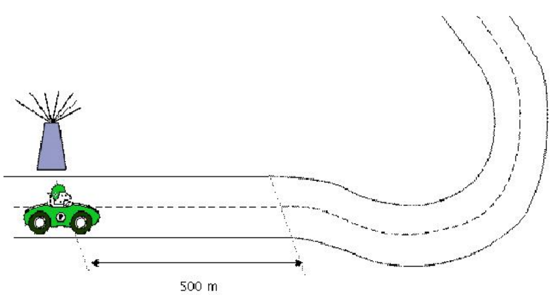


Figure 2.5: curved road segment warning

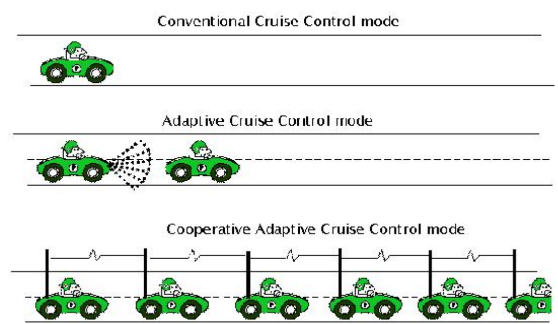


Figure 2.6: different cruise control modes

- *Cruise control (CC) -like functionalities.* Modes are: conventional CC (no predecessor), Adaptive CC (predecessor detected by radar, no V-V communication), Cooperative adaptive CC (predecessor(s) detected by V-V communication (and possibly radar)). The primary aim of the CC functionalities is to increase comfort. The system is expected to also contribute to improvements in traffic throughput and safety.

- *Leaving the traffic jam*; as soon as a predecessor, a pre-predecessor, or a pre-pre-predecessor etc. starts accelerating out of a queue, a message is broadcasted. The driver and/or vehicle can react immediately, thus improving the outflow of a traffic jam or at a traffic signal.

- *Headway advice;* A recent study showed that the platoon formation caused by the introduction of Cooperative Adaptive CC might seriously hamper merging processes at merging or weaving sections (Visser, 2005). The time headway advice will aim at increasing the gaps between vehicles, to create a smooth merging flow.

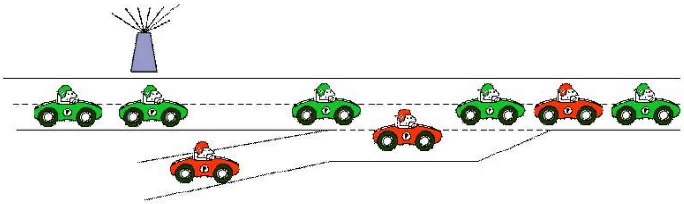


Figure 2.7: headway advice

2.3.2 Congestion assistant

The Congestion Assistant supports the driver during congested traffic situations. The system consists of three functions which are explained below (Van Driel, 2006).

- *Congestion warning and information*. The CA gives the driver a warning when he approaches a traffic jam. The warning is presented on a display, which is mounted on the centre console. Besides, the first congestion warning is introduced by a sound signal and a corresponding icon lighting up (see Figure 2.8). The warning consists of a text message informing the driver about the distance and time he is removed from the traffic jam. Furthermore the CA provides the driver with information when he is driving in the traffic jam. The congestion information is presented on the display. The corresponding icon is still lightened up. The information consists of a text message informing the driver about the remaining length of the traffic jam.

Icon off	Icon on
	

Figure 2.8: icon congestion warning

- *Active gas pedal*. When the driver has received the congestion warning and comes nearer to the traffic jam, the active gas pedal of the CA is activated. The active gas pedal gives the driver a warning by means of counterforce on the gas pedal when he is approaching the traffic jam with too high speed. The active gas pedal is introduced by a sound signal and the accompanying icon lighting up (see Figure 2.9). The driver can override the counterforce by pressing the gas pedal harder.

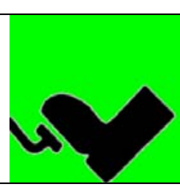
Icon off	Icon on
	

Figure 2.9: icon active pedal

- *Stop & Go.* When the driver reaches the tail of the traffic jam, the Stop & Go of the CA takes over the longitudinal driving task (regulating speed, car following). The system can also stop the car automatically and accelerate again. Activation of the Stop & Go is introduced by a voice “The Stop & Go becomes active”, a sound signal and corresponding icon lighting up on the display (see Figure 2.10). At the same time, the active gas pedal is deactivated. The activation of the Stop & Go and deactivation of the active gas pedal is delayed, if the driver is: braking with the brake pedal, accelerating hard (>1 m/s^2) or changing lanes. At the end of the traffic jam, the Stop & Go and the congestion information are deactivated. This is introduced by a voice “The Stop & Go becomes inactive”. Next, a sound signal is presented and the corresponding icons are turned off. The driver has to take over from the Stop & Go and perform the longitudinal task himself again.

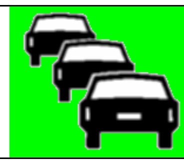
Icon off	**Icon on**
	

Figure 2.10: icon Stop & Go

It is expected that the driver is better prepared for the traffic conditions ahead with the congestion warning and information. Expectations of the active gas pedal are that the driver will anticipate better on the traffic jam ahead by earlier and smoother deceleration. Finally, it is expected that the Stop & Go will perform ‘better’ than the driver when driving in stop-and-go traffic. For example, the Stop & Go might better anticipate on leading vehicles and thus accelerate and decelerate in a smoother way. Also, the Stop & go could lead to car following at closer headways with less variation, which increases road capacity.

Basically, the primary aim of the Congestion Assistant is similar to that of IRSA systems, which is to calmly reduce the speed of the traffic flow to prevent the formation of shock waves due to abrupt braking manoeuvres and primary increase traffic safety. Secondary benefits are expected with regard to throughput, vehicle emissions and driving comfort.

2.4 System availability

Before starting with scenario analysis it is useful to have some foreknowledge about expected developments and plausible scenarios. In the upcoming chapters, and in particular in section 5.3.5, important choices are made on the basis this knowledge. This knowledge can be gained from deployment scenarios, which main purpose is to provide a concrete, plausible idea of which ADA systems can be introduced at a certain moment in time (Zwaneveld, et al. 1999). An effective way of visualising deployment scenarios and creating an image of likely developments is on the basis of ‘roadmaps’. In this report a distinction is made between ‘technology roadmaps’ and ‘deployment roadmaps’, which are defined as follows:

- Technology roadmaps discuss either: the moment of technological availability of ADA systems, when a manufacturer can offer a new ADA system, the timing of the launch on the global market or the time when an ADA system has reached a minimum deployment rate. In most cases, roadmaps refer to the time when a manufacturer starts series production of an ADA system for the market of interest.

- Deployment roadmaps are based on the knowledge that, despite their potential, most ADA systems not automatically make it to wide market implementation and high penetration. These roadmaps discuss the events and necessary actions to ‘guide’ a system through the process from technological availability to wide market implementation. The insights gained from these roadmaps can be used to formulate a deployment strategy.

In section 2.4.1 a number of technology roadmaps developed by the industry or in (European) projects are discussed. Next, all elements relevant with regard to Speed Assistance are extracted from these roadmaps and synthesised in section 2.4.2. On the basis of this synthesis a roadmap for Speed Assistance systems is made. Finally, section 2.4.3 briefly discusses deployment roadmaps developed by several (European) projects.

2.4.1 Technology roadmaps

The technology roadmaps that are used for this section are presented in appendix A. These roadmaps originate from:

- The ADASE projects 1 and 2 (Zwaneveld et al., 1999; Ehmanss and Spannheimer, 2004).
- The RESPONSE 2 project (Schollinski, 2004).
- The MONET project (MONET project office, 2003).
- The supplier Hella (Hella, 2005).
- The supplier Bosch (Abele et al., 2005).
- The SEiSS project (Abele et al., 2005).
- The Speed Alert project (ERTICO, 2005).
- A presentation of Richard Bishop (Bishop, 2005).

For example, in Figure 2.11 the technology roadmap developed for the ADASE2 project is shown.

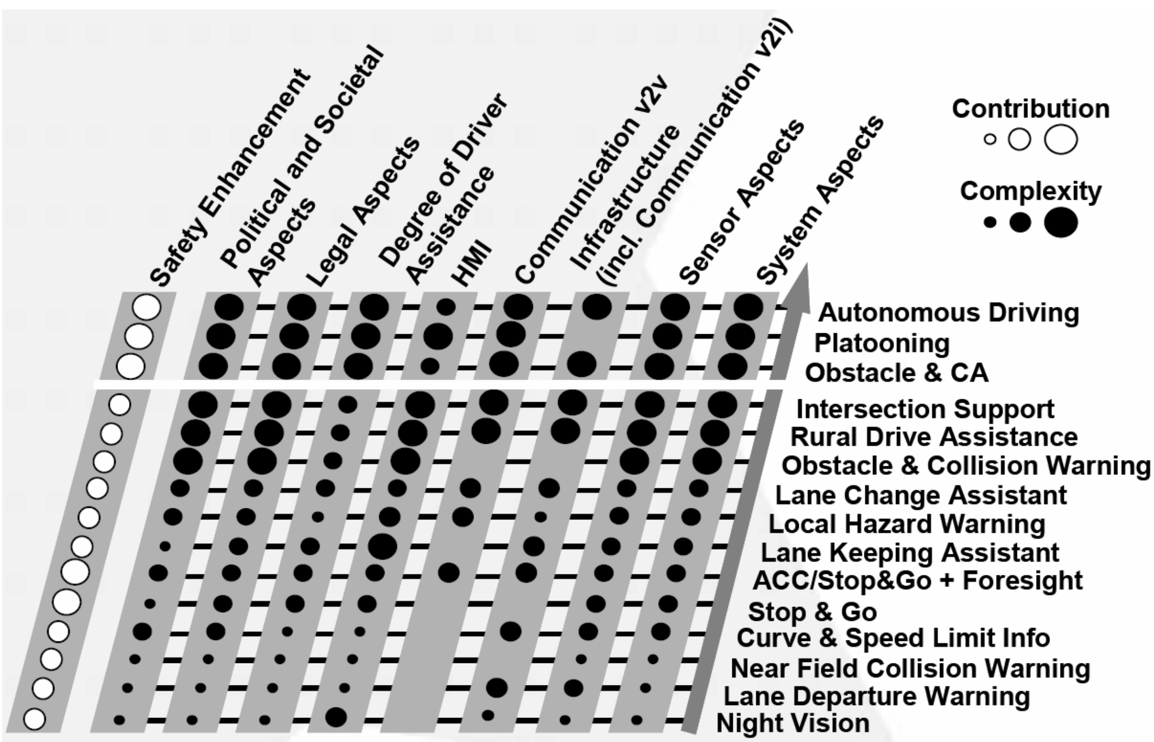


Figure 2.11: ADASE2 roadmap

The ADASE2 roadmap is often used as the basis for new roadmaps. The roadmap was one of the first roadmaps in which the technological focus was extended with many other aspects of driver assistance like legal aspects, political and societal aspects, etc. For every aspect the complexities of the system are indicated by the size of the dots. An overall consideration of these aspects and the functionality of the systems should lead to an assessment of the estimated safety benefit. Through the consideration of other aspects, the ADASE2 project and this roadmap showed the importance and need of deployment roadmaps.

2.4.2 Technology roadmap SA systems

In this section, a synthesis is made of the roadmaps discussed in appendix A with a specific focus on Speed Assistance technologies. All elements relevant to Speed Assistance were extracted from the roadmaps and synthesised in Figure 2.12. These elements provide information about the availability of functionalities similar to the functionalities of the IRSA systems and the Congestion Assistant. As a result, the synthesis of the roadmaps generally only contains systems which support or control the longitudinal movements of a vehicle. The synthesis shows time intervals in which it is likely that a certain system or technology will become available. For some systems like the Urban Driving Assistant or the Collision Avoidance System these time intervals are relatively large, indicating the uncertainty (and conflicting information) of when these systems will become available. Finally, a roadmap for SA systems could be extracted from the synthesis of the roadmaps. For the construction of this roadmap the medians of the time intervals from the synthesis are used. Obviously, this method is inaccurate but nevertheless assumed acceptable concerning the information available. The systems and technologies discussed in the figure are explained below.

- The *Adaptive Cruise Control (ACC)* maintains the speed of the vehicle, recognizes mobile obstacles only and reacts by keeping a safe distance to a predecessor. For ACC, the speed of the vehicle has to be higher than 50-60 km/h. The *ACC+* is an Adaptive Cruise Control in conjunction with Lane Departure Warning (LDW). Alternatively, the ACC-LDW combination is extended with curve speed warning, possibly in combination with a Speed Limit Assistant.

- An extension of ACC+ could be the *Stop & Go function*. Longitudinal control is used here to drive at low speeds, speeds lower than 50-60 km/h. Specific situations of use can be in congested traffic or at specific locations, for example around schools. An extended version of the Stop & Go is the *Stop & Go ++*, which uses lateral control for lane and road keeping and additionally can offer safe curve warning. Zwaneveld et al. (1999) suggest that the Stop & Go ++ aims at platooning on highways.

- An important technology in the development of SA systems is *Vehicle-Vehicle (V-V)* and *Vehicle-Infrastructure (V-I) communication*. It has to be noted that this involves a technology, not a system. The presence of communication technology enables that functions like ACC and Stop & Go can be extended to a dynamic, traffic related system.

- Next, again in Zwaneveld et al. (1999), the Stop & Go ++ is extended for driving on *rural roads* (Rural Driving Assistant). In order to do this, road geometry has to be known. A more complex task is driving in an *urban area* (Urban Driving Assistant). In order to fulfil the task of driving in a complex environment, the systems should be able to classify objects and predict movements and be able to exchange information with other vehicles and the infrastructure.

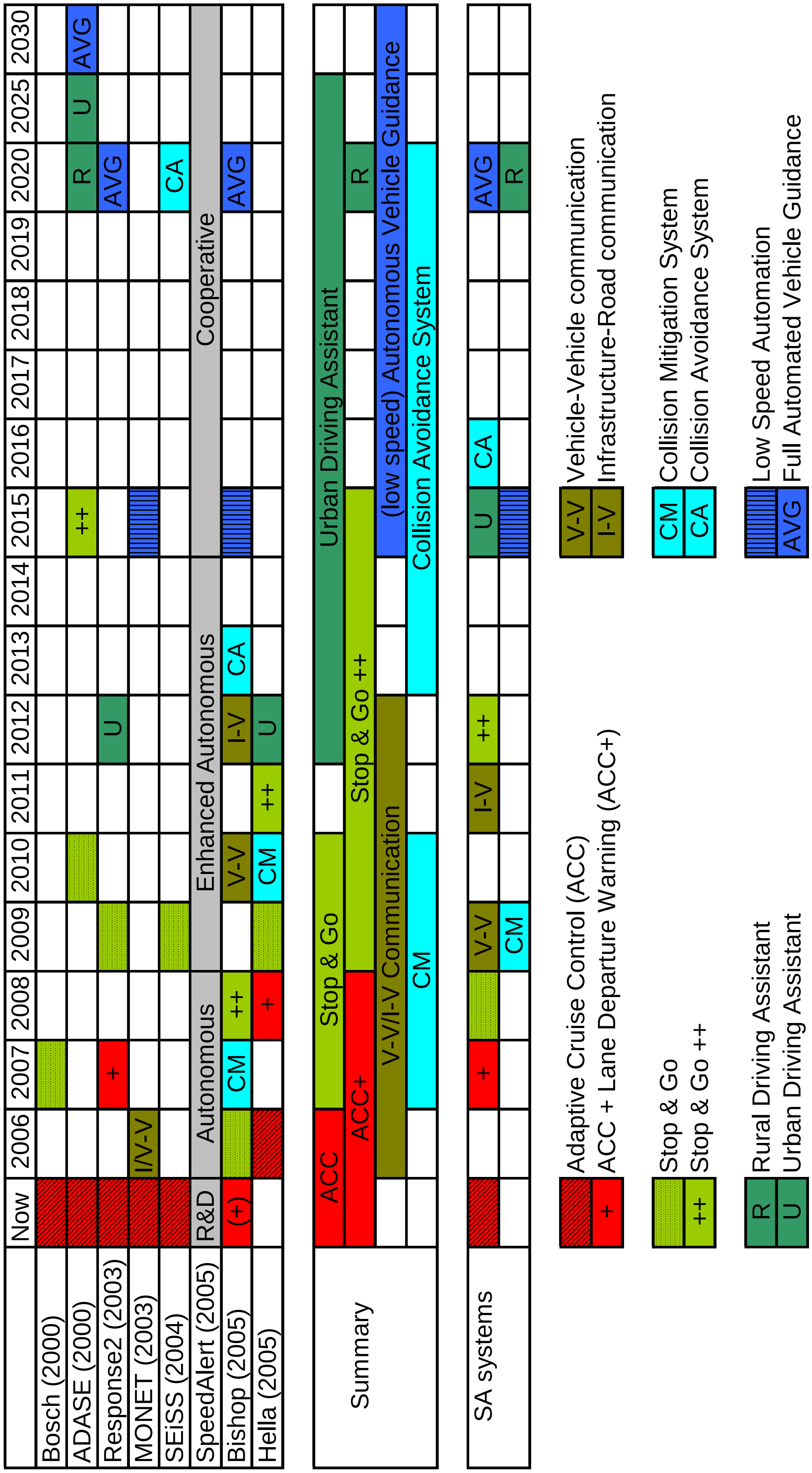


Figure 2.12: synthesis of technology roadmaps and roadmap for SA systems

- When vehicles are equipped with systems that scan the environment of the vehicle and communicate with other vehicles, obstacles and the infrastructure it becomes possible to first warn drivers for obstacles and collisions and in the end avoid obstacles and collisions. In order of degree of prevention, these systems are called: Collision Warning System (CWS), Collision Mitigation System (CMS) and Collision Avoidance System (CAS).

- The long-term vision of most roadmaps is *automated driving* or complete automated vehicle guidance.

What stands out is that an identical development path is followed for high speed (> 50-60 km/h) and low speed systems (< 50-60 km/h). First a system is developed for longitudinal control followed by a system that also uses lateral control. Next the system is extended with V-V and I-V communication. In the beginning systems are only developed for highway operation. Later on, the systems also become operational in rural areas and in the end urban areas. Finally, complete Automated Vehicle Guidance becomes available.

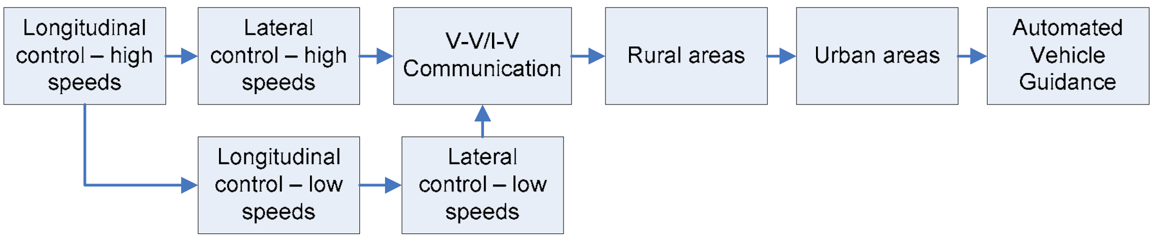


Figure 2.13: development path Speed Assistance systems

When several driver assistance technologies are working properly for all speed ranges, all different kinds of combinations of functionalities are possible. IRSA systems are an example of systems in which several functionalities are combined. The Congestion Assistant is an example of a system that combines the advisory, intervening and controlling mode for one specific situation.

From the roadmap of SA systems it can be concluded that longitudinal and lateral control for high and low speed are expected to be available within 6 years. The same is true for the communication technology. This means that from a technological perspective both the IRSA systems and the Congestion Assistant can be available within those 6 years.

2.4.3 Deployment roadmaps

Insights gained from deployment roadmaps can be used to formulate deployment strategies to accelerate the deployment process. The most recent work with regard to deployment roadmaps is done by the eSafety Forum (eSafety Forum, 2005), which discussed implementation issues relevant for several systems and provided insights in possible implementation (deployment) paths of these systems in terms of penetration rates, with and without implementation support. Besides, possible implementation strategies were suggested and presented on the basis of roadmaps. As an example, the implementation roadmap of the Speed Alert system is presented in Figure 2.14. The Speed Alert system alerts the driver with audio, visual and/or haptic feedback when the speed exceeds the locally valid legal speed limit. The left side of the ‘V’ summarises the past and indicates what is available now, while the right side of the ‘V’ represents the future in terms of events and actions.

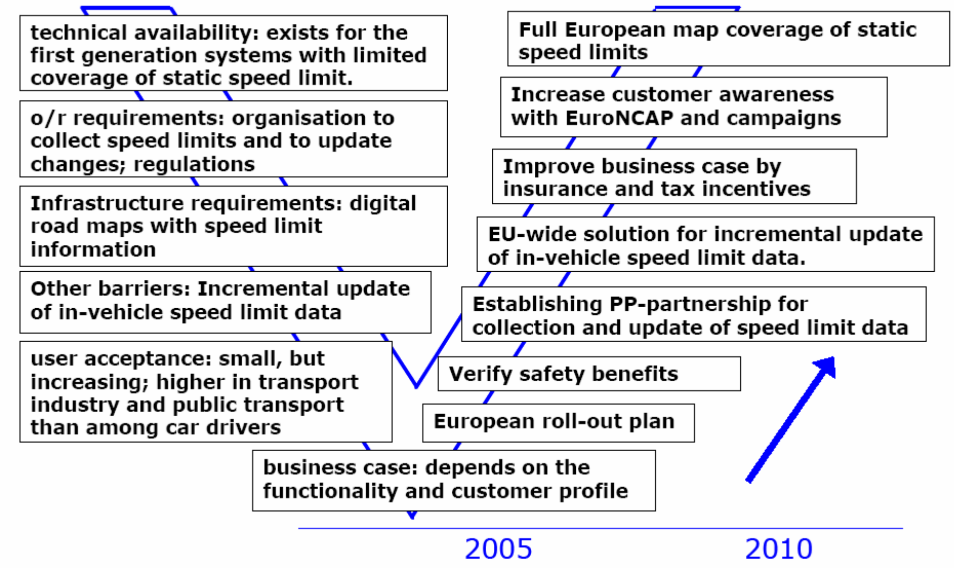
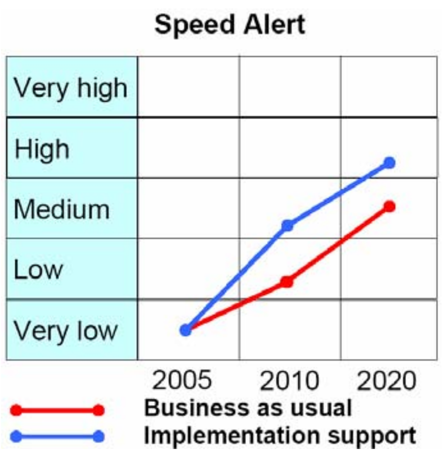


Figure 2.14: implementation roadmap Speed Alert

With regard to Speed Alert, the eSafety Forum (2005) expects the penetration rates to increase due to safety concerns and increased automated enforcement of legal speed limits. Implementation support involves a wide deployment strategy recorded in a Code-of-Practice concerning a definition of system and service requirement, a functional architecture and harmonisation of definitions and concepts. According to Bishop (2005), the Code-of-Practice could play an extremely important role in ADA system introduction, if successfully defined and accepted by the worldwide car industry. Large-scale implementation in the short term is expected to depend on European and national regulation aiming at mandatory or voluntary deployment of the system. The expected penetration rates for Speed Alert are shown in Figure 2.15.



Categories:

- Very high 80 up to 100%
- High 50 up to 80%
- Medium 20 up to 50%
- Low 5 up to 20%
- Very low 0 up to 5%

Figure 2.15: implementation path of Speed Alert (source: eSafety Forum, 2005)

With regard to the deployment of SA systems, projects like the eSafety project are very useful and provide insight in what possibly can happen. Now it is known what technological developments can be expected (section 2.4.2), future research should focus more on deployment issues (as section 2.4.3).

2.5 Market analysis – stakeholders

Projects like ADASE, RESPONSE and ADVISORS already showed that the deployment of ADA systems is very complex involving multiple factors and perspectives in a multi-stakeholder environment. For scenario analysis, it is important to know which stakeholders are involved, what their interests are and how powerful they are. The objective of this section is to identify the most powerful stakeholders with regard to the deployment of ADA/SA systems in order to limit the scope for further research.

The CONVERGE guidelines (Zhang et al., 1998) identified four main categories of 'users' who will be affected by, or have an effect on, the implementation of services like ADA systems. They are those who Want ICT, those who Make ICT, those who Use ICT and those who Rule ICT. For ADA systems they can be identified as follows (Van Arem, et al., 2002):

- *Want ICT* – These users want the system to solve (or diminish) traffic problems, or to enhance the overall safety of traffic and transport, for example city authorities, vehicle manufacturers, etc.

- *Make ICT* – Examples of this user category are system investors, vehicle manufacturers, telecommunication operators, service providers, etc.

- *Use ICT* – There are two categories of this class of users: primary and secondary. The primary users will benefit from the output of the system, for example commuters, business users, leisure users, etc. This group is looking for more comfort, ease of driving, safety, etc. The secondary users will control the system and provide the main input. Examples of this user category are traffic control operators and emergency services.

- *Rule ICT* – The local and national authorities have the responsibility for issuing the regulations on how to implement and use the systems. The international authorities may also issue regulations, as well as standards and recommendations for international inter-operability. Examples of this user category are government ministries (transport, finance, etc.), European Union bodies, etc.

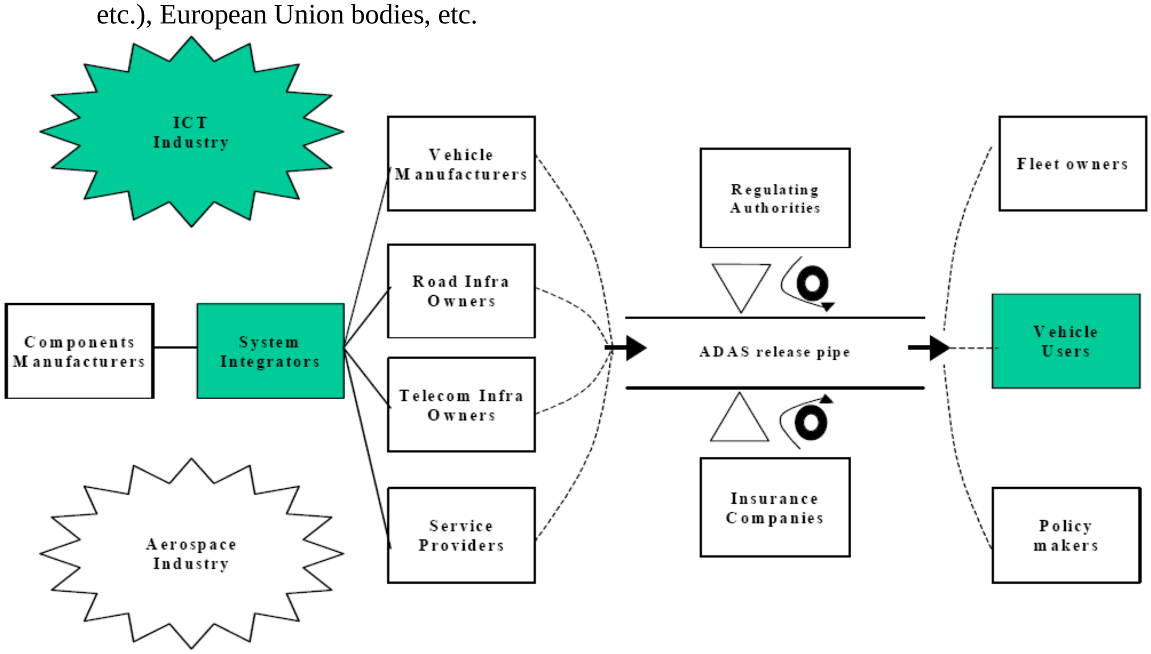


Figure 2.16: main ADAS stakeholders and their relations in ADAS development and marketing (source: Stevens et al., 2001)

A systematic overview of the main stakeholders and relations involved in ADAS implementation is shown in Figure 2.16. Stevens et al. (2001) suggest that the implementation of ADA systems is the result of a complex interaction between technology developers (those who Make and Use ICT; left from the ADAS release pipe), regulators (those who Rule ICT; around the ADAS release pipe) and demanders (those who want and use ICT; right from the ADAS release pipe).

The problem with the implementation of ADA systems might be (or proved to be) that ADA systems may queue up in the ‘release pipe’ until the circumstances improve. Regulating bodies and insurance companies may accelerate market release of ADA systems. It is important to remember that ADA system developers and manufacturers need to gain revenue in order to ensure their future existence. If there is no significant demand, a natural market introduction may therefore never take place, in spite of potential benefits for society in terms of safety, emissions, fuel consumption, and traffic flow efficiency (Stevens et al., 2001).

Walta (2004) concluded that the government and the automotive industry are the two most powerful stakeholders with regard to ADA system implementation. These findings are logical when compared to the ‘release pipe theory’ of Stevens et al. (2001). In addition, it has to be noted that the importance of the end users should not be underestimated since they have to buy and use the systems in the end. From these findings it can be concluded that the government, the automotive industry and the system users are the most important stakeholders with regard to the deployment of ADA/SA systems. As a result, the scope of the interviews and literature review discussed in chapter 4 is limited to the perspectives of these stakeholders.

2.6 Summary

Speed Assistance systems support the driver in their longitudinal driving task, in particular in operating a vehicle. In this research two systems are under investigation; Integrated full-Range Speed Assistance (IRSA) systems and the Congestion Assistant (CA). The primary aim of these systems is to calmly reduce the speed of the traffic flow to prevent the formation of shock waves due to abrupt braking manoeuvres and primary increase traffic safety. Secondary benefits are expected with regard to throughput, vehicle emissions and driving comfort.

Deployment scenarios were used to gain a concrete, plausible idea of which ADA systems can be introduced in a certain moment in time. An effective way of visualising deployment scenarios is on the basis of ‘roadmaps’. From the construction of a roadmap for SA systems it could be concluded that longitudinal and lateral control for high and low speed are expected to be available within 6 years. The same is true for the communication technology. This means that from a technological perspective both the IRSA systems and the CA can be available within those 6 years.

Finally, from the findings of a market analysis it could be concluded that the government, the automotive industry and the system users are the most important stakeholders with regard to the deployment of ADA/SA systems.

3 Methodology – scenario analysis

3.1 Introduction

Assessing the development of a technology, an object or a system is a very complex task involving a considerable level of uncertainty. Scenario analysis is used to address this uncertainty and describe future developments based on explicit assumptions (Masser et al., 1991). However, what this method implies and how it is related to other methodologies is often unclear. Like De Weger (2003) put it: "Ask five experts to define 'scenario analysis' and you will probably get five different answers".

In this chapter, scenario analysis and related methodologies are explored and discussed to make clear what is meant with 'scenario analysis'. The objective of this chapter is to find a method for scenario analysis, and formulate an approach for the development of scenarios and the construction of a scenario model in order to formulate plausible deployment scenarios of SA systems.

The structure of this chapter is as follows. Section 3.2 discusses the assessment of technology developments in general and positions scenario analysis by presenting an overview of the available methodologies for technology assessment. Section 3.3 more specifically focuses on scenario analysis, and scenario development and scenario modelling in particular. Finally, a research approach is chosen in section 3.4.

3.2 Technology assessment

The objective of technology assessment is: "*exploring technological developments and calculate the possible effects of these developments on the society and the environment, and influence the developments in a preferred direction to facilitate the foreseen negative effects*" (Smit and Van Oost, 1999).

Smit and Van Oost (1999) suggest that technology development can be described on the basis of a simple linear model containing five steps (see Figure 3.1). This research concentrates on the last three steps of the model, because the systems discussed are already designed. The last three steps of the model are referred to as 'selection ex-post' which is performed when a system is ready for market introduction. Selection ex-post discusses market, institutional, social and cultural factors. In this research the assessment will not be used to conclude whether a technology should be adjusted but, if and under which conditions, a technology is viable.

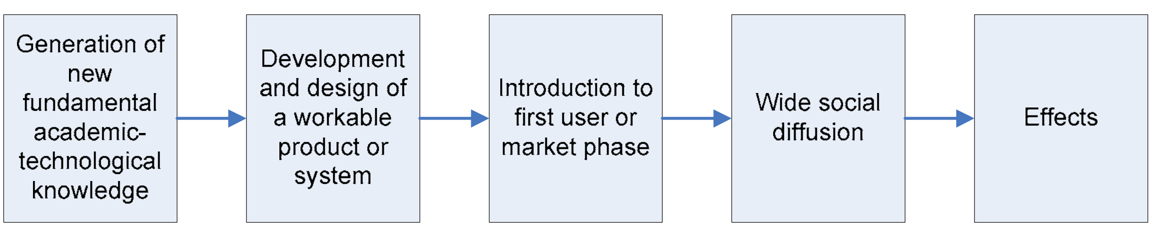


Figure 3.1: linear model of technology development (source: Smit and Van Oost, 1999)

With regard to technology assessment (TA), Moon et al. (in Marchau, 2000) suggest that three styles of technology assessment with different objectives can be distinguished:

- Awareness TA: focusing on providing forecasts and impacts of technological developments. Awareness TA often has an early warning function to the public at large, regarding technological opportunities and threats.

- Strategic TA: focusing on the provision of structured knowledge for specific decision makers concerning both the process and the contingency of the technology development. Furthermore, Strategic TA often aims at initiating the start of a debate among stakeholders.
- Constructive TA: focusing on the process architecture of technology implementation. Constructive TA emphasises on the dialogue among and involvement of stakeholders to initiate new technological avenues.

With the objective to structure the large variety of technology assessment methodologies, Marchau (2000) classified the methodologies by approach and aim. The result is presented in Table 3.1.

Table 3.1: categorisation of technology assessment methodologies (source: Marchau, 2000)

TA aim **TA approach**	**Analysis**	**Intervention**	**Reflection**
Assessment methodology	Technology forecasting Backcasting analysis Impact assessment Cost-benefit analysis Scenario analysis Market analysis	Interactive TA Consumer TA Strategic niche management	Structured reasoning Historical case research
Assessment methods	Analogies Monitoring Trend exploration Modelling Policy capture Structured interaction	Consensus conference Interactive workshops Gaming	Workshops Interviews Literature surveys

It can be concluded that the assessment methodologies for analysis are most applicable to this research. Besides scenario analysis, these methodologies include technology forecasting, identification and evaluation of impacts, market analysis, cost-benefit analysis and so on.

In the field of Intelligent Transport System (ITS) the CONVERGE project introduced a ‘Guidebook for Assessment of Transport Telematics Applications’ in which several methodologies for analysis were combined (Zhang et al., 1998). There are different types or categories of assessment, under which more specific and similar types of assessment objectives can be grouped. Examples of assessment categories as defined in CONVERGE are:

- Technical assessment (system performance, reliability);
- Impact assessment (transport effects, user behaviour);
- User acceptance assessment (users’ opinions, preferences, willingness to pay);
- Socio-economic evaluation (benefits and costs of system implementation);
- Market assessment (demand and supply), and
- Financial assessment (involves initial and running costs, rate of return, payback period).

For the assessment of driver assistance technologies the CONVERGE guidebook is sufficient. However, scenario analysis is not included in the guidebook and therefore is discussed in the following section.

3.3 Scenario analysis

Thinking about the future is often done by means of scenarios. Theoretically speaking, scenarios are hypothetical sequences of events, driving forces, consequences, actions and states, constructed for the purpose of focusing attention on causal processes and decision points (Kahn and Wiener, 1967). In practice, scenarios are descriptions of alternative images of the future, created from mental maps or models that reflect different perspectives on past, present and future developments. Ideally, they should be internally consistent, plausible and recognisable stories exploring the path into the future (Börjeson et al., 2005).

"Forecasting, at its best, gives the reader a hint of what will happen. This very markedly differs from scenarios that usually are developed to describe what can happen under a certain set of circumstances and assumptions. The difference is that of a probable versus a possible development. Giving the reader a number of scenarios leaves him with the impression that the scenarios represent the outer limits of what realistically can happen. The reader is left with an option to judge and choose for himself the most plausible path of events within those limits set by the scenarios. If on the other hand the author only gives one scenario alternative the reader will get the impression that the scenario represents the author's best estimate of what most likely will happen. In this case the scenario has become a method to present a forecast" (Svidén, 1986).

De Weger (2003) suggests that scenario analysis is strongly related to quantitative risk analysis. In fact, they are variations of a combined, probability-and-consequence analysis. Both consider the effects and consequences of unwanted events which are described as "accident scenarios", and in both analyses probabilities play a certain role. The difference between quantitative risk analysis and scenario analysis is that in a quantitative risk analysis probabilities are specially taken into account, while a scenario analysis focuses on the consequences. The difference between the two analyses is well visible when placing them on a scale between probability analysis and consequence analysis shown in Figure 3.2. Scenario analysis is a tool that fills the gap in the deterministic field next to quantitative risk analysis.

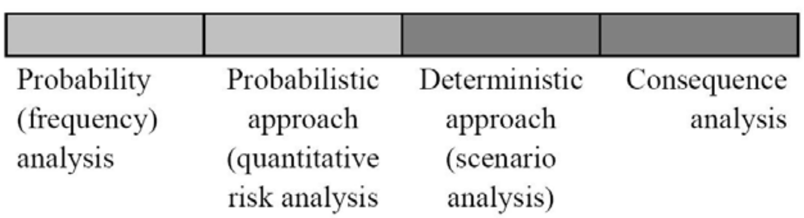


Figure 3.2: scenario analysis on a scale between probability and consequence analysis

In summary, scenario analysis can be described as a method to formulate alternative images of the future by representing the outer limits of what realistically can happen and focusing on the consequences.

3.3.1 Scenario development

"Scenario writing is a technique which tends to set up a logical sequence of events in order to show how, starting from the present (or any given situation), a future state might evolve step by step" (Jantsch in Sviden, 1986).

According to De Weger (2003), a scenario analysis consists of the following elements:

a. *System description*

b. *Selection of relevant scenarios* – scenarios should be realistic, test the system boundaries, cover all the parameters and be representative and reproducible. Especially testing the system boundaries is very important, because this is the actual goal of the scenario analysis; defining the outer limits of what realistically *can happen.*

c. *Analysis of effects and consequences* – analysis can be carried out at a qualitative or a quantitative level. During the analysis, a ‘picture’ is taken of every transition moment of the scenario. Each picture gives an overview of the system status and on the basis of key-words, key-figures, brief text or calculated data an account is given on the system development.

d. *Evaluation of results and optimisation of design* – evaluation is done by comparing the scenarios.

With regard to the selection of relevant scenarios Svidén (1986) suggests that it is practical to indicate the outer limits of probable futures by producing a set of rough scenario sketches defining the area under investigation (see Figure 3.3).

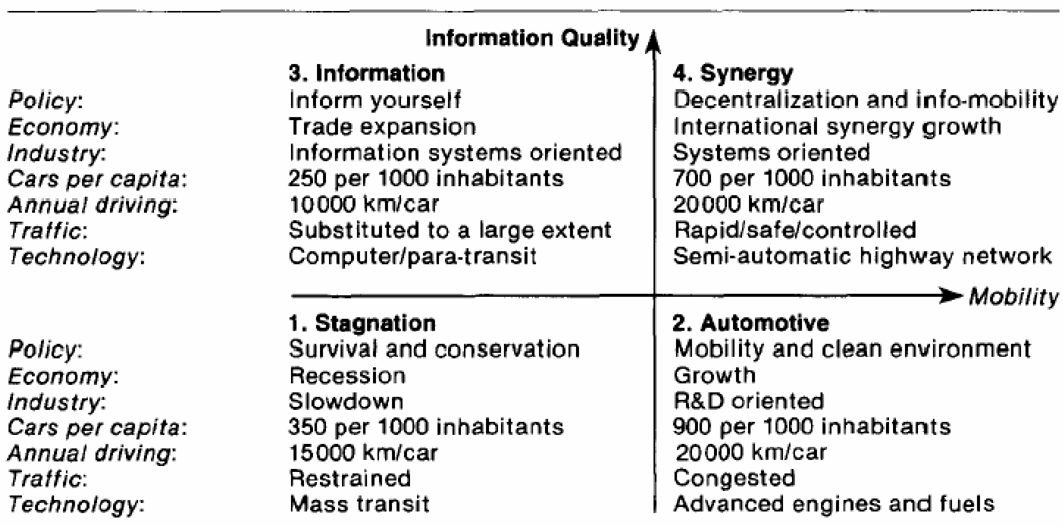


Figure 3.3: automobile usage strategies in a future information society: four scenarios (source: Svidén, 1986)

This approach of Svidén results in a ‘scenario landscape’ constructed upon two ‘scenario dimensions’, representing four scenarios. The system boundaries are defined by the extreme ends of the scenario dimensions. Everything within these ends assumably *can happen*. In Figure 3.3, Stagnation, Automotive, Synergy and Information are the four scenarios. The scenario conditions are outlined by the factors policy, economy, industry, cars per capita, annual driving, traffic and technology; seven factors with a huge impact on the auto usage in a future information society. On the basis of such a scenario landscape, scenarios can be written. Quantitative analysis of effects and consequences of scenarios by means of scenario modelling requires additional steps and is discussed in the following section.

3.3.2 Scenario modelling

“A model is an external and explicit representation of a part of reality as seen by the people who wish to use that model to understand, to change, to manage and to control that part of reality” (Pidd, 2003).

The objective of scenario building (or modelling) is to develop a coherent and consistent (quantitative) scenario for the problem at hand. The building of a coherent scenario proceeds along a number of steps with an increasing level of detail (Van Arem and Van der Vlist, 1994):

a. *Definition of the problem in general terms* – description of the aspects of which the developments have to be explored and the time horizon considered.

b. *Identification of the problem environment* – identification which factors affect the phenomenon to be explored (or the technology to be assessed) and in what way. Factors may affect the phenomenon to be studied directly and indirectly, in combination with other factors, delayed or undelayed. Contributions from experts are essential at this stage.

c. *Selection of variables* – stage concerned with a unique representation of the themes, factors and phenomenon to be considered. The scenario environment, the scenario itself and the phenomenon to be studied are presented by ‘steering, scenario and output’ variables:
   - The phenomenon to be considered is presented by output variables. Output variables should be chosen in such a way, that the developments of these variables provide a satisfying solution for the problem at hand.
   - For each theme the factors are represented by scenario variables. Scenario variables, which are typical ‘state’ variables that describe the actual scenario, should be sufficient to induce likely values for the output variables.
   - For each theme, one or more steering variables are defined. Steering variables are external variables that represent the overall tendencies supposed in a scenario and need to be general, development oriented and limited in number.

d. *Relationships between variables* – establishment of relationships between steering variables, scenario variables and output variables with safeguarding of the consistency between scenario variables and time. Given an input of steering variables, this step results in a set of mathematical relationships for obtaining a consistent set of scenario variables and a set of mathematical relationships for obtaining the desired output variables as a function of these scenario variables

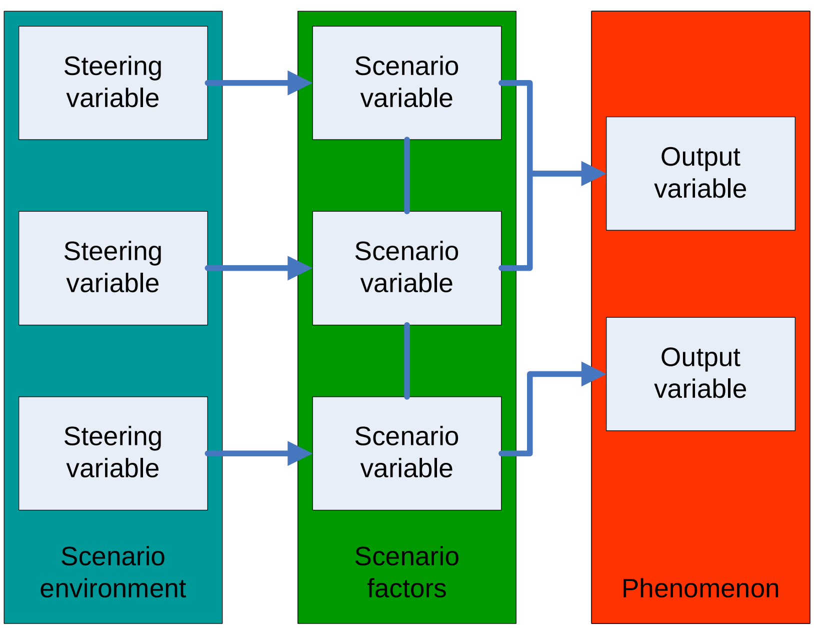


Figure 3.4: variables in scenarios

   - The set of output variables is determined as a function of the scenario variables. At this stage at least some qualitative knowledge of the interplay between the factors and the phenomenon to be considered is required.

- The scenario variables are determined as a function of other (sub-)scenario variables and steering variables. For the specification of the relation between scenario variables and steering variables, knowledge available from empirical studies has to be used as much as possible. If necessary, educated guesses and expert opinions have to be used.

e. *Specification of the present state and development of steering variables* – in order to provide the input necessary for computing scenario and output variables, the present state and the development of steering variables must be specified.

In the end, alternative scenarios may be studied by varying the steering variables and/or varying the assumptions and relations regarding the interplay of scenario and steering variables. Furthermore, it is suggested that considerations on the uniqueness of scenarios should be made.

A good reference with regard to scenario modelling is the work done for and with the 'Scenario Explorer' (Verroen et al., 1994). The model combines scenario building, system dynamics and strategic transport modelling techniques for nationwide travel demand and supply forecasting. The construction of the Scenario Explorer is well documented and a useful reference to derive new insights with regard to scenario modelling.

3.3.3 Qualitative versus quantitative

Precise quantitative answers are often not of primary interest and qualitative information like indications of impacts and effects or ranges and directions of change can be sufficient for satisfactory explaining and predicting the behaviour of a system. In summary, there are various reasons for choosing qualitative analysis instead of a quantitative analysis (Lang, undated):

- There is not enough information available to formulate a quantitative model;
- The available information is imprecise and/or uncertain, or
- The modeller is not interested in the details of the system.

Kemp-Benedict (2004) suggests that scenario modelling should address both qualitative and quantitative analysis to combine the strengths of the two approaches. "*One is to represent 'complexity', while the other is to represent what might be called 'complicatedness'. By complexity, the behaviour of complex systems is meant, as described by the complex systems theory. In particular, it refers to the behaviour arising from the interrelatedness of different components of a system, a feature of real systems that helps make the world so interesting. In contrast, by complicatedness is meant: a sort of bookkeeping that is necessary when there are a lot of factors to keep in mind like constraints, actors, and resources*".

What should not be produced is a predictive model, although it may have causal components. Instead, a model that allows exploring a numerical 'neighbourhood' of possibilities that is consistent with the narrative should be produced. The main role of a quantitative model is to take care of complications by keeping track of constraints and correlations (Kemp-Benedict, 2004). In short, appropriate models for exploratory analysis should at least (Kemp-Benedict, 2004):

- Represent the narrative;
- Reflect fundamental constraints (for example: land and energy balance, economic balances);
- Reflect the spatial and temporal scales of key processes;
- Offer several handles for the narrative team and other users;
- Implement likely correlations, and
- Reflect knowledge of the relevant literature.

3.4 Selected approach

In conclusion, exploration of scenario analysis resulted in a definition of scenario analysis and an overview of several methodologies. By combining several methodologies the following research approach could be defined:

a. To identify which factors affect the phenomenon to be explored and in what way, contributions from experts are essential (Van Arem and Van der Vlist, 1994). In this research expert knowledge will be obtained by interviews.

b. Four scenarios will be written on the basis of the approach suggested by Svidén (1986). The scenario landscape and scenario dimensions can be constructed on the basis of the results of the interviews with experts.

c. For scenario modelling the steps c, d and e suggested by Van Arem and Van der Vlist (1994) will be performed. It is assumed that this approach will lead to the scenario model as meant in the research objective. Based on Kemp-Benedict (2004) the objective is to construct a model that allows exploring a numerical 'neighbourhood' of possibilities that is consistent with the scenarios of b.

d. Finally, the effects and consequences of the scenarios will be analysed and the results of the analysis will be evaluated (De Weger, 2003). Based on Lang (undated) it is assumed that ranges and directions of change are sufficient to learn from the deployment scenarios.

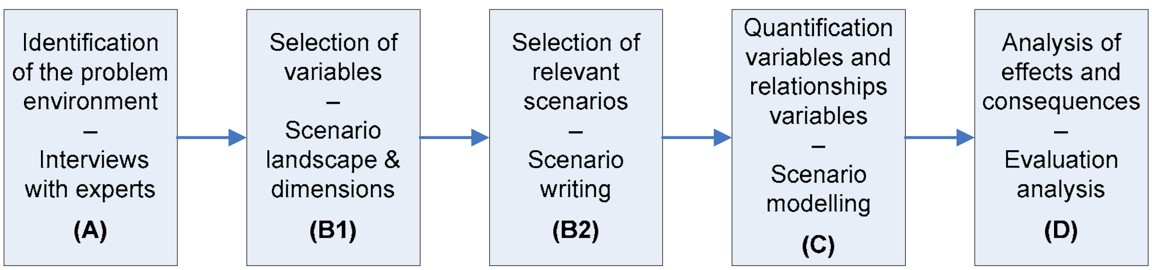


Figure 3.5: selected approach

The letters in Figure 3.5 refer to the phases of the research and relate to Figure 1.1 as well. Phase A is discussed in chapter 4. The selection of variables (phase B1) and the selection of relevant scenarios (phase B2) are discussed in chapter 5. In chapter 6 scenario modelling (phase C) is discussed and the chapters 7 and 8 describe phase D.

4 Interviews and literature

4.1 Introduction

In section 2.5 it was discussed that the deployment of ADA systems is very complex involving multiple factors and perspectives in a multi-stakeholder environment. The objective of this research is to identify these factors, find relations between them and use these insights to formulate scenarios and construct a scenario model. To guarantee the feasibility of this research it was suggested that the focus of the research had to be limited to the *most critical* factors with regard to the deployment of SA systems. As suggested by Van Arem and Van der Vlist (1994) it was expected that an answer to the question what these most critical factors are could be found through interviews with experts and stakeholders. Additionally, the results of the interviews were validated and expanded through a literature review.

This chapter discusses the approach and the results of the interviews and the literature review. Section 4.2 discusses the approach of the interviews and literature review. The most critical factors with regards to the deployment of SA systems are discussed in section 4.3, followed by a discussion of the position and attitude of the most important stakeholders in the deployment process (4.4). In the last section of this chapter (4.5) conclusions are drawn from the findings of the interviews and the literature review.

4.2 Approach

As stated previously the objective of the interviews was to limit the scope of the research to the most critical factors with regard to the deployment of SA systems. Based on the findings in section 2.5 the perspectives of only the three most important stakeholders were considered: the government, the automotive industry being the car manufacturers and the suppliers and the users. The respondents of the interviews were selected on the basis of their background and/or publications about the deployment of ADA systems, on condition that they were representative for one of the stakeholders. Eventually, thirteen respondents participated in the interviews, which could be divided in five respondent groups: experts (6), policy makers (3), suppliers (2), car manufacturers (1) and interest groups (1). A list of the interview participants is presented in appendix C.

A semi-structured approach was chosen, which meant that the respondents were guided with a list of questions but were allowed to speak freely about the subject. Before the respondents were interviewed either face-to-face or by telephone, a short introduction and some indicative questions about the subject were sent to the respondents. This document is presented in appendix B. On the basis of these questions the respondents were asked to speak freely about the deployment of SA systems based on their background and expertise. It was found that the respondents felt comfortable with this approach and eventually provided more information than originally intended. Besides an overview of the most critical deployment issues, the interviews also provided extensive insights in the opinions and attitudes of stakeholders towards the deployment of SA systems.

The following sections are written on the basis of statements of the respondents. It has to be noted that the statements presented here are interpreted by the author. To guarantee the reliability of this analysis it is tried to distinguish interpretations of the author from facts and only present the facts. Interpretations of the author are discussed in chapter 8.

Finally, the findings from the interviews are validated and extended on the basis of literature to raise their credibility and completeness. Here, the findings of the interviews are used as a tool to narrow the scope of the literature review and restrict the review to the most useful sources which could be found.

As a result, the following literature sources were found sufficient for the validation of the interview results and the identification of critical deployment factors: the Master thesis of Walta (2004) from the University of Twente, an actor analysis for Intelligent Speed Adaptation of Marchau et al. (2002) from the University of Delft and findings from a workshop of the Speed Alert project titled: “Challenges in implementing a Speed Limit Information Infrastructure” (Cuypers, 2004; Kenis, 2004; Reinhardt, 2004). The literature findings are discussed in section 4.3b.

4.3 Deployment factors

In general it could be concluded that there was consensus among the respondents of the interviews. Small differences in opinion could easily be explained by the different backgrounds of the respondents which are considered in this section. Five factors with regard to the deployment of SA systems were mentioned most frequently and by all respondent groups; vision and strategy, coordination and cooperation, technology, awareness and acceptance and legal issues. An overview of the frequency with which these factors were mentioned is presented in Table 4.1. The sections 4.3.1 till 4.3.5 discuss the five deployment factors in more detail. All information presented in these sections is originated from the respondents of the interviews.

Table 4.1: deployment factors by frequency and respondent group

Stakeholder group	# Respondents	Coordination and cooperation	Vision and strategy	Technology	*- Functionality/reliability*	*- Architecture/standardization*	*- Maps and data*	Awareness and acceptance	*- Human Machine Interface*	*- System costs*	Legal issues	*- Responsibility/liability*	*- Legislation*	*- Privacy*
Experts	6	4	5	3	*3*	*1*		5	*1*	*3*	3	*3*	*1*	*1*
Policy makers	3	3	3	1			*1*	2	*1*	*1*	2	*2*		
Supplier	2	2	1	1	*1*	*1*		2	*2*	*1*	2	*2*	*1*	
Car manufacturers	1	1	1	1			*1*	1			1	*1*	*1*	*1*
Interest group	1	1	1					1			1	*1*		
Total:	**13**	**11**	**11**	**6**	***4***	***2***	***2***	**11**	***4***	***5***	**9**	***9***	***3***	***2***

4.3.1 Coordination and cooperation

The multi-stakeholder environment of (cooperative) SA systems is found very complex and a barrier when it comes to the deployment of these systems. There is a need for better organisation and a leading coordinator. It is suggested that one stakeholder, most likely the government, should act as the initiator, coordinate the deployment process, provide guidelines for the industry and stimulate an agreement on a Code-of-Practice. An interesting point of discussion is whether the use of SA systems should be mandatory or voluntary. Mandatory use guarantees the use (and sales) of these systems, but is not awaited enthusiastically by most stakeholders. In particular the car manufacturers do not see (or do not want) this option as a realistic one. The relation between car manufacturers and the government is interesting, because both stakeholders are very strong market players with different objectives and powers. It is assumed that cooperation between stakeholders, in particular between car manufacturers and the government, can stimulate the deployment of SA system significantly.

4.3.2 Vision and strategy

The respondents suggested that successful deployment of SA system depends on a well defined, clear vision with benefits for all stakeholders and a good strategy to realise this vision. Most important is a positive cost-benefit ratio for all stakeholders. Currently, there is no clear vision and a lack of a good strategy. Most stakeholders aim for different, sometimes conflicting objectives. The reservation of stakeholders towards SA systems, because much is uncertain, is a huge barrier for an integrated vision and strategy. Again it is suggested that stakeholders should work cooperatively to break this barrier.

4.3.3 Technology

On a strategic level it is often assumed that technology is not the limiting factor for the deployment of SA systems. However, for example when external sensors are concerned, the technology is still very unreliable, unstable or not available yet. More alarming is the unfamiliarity with the impact of failure of one of the components of the system, like a poor signal from the sensor or the supply of inaccurate external information. Furthermore, a necessary input component, the speed limit maps and databases, are currently not fully available and reliable. Once systems reach high penetration rates some respondents foresee string stability problems when systems from different manufacturers have to operate together. From this point of view it is suggested that standardisation of system design is necessary.

4.3.4 Awareness and acceptance

Currently, users as well as policy makers are very unaware of the existence and benefits of SA systems. It is suggested that this is one reason why these systems do not reach high penetration rates. Beside awareness, systems also have to be accepted before they can reach high penetration rates. It is known that some system variants or functionalities are more accepted than others. It makes a huge difference whether the character of the system is supporting or enforcing or whether the level of support is low (advisory) or high (controlling). Also the importance of the Human Machine Interface (HMI) has to be taken into account. It is expected that users will start to appreciate and accept systems if information about the actions of the system and the reason of these actions is communicated to the driver. It is suggested that users should always have the feeling to be in control of their vehicle and have the possibility to overrule the system. Furthermore, a system has to be affordable. From a user point of view it is assumed that a system should not be more expensive than a car radio. Even then, the economic situation, more specific the growth of the purchasing power of consumers, has to allow the expenditure for driver assistance systems. Finally, it is suggested that awareness and acceptance are correlated with the social need of a system. For instance, if traffic problems worsen and traditional measures are all deployed, the public and political awareness and acceptance towards SA systems is expected to increase. In summary, the most important factor with regard to acceptance is the presence of a positive business case for all stakeholders involved. The respondents suggested that the deployment of SA system can not succeed until all stakeholder business cases are positive.

4.3.5 Legal issues

With regard to legal issues three factors were identified: liability, legislation and privacy. The responsibility for system failure is most important, because the risk of liability in these situations involves high financial costs. Currently, none of the stakeholders is willing to take full responsibility for system failure and the government and car manufacturers both suggest that the other should be responsible. It is clear that this issue needs full attention before SA systems ever can be successful. Furthermore, there are some general legislation issues that have to be overcome. One of them is the supposition of law that a vehicle is driven by the driver, which has full control over his vehicle at all times. Where SA systems or other ADA systems are concerned this situation will change. Unlike the liability problem, this legislation issue is expected to be solved easily. A third legal issue concerns the privacy of the users. Especially the industry foresees privacy problems once communication between vehicles and infrastructure is introduced and information about the whereabouts of a vehicle or a person is distributed. The industry fears that this information will be used for other purposes than initially intended like enforcement and expects that the privacy of the users will be in dispute.

4.3b Literature on deployment factors

This section presents the literature findings which were found sufficient to validate and complement the findings from the interviews. Conclusions are drawn in section 4.5.

Marchau et al. (2002) distinguish two measures for the market expectation of Intelligent Speed Adaptation (ISA) products: market introduction barriers and market penetration. Market introduction barriers are related to the initial marketing phase of the development of a product-market combination and attributes of market penetration are determined in terms of critical success factors. The attributes which they selected have been ordered in four categories: general transport policy goals, system related barriers, market introduction related barriers and market penetration related factors. This multi-attribute assessment for ISA is based on a general model that is presented in the Figure 4.1.

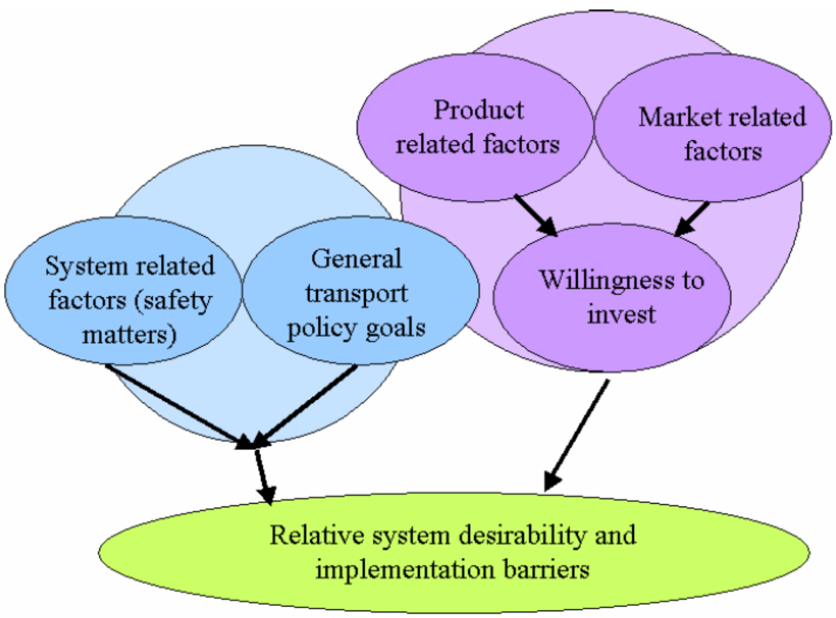


Figure 4.1: multi-attribute environment of Intelligent Speed Adaptation

For each category the participants of an actor analysis, representing several stakeholders, were asked to indicate the desirability or importance of the selected attributes, which next were ranked from most desirable to most undesirable or from most important to most unimportant. The results are listed below.

General transport policy goals (ranked on desirability, 1 is most desirable):

1. reduction of accidents
2. less penalties and speeding
3. increased driving convenience
4. less fuel consumption/environmental load
5. increased road capacity

System related barriers (ranked on importance, 1 is most important):

1. reliability: system does not support when expected
2. accuracy: system does not support in the right way
3. possible counteracting driving behaviour
4. lack of driver education
5. dangers of loosing driving skills

Market introduction barriers (ranked on importance, 1 is most important):

1. clarification of liability allocation to users, producers and road owners
2. consumers perception of system usability
3. purchase costs for consumer
4. investment willingness of authorities for road adaptations
5. limited road network applicability of system use

Critical factors for market penetration (ranked on importance, 1 is most important):

1. price elasticity (consumer price erosion)
2. promotional actions
3. product image
4. concurrential considerations (e.g. corporate image)

With regard to the results of the interviews it can be concluded that the general transport policy goals are similar to the issues discussed under vision and strategy, while system related barriers mostly deal with technology factors and legal issues. Most interesting for this research are the market introduction barriers and the critical factors for market penetration. The approach of Marchau et al. (2002) to split deployment factors into a category of factors which influence developments before market introduction and a category of factors which influence developments after market introduction is interesting to note. Both categories correspond with the issues discussed with regard to vision and strategy, awareness and acceptance and legal issues.

Walta (2004) combined a literature review and stakeholder interviews in order to identify driving forces and barriers for the deployment of cooperative systems and identify viable concepts for development. These driving forces and barriers were identified from the perspective of the authorities, the industry and consumers. The results of the study are shown in Table 4.2.

Table 4.2: driving forces and barriers for deployment of cooperative systems (source: Walta, 2004)

Perspective	**Driving forces**	**Barriers**
General		Cooperation Market penetration
Authorities	Policy goals (efficiency and safety) Cost savings	
Industry	Competitive advantage Unique selling point Regulation Comfort Safety Profits	External control
Consumers	Efficiency (business) Comfort (private) Safety Image Clear benefits	Willingness to pay Privacy

It can be concluded that the driving forces indicate which aspects should be taken into account to make the business case of all stakeholders. Previously, it was suggested that a positive business case for all stakeholders is essential for successful deployment of SA systems. With regard to the barriers it can be concluded that they correspond with issues discussed with regard to coordination and cooperation, vision and strategy and awareness and acceptance.

4.4 Stakeholders

As mentioned previously, three stakeholders were considered: the government, the automotive industry being the car manufacturers and the suppliers and the consumers (users). On the basis of the results of the interviews and literature this section discusses the objectives, intentions, positions and attitudes of these stakeholders with regard to SA systems. All information presented in the section 4.4.1, 4.4.2, 4.4.3 and 4.4.4 is originated from the respondents of the interviews. The 'b-sections' discuss the findings from literature which were found sufficient to validate and complement the literature findings. Conclusions are drawn in section 4.5.

4.4.1 Government

The high potential of SA systems with regard to traffic safety makes these systems very interesting for politicians. Especially since almost thirty percent of all accidents in the Netherlands are caused by speed. Yet, most policy makers are not fully aware of the existence of SA systems. Moreover, the attitude of the government is very sensitive for trends, which makes it hard to predict how things take course.

All respondents agreed that the role of the government should be to initiate research and start pilots to raise the public awareness and acceptance of SA systems. Although the market introduction of SA systems should come from the market, the government can play an active role by stimulating the market. Furthermore, the government can act as the 'launching costumer' or force the use of a system. However, from a government point of view, mandatory deployment is not seen as a realistic option. (Financial) incentives like subsidy, tax reduction or target group lanes for system-users are agreed more realistic by all respondents.

Additionally, the government should stimulate the supply side of the market. They should have a facilitating role, provide guidelines and deadlines and create conditions with which the industry can work. Nevertheless, a relatively short time-horizon on which ADA systems are not interesting keeps the government from stimulating the deployment of these systems. Besides, the government (and the industry) make (electoral) considerations compared to other developments, because they have a higher priority in this time-horizon.

Finally, it has to be noted that the government does not want to take responsibility for possible system failure. According to the government, the industry should take responsibility for system failures.

4.4.1b Literature on government

Marchau et al. (2002) provided an overview of the types of roles the government can have and the types of measures the government can take. Both are summarized below.

Types of roles for governments:

- Neutrality: no intervention
- Monitor: being informed about technological domains
- R&D agent: initiative taking in R&D
- Regulator: creating frameworks
- Innovation agent: creating conditions for successful implementation of innovations

- Market development enhancer: e.g. pricing instruments, support promotion activities

Types of measures governments can take:

- Structural measures – adaptation of legal and regulatory framework conditions (e.g. taxation).
- Technology measures – these involve research, development and experimentation.
- Compatibility measures – standardisation issues, either for increasing compatibility between technologies or for increasing critical weights for introducing these measures.
- Cultural measures – government policy can play an important role in influencing attitudes.
- Institutional measures – sometimes parties have to cooperate in order to enable e.g. multi-model transport. Competitive pressure in the market determines innovative investments.

Bishop (undated) presented an overview of actions which the government should carry out as part of their role in the deployment process.

- Quantify benefits via well-designed evaluation projects.
- Encourage individuals and companies to buy and use the systems for societal benefit.
    - Support public awareness activities to accelerate market uptake.
    - Promote systems with commercial vehicle operators.
    - Create financial incentives.
- Support deployment of cooperative system elements.
- Re-evaluate crash testing regulations.

From Marchau et al. (2002) and Bishop (undated) it can be concluded that the role of the government should be to: initiate, facilitate and stimulate the deployment process of SA systems.

Kenis (2004) states that the policy targets generally are: safety, tackle congestion and environmental impact. Based on the potential impact of speed management with SA systems, the public authorities clearly have an interest. With speed management the public authorities expect to enhance traffic safety, improve driver comfort and reduce congestion by smoothening traffic flows and avoiding accidents. The main barriers from a public authority point of view are the availability of a digital speed database and keep it up-to-date, system acceptance and financing.

Finally, Walta (2004) concluded that besides the automotive industry, the government is the most powerful stakeholder. As was pointed out previously, her results also showed that the main driving forces for the authorities are policy goals (efficiency and safety) and cost savings.

4.4.2 Car manufacturers

Car manufacturers work profit based and do not expect that SA systems to be money making. Besides, they do not associate these systems with their desired image, which makes them conservative towards the deployment of SA systems.

The complex multi-stakeholder environment of (cooperative) SA systems is relatively new for car manufacturers and forms a large barrier. Furthermore, the competitiveness of the car industry in which much information is kept secret, because all manufacturers want to distinguish themselves from others is a second barrier for an open market. As a result, car manufacturers make clear considerations based on other developments that might have a higher priority.

By far the most important barrier for car manufacturers is liability. Currently, car manufacturers are responsible for system failure but do not want to take this responsibility. As a result, until systems are 100 percent fail safe or the liability issue is solved, systems are sold as comfort systems instead of safety systems to avoid liability claims. Basically, car manufacturers make considerations between much use and less liability.

Car manufacturers like to make a clear difference between supporting systems and enforcing systems. Supporting systems are systems that help the driver in critical (collisions) or unpleasant (traffic jam) situations and enforcing systems are systems that control the driver to keep to the speed limits. Car manufacturers only want to be associated with supporting systems. Furthermore, car manufacturers are not interested in mandatory use of SA systems, but rather see the market deal with the implementation. The reason for this is simple: mandatory use means that all cars have to be equipped with a system which increases the price of a car and decreases sales.

In general it can be concluded that car manufacturers are conservative towards SA systems because there is no clear business case for them. For instance, car dealers rather sell leather seats in 3 minutes than an Adaptive Cruise Control in 45 minutes, since they gain the same commission for both accessories. Besides their own business case, car manufacturers feel responsible for addressing the costumers' concerns on privacy and protect them from unintended use of system data for enforcement purposes. Some of the respondents suggested that the car manufacturers will never start widely implementing SA systems until it is a law.

4.4.2b Literature on car manufacturers

Reinhardt (2004) gave a presentation about the position of car manufacturers with respect to Speed Alert systems (for Speed Alert systems, see section 2.3.3). Basically, it involved a presentation about the intentions and objectives of the Speed Alert project adjusted with comments and visions of the car manufacturers. The comments give a good indication about the attitude of car manufacturers towards SA systems. Below, the comments are summarised and printed bold.

- The driver ***must*** remain in control of the vehicle at all times.
- System should provide ***supportive*** speed limit information.
- ***No vehicle manufacturer liability for displaying inaccurate/outdated speed information as received from database media.***
- Future challenge is how to handle temporary and variable speed limit information ***as well as related databases.***
- Adaptive speed vs. speed limits: in 34% of all heavy accidents in Germany ***in-appropriate speed*** is mentioned as one of the causes. As in the vast majority of the cases the driver had problems with adapting his speed ***below*** an official speed limit, the information to the driver on actual speed limits will only solve the minor part of the problem.

What the automobile industry does not want is Automatic Speed Adaptation, Intelligent Speed Adaptation, Intelligent Speed Adaptation with enforcement or any kind of mandatory system.

- According to the limitations mentioned before, speed alert systems should be ***optional*** and ***only support the driver, warn against dangers, and increase*** his ***comfort***. They should not impose a pre-prescribed model of conduct.
- ***The automotive industry, therefore, supports a kind of speed alert system with speed information and warning hints, where the driver keeps the full responsibility and competence to take right experience base decisions.*** This would be in line with the European "Code of Practice" where telematics- and assistance functions should not have an enforcement character but be informative and supportive.
- The automobile manufactures had drafted a matrix to bring discussions back on a more "matter-of-fact" level. Other stakeholders have not responded to this initiative so that the matrix is still incomplete. ***The automobile manufacturers expect that this work will now be done as a first step under the current initiative to start from a jointly agreed basis.***

Finally, Walta (2004) concluded that besides the government, car manufacturers are the most powerful stakeholder. As was pointed out previously, her results also showed that the main driving forces for car manufacturers are competitive advantage, unique selling point, regulation, comfort, safety and profits. The main barrier for car manufacturers is that they will not accept external (government) control.

4.4.3 Suppliers

Suppliers make system for two markets: the car market and the aftermarket. On demand, systems which intervene with the motor management are installed in cars by the suppliers. Advisory system variants like navigation systems can be sold to the costumers directly via the aftermarket. For both markets suppliers are very pleased when the use of support systems is mandatory, because high penetration rates guarantee sales. This is what makes suppliers different from car manufacturers; they are more eager to sell any kind of driver assistance system. With regard to liability the suppliers face the same difficulties as car manufacturers; they do not want to be responsible for system failure and only sell systems if they are 100 percent fail safe. In conclusion, the success of the deployment of SA systems for a large part depends on the willingness to invest of car manufacturers and suppliers.

4.4.4 Consumers

Advisory system variants are well accepted by consumers (users). Intervening and controlling variants, where users have to hand in their freedom or control, are less accepted. Nevertheless, users seem more enthusiastic when there is the possibility to switch off the system and can choose when and where to be controlled. In specific situations, when the freedom or control of the user is not limited by a system but buy the environment of the car, systems are expected to be more accepted. For instance, in congested areas, SA systems can take over parts of the driving task and increase the driving comfort. Also in vulnerable areas where SA systems can increase the traffic safety, for instance around schools, they are expected to be more accepted. In general, users are willing to be supported in their driving task in specific situations, but they are not willing to be controlled on the basis of speed limits and law enforcement grounds. From this perspective, active safety systems are very straight forward; the systems are autonomous and deal with critical situations in which almost every user will accept a system that takes over the control of the vehicle. Although the user acceptance of these systems is high, the user awareness is still very low. People are not experienced with SA systems and not familiar with the benefits and social need.

It is important to note that users are very sensitive for system handlings other than expected or different from what the user normally would do. The users can become irritated, adjust the settings of the system or even turn it off. Furthermore, the consumers are very sensitive for the price of SA systems; if the system is not affordable, it will not be bought. In conclusion, it is not guaranteed that once driver assistance systems are available they will be bought and if they are bought that they will be used, before the benefits are made clear.

As was mentioned previously there are some concerns about the privacy of consumers when vehicle data is communicated via Vehicle-Vehicle or Vehicle-Infrastructure communication. The biggest fear is that the information about the whereabouts of the vehicle (and thus the consumers) is registered and used in a way that was not intended. The worst case from the perspective of the consumer is that the information is used for enforcement purposes.

4.4.4b Literature on consumers

During the same workshop of the Speed Alert consultation group in Brussels that was mentioned previously, Cuypers (2004) gave a presentation about the road users' point of view with regard to SA systems. The acceptability of speed alert systems can be indicated by the objectives and concepts of the systems that were found attractive by the users:

- Speed Alert systems are advisory and provide information.
- Fitting and use of speed alert system are voluntary.

- Raise awareness of the driver with regard to maximum and appropriate speed.
- They can reduce the need for speed enforcement.
- More friendly than physical obstacles such as speed humps.
- Can contribute to reducing speeding and speed-related traffic accidents and improve road safety.
- Especially helpful in built-up areas, especially where cars and vulnerable road users mix.

A huge concern for users is the ‘Big Brother’ fear. This fear involves the issue of driver control in the vehicle, possible resistance to intrusive systems, the issue that systems should not be a substitute for speed enforcement and protection of private data.

Cuypers (2004) emphasised that is it very important how systems are introduced. The public will expect a genuinely intelligent system, with accurate digital road maps, flawless technology and smooth transition between speed limits, easy to operate. Cuypers also suggested that accurate information and education is required. The public must be informed of speed limits; static and dynamic. Some drivers may over rely on speed alert systems or be diverted from their task.

The liability issue is also found very important from the perspective of the users. It is questionable if the driver will always make the right decision or have the right interpretation on the basis of the information provided. Even more questionable is how this will affect accident liability.

As was pointed out previously, the results of Walta (2004) showed that the main driving forces for consumers are efficiency (business), comfort (private), safety, image and clear benefits. The main barriers with regard to the consumers are their willingness to pay and privacy.

4.5 Summary and selection

The interviews indicated that the most critical deployment factors are: coordination and cooperation, vision and strategy, technology, awareness and acceptance and legal issues. On the basis of the objectives, intentions and position of the government, car manufacturers, suppliers and consumers some elements of these deployment factors were discussed in more detail. The interviews were found useful to narrow the scope of the literature review and restrict the review to the most interesting and complete sources. The findings in literature were very similar to the results of the interviews from which it can be concluded that the deployment factors found in the interviews are representative for the current situation. It has to be noted that it is not clear if and how these factors might change over time.

From the five deployment factors, technology and legal issues were found less important because they are expected to be overcome easily. Therefore these factors will not be taken into account for scenario development. The position of the suppliers seems straight forward as long as they can sell their products one way or another and therefore will be left out of consideration in further research. In further analysis only the government, car manufacturers and users are considered.

In conclusion, the three remaining deployment factors can be grouped in two categories: market demand factors (awareness and acceptance) and market structure factors (vision and strategy, and coordination and cooperation). If the market demand is high the hypothesis is that the market as a whole will grow. This is called market pull (Smit and Van Oost, 1999). Alternatively, if the market structure increases (i.e. the market is organised through cooperation, coordination and the presence of a vision and strategy, etc.) the hypothesis is that the deployment of SA systems is stimulated by the government and car manufacturers. This is called technology push (Smit and Van Oost, 1999). From this it can be concluded that the two most critical overall factors with regard to the deployment of SA systems can be defined as *market development* (the development of market demand) and *market organisation* (market structure through cooperation, coordination, vision and strategy).

In the following chapter a method opposed by Svidén (1986) is applied in which these two factors are used as the basis for a scenario landscape and the development of four scenarios for the deployment of SA systems (see Figure 4.2).

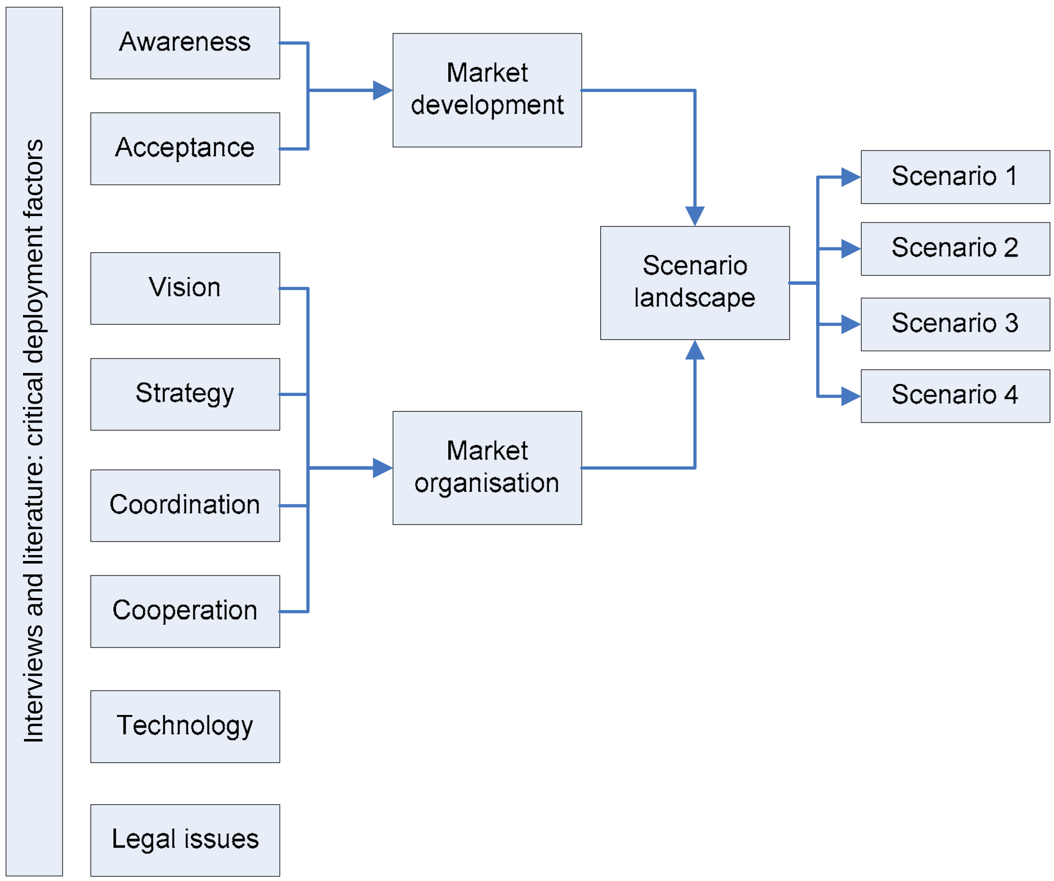


Figure 4.2: transformation interview results to scenarios

5 Scenario development

5.1 Introduction

The previous chapter indicated that *market development* and *market organisation* are the two most critical factors with regard to the deployment of SA systems. This section deals with possible future deployment scenarios resulting from the scenario conditions created by these two factors. What these conditions are and how they can develop is uncertain. Scenario analysis is used to address this uncertainty and describe future developments of the deployment of SA systems based on explicit assumptions (Masser et al., 1991). The objective of the scenario analysis in this research is to provide insights into the future development of the deployment of SA systems. A measure for the development of the deployment of SA systems is the development in time of the penetration rate of SA systems. Penetration rate is the percentage of vehicles equipped with a particular system. Due to the unavailability of complete, accurate information and data the analysis does not discuss exact numbers but focuses on the *mechanisms* of the market that lead to market penetration. The results of the analysis have to be interpreted and are discussed on a hierarchical scale. With the insights obtained from the analysis it is assumed that an effective deployment strategy can be formulated.

The structure of this section is as follows. In section 5.2, on the basis of a scenario landscape, a rough sketch of the area of investigation is given. Next, the variables describing the actual scenario along with a number of assumptions are defined in section 5.3. In section 5.4 a schematic presentation of the scenario model is given. Finally, in section 5.5 four scenarios for the deployment of SA systems are presented.

5.2 Scenario landscape

To indicate the outer limits of probable future developments it is practical to produce a set of rough scenario sketches defining the area of investigation (Svidén, 1986). Concentrating on the most critical influencing factors makes that scenarios are developed upon the key factors of the scenario context and a manageable number of scenarios can be derived. In the method of Svidén the two most critical factors represent the two dimensions of a scenario landscape of which the four quadrants represent four scenarios. Through extreme projection of the dimensions, both ends of the dimensions can be defined and evaluated. From previous research it was learned that both ends of a dimension have to be useful for scenario development in order to obtain four interesting scenarios (RESPONSE 2, 2004). Although all dimensions have their own advantages and disadvantages, dimensions in which developments stagnate do not lead to new insights and therefore are less useful.

The results of the interviews and literature review showed that *market organisation* and *market development* are the two most critical overall factors with regard to the deployment of SA systems. That these two factors represent market demand and market supply implies that the scenario landscape represents four scenarios with four different combinations of supply and demand. Extreme projection indicates that market organisation can range from ‘individual’ to ‘collective’ and that market development can range from ‘stable’ to ‘growth’. The scenario landscape is shown in Figure 5.1.

5.2.1 Scenario dimensions

Market development is assumed to indicate the movements of the demand side of the market. To define stability and growth it is necessary to describe factors that generate market demand. The interviews and literature review indicated that system acceptance, social need and growth of the purchasing power of consumers are of influence to the market demand. With regard to a stable market it is assumed that the system acceptance is low, the social need is stable or decreases and that there is little growth in the purchasing power of consumers. As a result, all stakeholders, in particular the users, are conservative towards SA systems. In summary, there is little or no demand for SA systems and there are no intentions to change this situation. When the market is growing the opposite of the above mentioned is true.

Market organisation is assumed to indicate the structure of the supply side of the market. To define collectivity and individuality it is necessary to define structure. The interviews and literature review indicated that structure describes the level of coordination and cooperation, the presence of a vision and a strategy and the commitment of the stakeholders. With regard to a collective market it is assumed that stakeholders are committed and have a clear vision, the market is coordinated and that there is cooperation between the government and car manufacturers because both see the potential of SA systems. Through market forces a free market strategy is sufficient for fast development of technology. In summary, the deployment of SA systems is very promising and strongly stimulated by the government and car manufacturers. When the market is individual the opposite of the above mentioned is true.

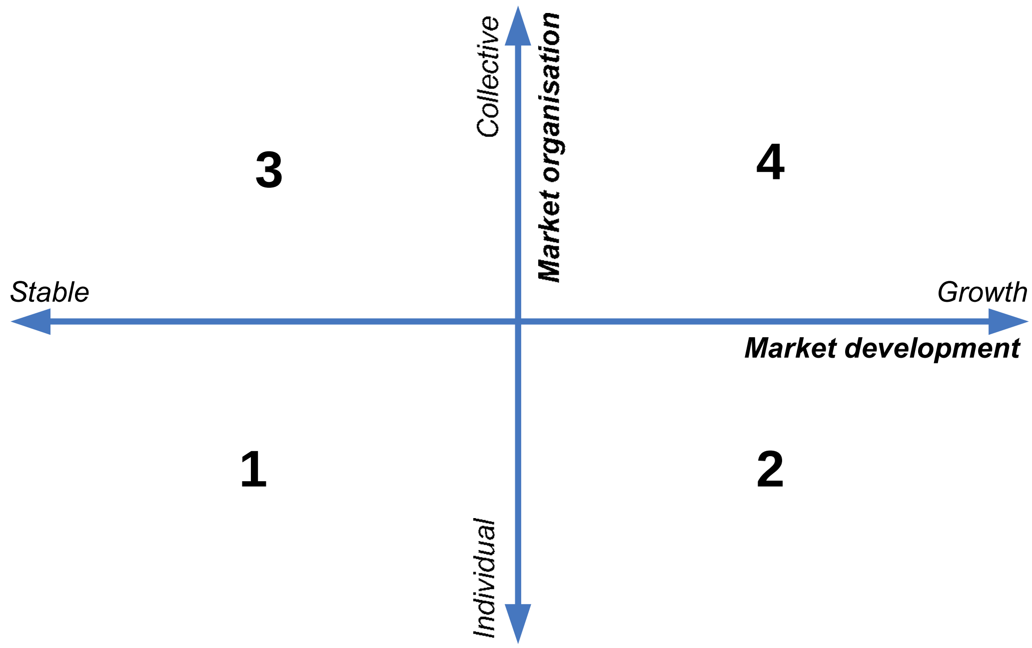


Figure 5.1: scenario landscape

5.2.2 Assumed conditions

The knowledge that both ends of a dimension have to be useful for scenario development is also applicable to some scenario variables. Due to practical reasons it is assumed that the useful ends of these variables are applicable for all scenarios. This means that a number of potential barriers for the deployment of SA systems are assumed to be dealt with and removed. These variables will be left out of consideration in further analysis. It has to be noted that these assumptions create scenario conditions that suppose a perfect world, which obviously has consequences for the outcome of the analysis. These consequences are discussed in chapter 8. The assumptions are discussed below.

- Liability risk is assumed to be low to make the stakeholders and especially the car manufacturers willing to invest in SA systems. None of the stakeholders is willing to be held responsible for any financial compensation for system malfunctioning. If the liability risk is not low, one or more of the scenarios will be less useful because the deployment of SA systems can not succeed due to the lack of investments.

- System usability is assumed to be high, which means that a system is: comprehensible, predictable, controllable, robust, has a significant impact on traffic safety, traffic flow or vehicle emissions and a considerable market potential. High system usability makes systems potentially accepted by public and politicians, because it comes towards the individual interests of the stakeholders and satisfies their wants. Whether a system is accepted still differs per scenario depending on the system variant and the scenario conditions.

- System operation: all systems are assumed to be overrulable by the user at all times. This means that a system can be switched off or ignored at all times. As a result, systems have the potency to be accepted by the public.

- System purpose: systems are assumed to be introduced with the objective to support the driver in his driving task. They are not introduced as enforcing applications which can fine users when they violate traffic law. As a result, systems have the potency to be accepted by the public.

- Political and public awareness involves knowledge about the benefits and necessity of systems and more general the existence of systems. It is assumed that marketing and promotion activities are initiated to raise public and political awareness. The next step is to raise the public and political *acceptance*, which differs per scenario depending on the scenario conditions.

5.3 Scenario variables

As discussed in chapter 3 scenario variables are typical ‘state’ variables that describe the actual scenario. For scenario modelling it is important that the scenario variables are measurable and quantifiable. This scenario analysis focuses on the development of the penetration rate of SA systems. The penetration rate of the system is assumed equal to the number of systems sold. The scenario variables that are sufficient to induce likely values for the penetration rate of the system are assumed to be factors which determine whether a person buys a system or not. In the interviews and literature, four of these factors were identified: the price of the system, the system acceptance, the growth of the purchasing power of consumers and the social need of the system. Obviously, the availability of a system in the different market segments is relevant as well. Figure 5.2 represents the basis of what will become a scenario model. All variables in the yellow box together represent a scenario in which scenario variables are red and output variables are green. An arrow between two variables indicates a relation between the two variables. If an arrow points towards a variable it means that in this relation the variable is influenced by the other variable. Vice versa it means that the variable is a decisive factor with regard to the other vehicle.

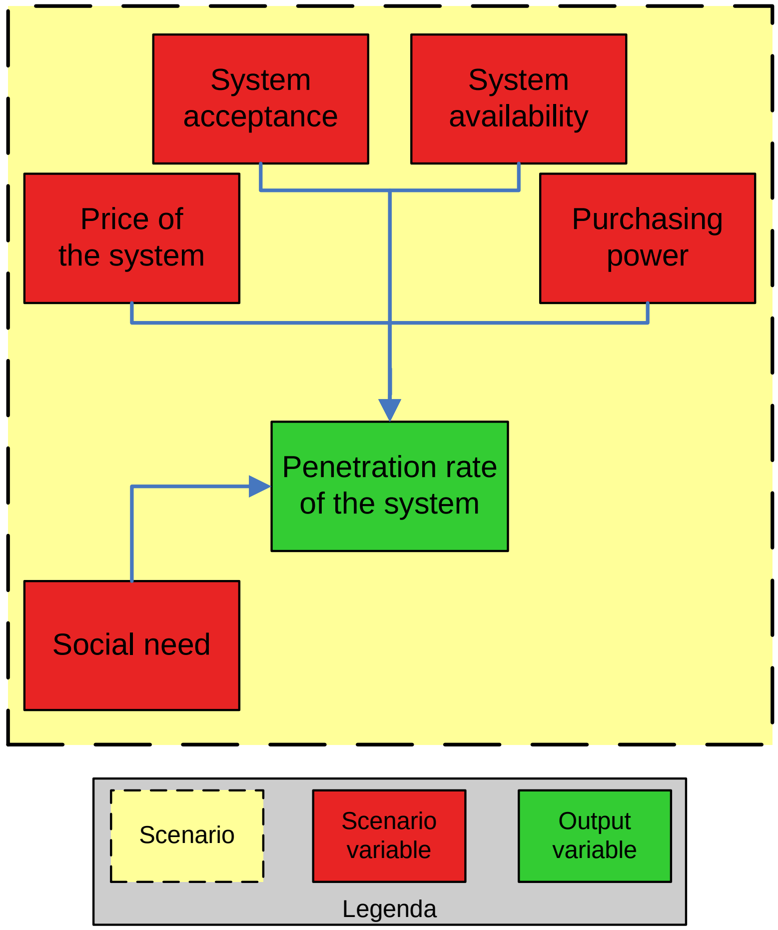


Figure 5.2: schematic presentation of a scenario

Sub-variables are determinants of scenario variables and are discussed in the sections 5.3.1 through 5.3.5. Additionally, the sub-variable 'government regulation' is discussed in section 5.3.6. In chapter 6 the scenario variables and sub-variables are quantified. Before going into detail several assumptions are made to limit the scope, complexity and the number of (sub-) variables of the scenario model. These assumptions are listed below.

- The scope of the model is limited to passenger cars, being privately owned passenger cars and company cars (vans and leased passenger cars), but no distinction between travel purposes is made.

- It is assumed that SA systems are only available on new cars and sold as an accessory, not as a standard. The market for SA systems is divided in three market segments: high-end, mid-range and low-end. This assumption is made because different system variants are expected to be introduced in the three market segments sequentially.

- Since SA systems are only available on new cars it is assumed that there are no limitations with regard to the production capacity of SA systems.

- Only the system effects on motorways are taken into account, because effects on rural and urban roads are unknown so far. Once these effects are known, the model can be adjusted easily.

- It is assumed that once a system is bought it will be used a well. Additionally, it is assumed that once people have bought a system they will buy the system again every time they purchase a new vehicle.

- It is likely that systems profit from the market position obtained by preceding systems. For example, controlling system variants can profit from the development of the penetration rate of advisory system variants. Due to the lack of insight in this relation it is left out of consideration.

- In addition to the latter: it is likely that several system variants are available on the market simultaneously, which means that consumers have the possibility to choose. Due to practical reasons it is assumed that only one system (variant) is available at the same time. The consumers are left with the option to buy the system under investigation or to buy no system at all.

5.3.1 Price of the system

The price of the system *(C_t)* obviously interferes with pricing strategies of car manufacturers (Baum, et al., 2002). Therefore the price of the system is based on system cost estimations. The basis for the price of the system is the ***cost price of the system (c_c)***, which is the cost for development and production of the system. Considerable savings in the cost price are expected in particular due to the use of other, cheaper materials. Furthermore, the price of the system can decrease through the principle of '***economy of scope***' ***($c_{e,t}$);*** the situation that arises when the cost of performing multiple business functions simultaneously proves more efficient than performing each business function independently (Muriel Siebert and Co., Inc., 2006). It is assumed that economy of scope arises when the government and car manufacturers cooperate and the market becomes organised. Other cost savings are ***financial incentives ($c_{i,t}$)*** provided by the government or car manufacturers in the form of subsidy, tax reduction or discounts, and cost savings through the ***growth of the production scale ($c_{s,t}$)***.

It is assumed that the price of the system can be determined on the basis of equation 5.1.

$$C_t(c_c, c_{e,t}, c_{i,t}, c_{s,t}) = c_c * \frac{(100 - c_{e,t})}{100} * \frac{(100 - c_{i,t})}{100} * \frac{(100 - c_{s,t})}{100} \tag{5.1}$$

In which:	C_t	price of the system at time t (€)
	c_c	cost price of the system (€)
	$c_{e,t}$	economy of scope at time t (%)
	$c_{i,t}$	financial incentives at time t (%)
	$c_{s,t}$	production scale at time t (%)

5.3.2 Purchasing power

The growth of the purchasing power of consumers *(G_t)* is a generic term that represents the economic situation and is a product of the ***economic growth (g_e)*** and the ***inflation (g_i)***. It is assumed that an increase in the growth of the purchasing power leads to an increase in the consumer's willingness to pay for SA systems, which is assumed to lead to higher penetration rates.

Due to the lack of data, the purchasing power will not be determined as the result of economic growth and inflation, but set to a specific value for each scenario (see section 6.3.2). Therefore the equation for the purchasing power is straightforward.

$$G_t(g_{e,t}, g_{i,t}) = G_t \tag{5.2}$$

In which: G_t growth of the purchasing power at time t (%)
$g_{e,t}$ economic growth at time t (%)
$g_{i,t}$ inflation at time t (%)

5.3.3 Social need

The social need of a system *(N_t)* is an indicator for the indirect traffic costs like ***time losses ($c_{tt,t}$)*** due to congestion, ***accident cost ($c_{a,t}$)*** and ***emission cost ($c_{e,t}$)***. It is assumed that if the indirect traffic cost increase and traditional measures are fully deployed the social need of SA systems increases and lead to higher penetration rates. Once considerable penetration rates are reached the social need is assumed to decrease as a result of the expected ***impact of the system ($I_{N,t-1}$)*** on traffic flow, traffic safety, vehicle emissions and driving comfort. The impact of the system is not only a sub-variable, but an output variable as well, based on the penetration rate.

It is assumed that the social need of the system can be determined on the basis of equation 5.3. The weights in the equation are optional and can be used if particular traffic costs are more important than others. In this analysis the weights are left out of consideration.

$$N_t(c_{tt,t}, c_{a,t}, c_{e,t}, I_{N,t-1}) = \frac{(\alpha_{tt} * c_{tt,t} + \alpha_a * c_{a,t} + \alpha_e * c_{e,t})}{(\alpha_{tt} + \alpha_a + \alpha_e)} * (1 - (I_{N,t-1}/100)) \tag{5.3}$$

In which: N_t social need at time t (index number)
$c_{tt,t}$ travel time losses at time t (index number)
$c_{a,t}$ accident cost at time t (index number)
$c_{e,t}$ emission cost at time t (index number)
$I_{N,t-1}$ impact of the system at time t-1 (%)
α_{tt} weight travel time losses (#)
α_a weight accident cost (#)
α_e weight emission cost (#)

It is assumed that the impact of the system I_N can be determined on the basis of equation 5.4.

$$I_{N,t-1}(P_{t-1}) = \sum_{i,c} a_{i,c} * P_{t-1}^{n_i} + c_c \tag{5.4}$$

In which: P_{t-1} penetration rate of the system at time t-1 (%)
$a_{i,c}$, c_c parameters for indirect traffic cost c (time, accident or emission cost) (#)
n_i exponent of P_{t-1} (#)

5.3.4 System acceptance

System acceptance *($A_{t,s}$)* is a so called ‘soft’ variable that represents the natural resistance or acceptance of the public towards new technology, in particular technology that limits the freedom of the user. Acceptance involves numerous factors and is often tried to be comprehended with a rational approach. However, it is questionable if humans act rationally. For instance, the status of a car generally does not correspond with the rational thought that it is just an object to move from A to B.

The interviews and literature review indicated that system acceptance is subject to the ***level of control ($a_{l,s}$)*** of the system. Users clearly prefer advisory system variants to intervening and controlling variants. Besides the level of support, system acceptance is also subject to ***market development ($a_{md,t}$)*** and ***market organisation ($a_{mo,t}$)***. For instance, in a growing market with a high social need, systems are assumed to be accepted sooner. Furthermore, high social need is assumed to increase the interest of the government in SA systems and increase the government's willingness to stimulate the deployment of SA systems. In this way, via market organisation, the government indirectly influences the system acceptance of the public.

Due to the complexity of this variable, the system acceptance will not be determined as a function of other variables, but will be set to a specific value based on literature findings. Therefore the equation for the system acceptance is straightforward. Nevertheless, the system acceptance is different per scenario and per system variant (see section 6.3.4).

$$A_{t,s}(a_{l,s}, a_{md,t}, a_{mo,t}) = A_{t,s} \tag{5.5}$$

In which:	$A_{t,s}$	system acceptance for system s at time t (%)
	$a_{l,s}$	level of control of system s (%)
	$a_{md,t}$	market development at time t (index number)
	$a_{mo,t}$	market organisation at time t (index number

5.3.5 System availability

The availability of certain technology may enable the existence of a functionality or improve the performance of a system variant. The technology roadmaps discussed in section 2.3 are very useful to determine the availability of SA systems *(U_t)* at a certain moment in time. The availability of SA systems depends on the ***availability of a system in a specific market segment (u_s)*** and the ***availability of a specific system variant (u_v)***. Based on Zwaneveld et al. (1999) a step by step development is chosen in both cases. This means that SA systems are assumed to become available in the high-end market first and lastly, two time steps later, in the low-end market segment. With regard to system variants it is assumed that first the advisory variant becomes available, followed by the intervening variant and at last the controlling variant.

The system availability can be described on the basis of equation 5.6.

$$U_t(u_{s,t}, u_{v,t}) = u_{s,t} * u_{v,t}, \forall s, v \tag{5.6}$$

In which:	U_t	system availability at time t (binary)
	$u_{s,t}$	availability market segment s at time t (binary)
	$u_{v,t}$	availability market variant v at time t (binary)

5.3.6 Government regulation

As discussed in section 4.4.1, the government has the ability to change legislation and force the use of SA systems. In this research, mandatory deployment is represented by the sub-variables government regulation. With regard to government regulation it is assumed that the other deployment factors or scenario variables are overruled and that the penetration rate of the system will reach its maximum. It is questionable whether this assumption is realistic, but based on its impact certainly interesting to examine.

5.4 Scenario model

All the scenario variables, sub-variables and output variables together are assumed to be sufficient as the basis of the scenario model. In this section the findings of the previous sections are summarised.

Table 5.1 shows the scenario dimensions upon which the scenarios will be developed. Also the assumed conditions are listed in this table.

Table 5.1: scenario dimensions and assumed conditions

Scenario dimensions	Market organisation *(individual vs. collective)* Market development *(stable vs. growth)*
Assumed conditions	Liability risk *(low)* System usability *(high)* System operation *(overrulable)* System purpose *(supporting)* Public and political awareness *(promotion activities)*

From the findings of this chapter a schematic presentation of the scenario model was drawn, which is presented in Figure 5.3.

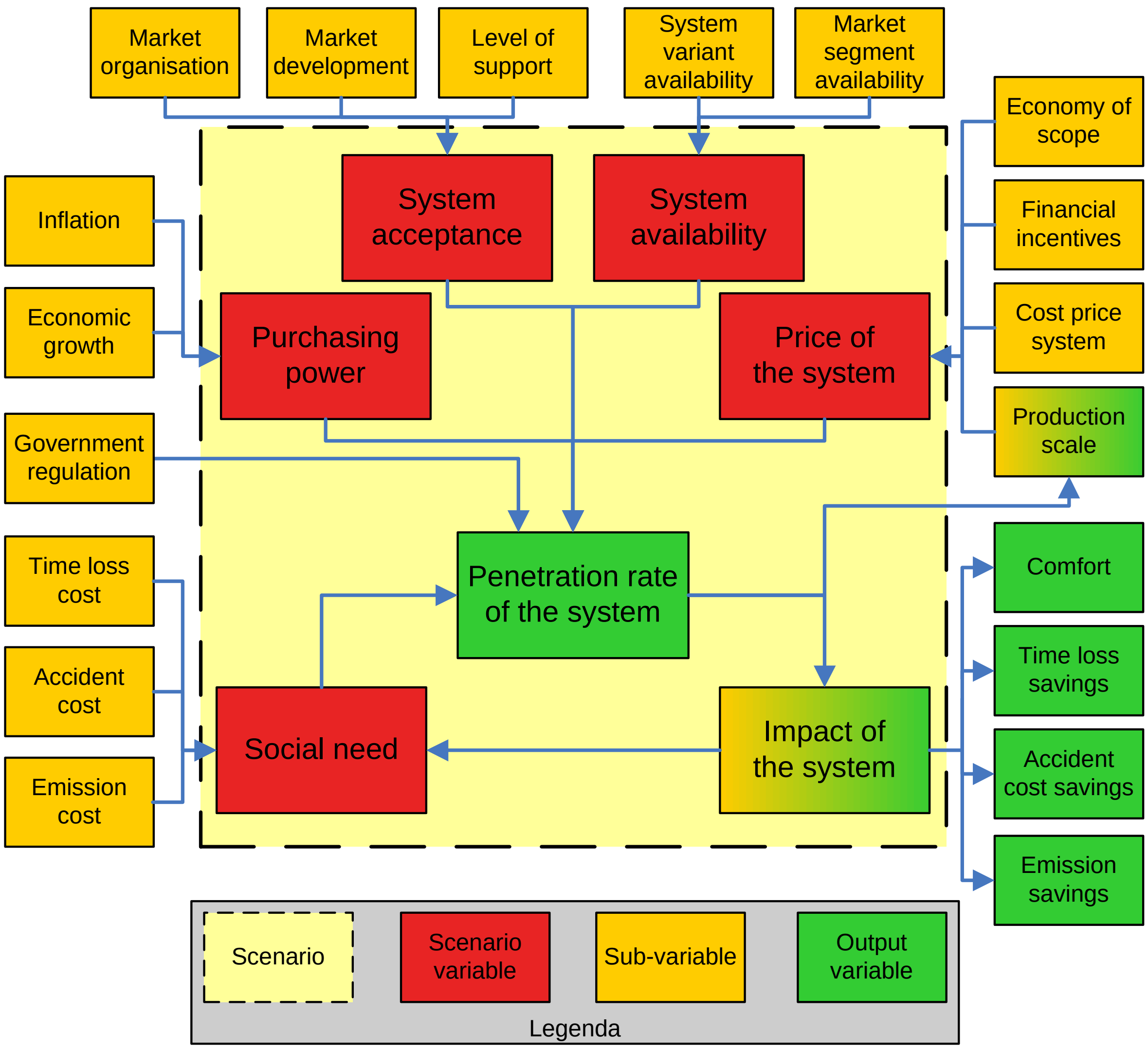


Figure 5.3: schematic presentation of scenario model

In this figure the output variables are green, the scenario variables are red and the sub-variables are yellow. All variables in the yellow box together represent a scenario. An arrow between two variables indicates a relation between the two variables. If an arrow points towards a variable it means that in this relation the variable is influenced by the other variable. Vice versa it means that the variable is a decisive factor with regard to the other vehicle.

The next and final section of this chapter combines the scenario model and the scenario landscape from section 5.2 to formulate four scenarios for the deployment of SA systems.

5.5 Scenarios

The next step of this scenario development exercise is to define scenarios on the basis of the scenario model and the scenario landscape. Most important is that these scenarios are useful, likely and provide new insights with regard to the deployment of SA systems. Six 'themes' are used to characterise the four quadrants. Four of the five scenario variables are used to describe the state of the scenario and two themes are used to indicate the result of the scenario conditions of a scenario. The theme 'penetration rate' describes the expected penetration rate of SA systems as the result of the scenario conditions of a particular scenario. Figure 5.4 presents an overview of the characteristics of the four quadrants featuring the four scenarios 'Conservative', 'Regulation, 'Free market' and Progressive'. In the following sections these four scenarios are described in detail. The scenarios and the scenario model are quantified in chapter 6.

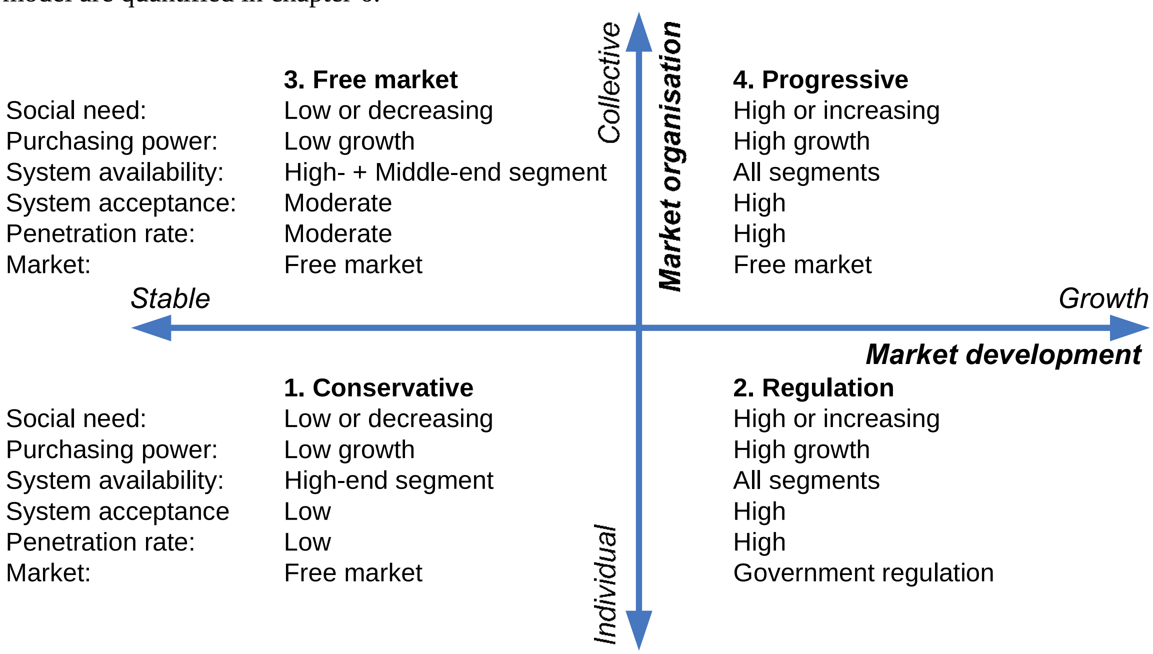


Figure 5.4: four scenarios for the deployment of SA systems

5.5.1 Conservative

The scenario conditions of this scenario are characterised by stable market developments involving a stable or decreasing social need, low growth of the purchasing power and low system acceptance. Due to the lack of a technology push there is neither a strong demand nor a strong supply, which results in poor development of the deployment of SA systems.

This scenario results from a combination of the scenario dimensions *individual* and *stable*. Due to a stable market, the traffic problems are stable or decreasing which leads to low social need. Also the growth of the purchasing power is low, which means that potential SA system users are hardly willing to pay. The supply side of the market is characterised by the lack of cooperation between the government and car manufacturers, thus no collective market organisation. As a result, there is no stimulation of the deployment of SA systems, thus no technology push. Since the market is stable and particularly social need is low, government regulation, financial incentives and marketing and promoting activities are not expected. As a result of the latter and low social need, the public acceptance is low. The conservative attitude of the government, car manufacturers and users, resulting in neither a strong supply nor a strong demand, leads to a poor development of the deployment of SA systems and other relevant technologies like communication and sensor technologies. Therefore, SA systems are expensive and only available on vehicles in the high-end market segment. Under these scenario conditions, the penetration rates of SA systems are expected to be low.

5.5.2 Regulation

The scenario conditions of this scenario are characterised by a growing market involving a high or increasing social need, high growth of the purchasing power and high system acceptance. Due to the lack of a technology push the government acts as the manager of the social interest and regulates the market by forcing the use of SA systems. As a result the deployment of SA systems develops strongly.

This scenario results from a combination of the scenario dimensions *individual* and *growth*. Due to a growing market, the traffic problems are serious and worsening rapidly which leads to high social need. Also the purchasing power is high, which means that potential SA system users are willing to pay for SA systems. The supply side of the market is characterised by the lack of cooperation between the government and car manufacturers, thus no market organisation. As manager of the social interests, the government takes the initiative to stimulate the deployment of SA systems as a measure for the traffic problems. Mandatory use of SA systems, promotion and marketing campaigns and financial incentives are expected due to government regulation. As a result of the latter and high social need, the public acceptance is high. The conservative attitude of car manufacturers is counterbalanced by the provision of guidelines. Strong demand, strong supply, but especially government regulations lead to a strong development of the deployment of SA systems and other relevant technologies like communication and sensor technologies. Therefore, and due to the financial incentives, SA systems are affordable and available in all market segments. Under these scenario conditions, the penetration rates of SA systems are expected to be high.

5.5.3 Free market

The scenario conditions of this scenario are characterised by stable market developments involving a stable or decreasing social need, low growth of the purchasing power and initially, low system acceptance. Due to cooperation between the government and car manufacturers a strong technology push arises. As the result of promotion and pricing strategies the system acceptance increases and the deployment of SA systems starts to develop moderately.

This scenario results from a combination of the scenario dimensions *collective* and *stable*. Due to a stable market, the traffic problems are stable or decreasing which leads to low social need. Also the growth of the purchasing power is low, which means that potential SA system users are hardly willing to pay. The supply side of the market is characterised by organisation as the result of cooperation between the government and car manufacturers. As a result, there is a technology push due to strong stimulation of the deployment of SA systems. The stimulation involves the provision of guidelines, an agreement on a Code-of-Practice, marketing, promoting and pricing activities and (small) financial incentives to users. As a result of the latter and low social need, the public acceptance is moderate. Furthermore, due to the financial incentives potential users become more willing to pay for SA systems. The progressive attitude of the government and car manufactures, resulting in a strong supply and moderate demand, leads to a moderate development of the deployment of SA systems and other relevant technologies like communication and sensor technologies. Therefore, and due to the pricing activities and financial incentives, SA systems are more affordable and available on vehicles in the high-end and mid-range market segments. Under these scenario conditions, the penetration rates of SA systems are expected to be moderate.

5.5.4 Progressive

The scenario conditions of this scenario are characterised by a growing market involving a high or increasing social need, high growth of the purchasing power and high system acceptance. Due to cooperation between the government and car manufacturers a strong technology push arises. The combination of strong demand and strong supply results in a strong development of the deployment of SA systems.

This scenario results from a combination of the scenario dimensions *collective* and *growth*. Due to a growing market, the traffic problems are serious and worsening rapidly which leads to high social need. Also the purchasing power is high, which means that potential SA system users are willing to pay for SA systems. The supply side of the market is characterised by organisation due to cooperation between the government and car manufacturers. As a result, there is a technology push due to strong stimulation of the deployment of SA systems as a measure for the traffic problems. The stimulation involves the provision of guidelines, an agreement on a Code-of-Practice, and marketing, promoting and pricing activities. As a result of the latter and high social need, the public acceptance is high. The progressive attitude of the government, car manufacturers and users, resulting in strong supply and strong demand, leads to a strong development of the deployment of SA systems and other relevant technologies like communication and sensor technologies. Therefore, SA systems are affordably and available on vehicles in all market segments. Under these scenario conditions, the penetration rates of SA systems are expected to be high.

5.6 Summary

To indicate the outer limits of probable future developments a scenario landscape was constructed upon the landscape dimensions market development and market organisation. Extreme projection of these dimensions indicated that market organisation could range from ‘individual’ to ‘collective’ and that market development could range from ‘stable’ to ‘growth’. On the basis of five scenario variables (price of the system, purchasing power, social need, system acceptance and system availability) and a number of sub-variables a schematic presentation of the scenario model was drawn. The last step of scenario development was the formulation of scenarios on the basis of the scenario landscape and the scenario model. This resulted in the four deployment scenarios ‘Conservative’, ‘Regulation, ‘Free Market’ and ‘Progressive’.

6 Scenario modelling

6.1 Introduction

The first phase of this research involved interviews and a literature review to identify the most critical factors with regard to the deployment of SA systems. In the previous chapter these factors were used to formulate four scenarios by analysing the coherence between these factors and presenting the mechanisms of the deployment of SA systems schematically. This schematic presentation forms the basis of the scenario model which is quantified in this section. From this point forward the focus is more specifically laid on IRSA systems and the Congestion Assistant instead of SA systems in general.

The structure of this chapter is as follows. First some general concerns and assumptions with regard to the making of the scenario model are recollected in section 6.2. Secondly, the scenario variables of the scenario model are quantified in section 6.3. Next, in section 6.4 the relations between the scenario variables and the penetration rate of the system are identified. Finally, for each scenario described in section 5.5 the initial values for the scenario variables are determined in section 6.6. In chapter 7 the model is tested, a sensitivity analysis is carried out and the model results are presented.

6.2 Assumptions

Before going into detail it is good to recollect the assumptions made previously. In section 5.2.2 the following assumptions are made for all scenarios:

- The liability risk is low
- The system usability is high
- All systems are overrulable
- All systems are supporting
- Public and political awareness is created

With regard to the comprehensiveness of the scenarios the following limitations were imposed:

- Focus on passenger cars, being privately owned cars and company cars (vans and leased cars)
- Three market segments: high-end, mid-range and low-end
- Speed Assistance systems are only available on new cars as an accessory
- There are no limitations with regard to the production capacity of SA systems
- Only the impact of the systems on motorways is measured
- No distinction between travel purposes
- Once a system is purchased by a user it will be purchased with every new car again
- There is only one system (variant) available at the time
- Time horizon: present till the year 2025 with the time steps 2006, 2010, 2015, 2020 and 2025.

The first four limitations concerning the size of the vehicle fleet are discussed in more detail in section 6.2.1. In section 6.2.2 it is explained how the impact of the system is modelled and section 6.2.3 discusses the time horizon and the dynamics of time.

6.2.1 Vehicle fleet

Focussing on passenger cars and assuming that systems are only available on new vehicles requires statistics of the national vehicle fleet, the number of new vehicles sold per year, and the distribution of the vehicles between the three market segments. On the basis of statistics of the BOVAG (2006), Broekhuijsen et al. (2006) and the Dutch Bureau for Economic Policy Analysis the following information is available:

Table 6.1: forecasted statistics of the vehicle fleet of the Netherlands

Variable	2006	2010	2015	2020	2025
Number of privately owned passenger cars	7.500.000	8.269.000	9.239.000	10.209.000	11.179.000
Number of company cars (vans of leased)	676.000 (918.000)	744.000	832.000	920.000	1.000.000
Number of new cars per year	+/- 500.000				
Distribution of car high-; middle-; low-end	30%; 45%; 25%				

6.2.2 Impact of the system

In this analysis, 'impact of the system' is a measure for the average system impact on traffic safety, traffic flow and vehicle emission *together* and calculated similar as the social need like discussed in section 5.3.3. The impact of a system is known to be correlated with the penetration rate of the system (De Jong, 2004; Van Mieghem, 2004). However, the exact relation between the impact of a system and the penetration rate of a system is often unknown. Research has indicated that for some systems the impact-penetration relation is linear and for others quadratic depending on the system functionalities. For example, the impact-penetration relation of Adaptive Cruise Control (ACC) is found to be more or less parabolic. First, with low to moderate penetration rates, ACC has the ability to improve the traffic situation. Though, depending on the headway, the marginal impact of the system diminishes and becomes negative as the penetration rate increases (VanderWerf et al., 2001). In other words; the total impact of the ACC-equipped vehicle fleet first increases and later decreases again when a certain optimal penetration rate is exceeded.

With regard to the IRSA systems and the Congestion Assistant the exact impact of these system is unknown as well. Currently, TNO is performing several studies to evaluate the impact of these systems. To leave all options open a generic equation for the impact-penetration relation is used for this analysis. In this equation, $y = \sum a_i \cdot x^{n_i} + c$, the parameters a_i, c and n can be adjusted to define any linear or polynomial relation.

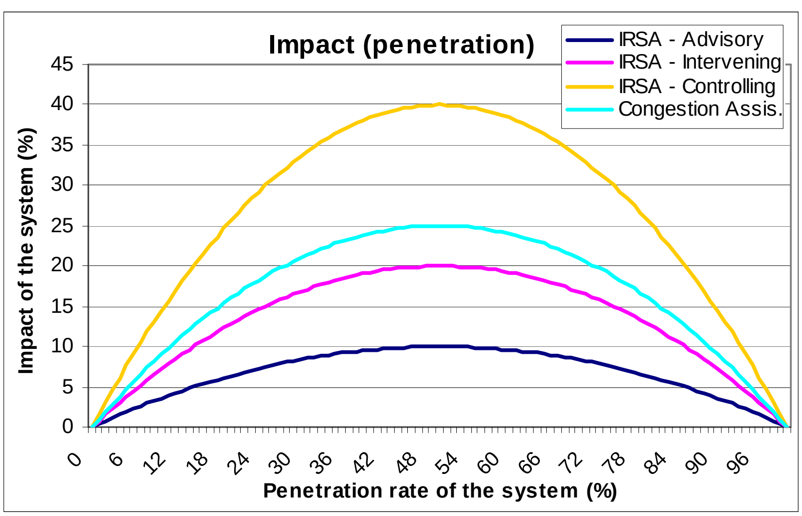


Figure 6.1: impact on safety, flow and emissions together as a function of the penetration rate

Since IRSA systems and the CA both contain ACC-functionalities it is assumed that the impact-penetration relation of these systems is similar to ACC. Due to practical reasons and the lack of detailed information, the impact-penetration relation of IRSA systems and the CA is assumed parabolic with an optimum at a penetration rate of fifty percent (see Figure 6.1).

Furthermore it is known that the impact of a system increases as the level of control increases (for example: Carsten and Tate, 2004). Therefore it is assumed that the maximum impact of controlling system variants is 40 percent, of intervening variants 20 percent, of advisory variants 10 percent and that the maximum impact of the Congestion Assistant is 25 percent. When the penetration rate of the system is nil or hundred percent the impact of all system variants is assumed nil. The parameters which describe these relations are presented in Table 6.2.

Table 6.2: parameters impact of the system

System variant	a_1	a_2	**c**	n_1	n_2
IRSA – Advisory	-0.004	0.4	0	1	2
IRSA – Intervening	-0.008	0.8	0	1	2
IRSA – Controlling	-0.016	1.6	0	1	2
Congestion assistant	-0.010	1.0	0	1	2

6.2.3 Dynamics of time

The dynamics of time describe how the model variables and model output evolve in time. To understand the model output it is important to understand the dynamics of time. Due to the limited availability of data the scenario model calculates with intervals of five years, thus not on a yearly base like the Scenario Explorer (Verroen, 1994). Therefore, this model evaluates the time steps 2006, 2010, 2015, 2020 and 2025. The dynamics of time of the model is presented schematically in Figure 6.2 and discussed below.

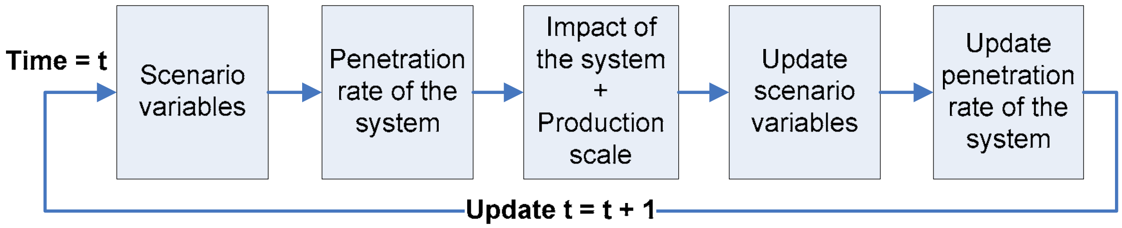


Figure 6.2: dynamics of time

Basically, in every time step the penetration rate of the system (*P*) is calculated as a function of the penetration rate as the result of the previous time step (P_{t-1}) plus the growth as the result of the current time step (ΔP_t) (see equation 6.1).

$$P_t = P_{t-1} + \Delta P_t \qquad (6.1)$$

In theory, the penetration rate of the system is calculated as follows (see Figure 6.2). First the scenario conditions are defined and quantified on the basis of the scenario variables. Next, the penetration rate of the system is calculated. With the penetration rate of the system, the impact of the system and the production scale are calculated and the scenario variables price of the system and social need are updated. Finally, the penetration rate of the system is updated. The penetration rate of the system as the result of this loop is used as the input for the next cycle.

6.3 Quantification of variables

In this section the scenario variables and sub-variables are quantified for scenario modelling. The following variables are discussed: purchasing power, system availability, social need, system acceptance and as determinant of the price of the system: cost price of the system, economy of scope, financial incentives, and production scale.

6.3.1 Price of the system

In section 5.3.1 the following equation for the price of the system was determined.

$$C_t(c_c, c_{e,t}, c_{i,t}, c_{s,t}) = c_c * \frac{(100 - c_{e,t})}{100} * \frac{(100 - c_{i,t})}{100} * \frac{(100 - c_{s,t})}{100} \quad (6.1)$$

In which:

In which:	C_t	price of the system at time t (€)
	c_c	cost price of the system (€)
	$c_{e,t}$	economy of scope at time t (%)
	$c_{i,t}$	financial incentives at time t (%)
	$c_{s,t}$	production scale at time t (%)

Below, the variables of this equation are quantified.

6.3.1.1 Cost price of the system

The cost price of the system (c_c) is a difficult variable to quantify, because these price figures are strongly interfered with pricing strategies of the manufacturers (Baum et al. 2002). Therefore the assessment is strictly based on system cost estimations. On the basis of multiple sources (Carsten and Tate, 2004; Abele et al., 2005, Maccubbin et al., 2005, Lewin, 2006 and LaGuarra, 2004) which gave an indication of the price of Intelligent Speed Adaptation, Adaptive Cruise Control, Collision Warning System or Radar Systems, assumptions are made for the prices of the advisory, intervening and controlling variants of IRSA and the Congestion Assistant. The prices are shown in Table 6.3.

Table 6.3: cost price of the system

System	Cost price of the system (c_c)
IRSA – Advisory	€ 750,-
IRSA – Intervening	€ 1500,-
IRSA – Controlling	€ 2500,-
Congestion Assistant	€ 2500,-

6.3.1.2 Economy of scope

Cooperation between the government and car manufacturers is expected to lead to cost reductions as suggested by the principle of ‘economy of scope’ $(c_{e,t})$. Economy of scope refers to the situation that arises when the cost of performing multiple business functions simultaneously proves more efficient than performing each business function independently (Muriel Siebert and Co., Inc., 2006). Normally economy of scope refers to cost savings through the production of one output in the presence of another (Laband and Lentz, 2005). In this analysis it is assumed that this principle also works the other way around, namely that cost savings can be gained through combining two business functions, in this case those of the government and the car manufacturers, into the production of one output.

No academic sources were found on this subject, but some articles of different news bulletins indicated that the average cost savings through cooperation between multiple stakeholders can increase up to 10-20 percent.

6.3.1.3 Financial incentives

Cost reductions through governmental subsidies $(c_{i,t})$ are expected to stimulate the deployment of new products. In the past years the Dutch government has provided subsidies for products which decreased the energy use of cars (Jansen, 2006). On energy efficient cars a discount on the vehicle tax of maximally € 1000,- could be gained. Hybrid cars were, and still are, subsidized with a maximum of € 6000,-. Currently, a € 600,- subsidy for smut filters can be gained.

On the basis of these numbers it is assumed that with regard to IRSA systems and the CA the government will provide subsidies of maximally 50% of the cost price of these systems. The equivalent amount of money is subject to the price and the penetration rate of the system.

6.3.1.4 Production scale

Based on the principle of 'economy of scale' $(c_{s,t})$ is assumed that cost savings can be gained when the production of a product increases (Muriel Siebert and Co., Inc., 2006). Since there is no detailed information available about the production cost of SA systems it is assumed that the percentage of cost savings is equal to the penetration rate of SA systems. This means that if the penetration rate of a system is 20 percent, the price of this system is reduced with 20 percent in comparison with the cost price of the system. To prevent that this variable becomes too dominant, the price reduction as the result of an increasing production scale can maximally be 75 percent of the cost price of the system.

6.3.2 Purchasing power

The growth of the purchasing power (G_t) of costumers is subject to the economic growth and the inflation. If the economic growth exceeds the inflation the purchasing power grows. Statistics Netherlands (2003) showed that the growth in purchasing power ranged from approximately 1 to 5 percent per year in the last fifteen years. The average growth of the purchasing power in this period was about 2 percent. Forecasts of the Dutch Central Planning Bureau indicated that the average growth in purchasing power in the next twenty years will be about 1.5-2 percent per year (Huizinga and Smid, 2004). In this analysis it is assumed that low growth of the purchasing power is equal to 1 percent and high growth of the purchasing power is equal to 5 percent.

6.3.3 Social need

Social need (N_t) is a measure for the weighted average of the time losses, number of casualties and vehicle emissions together as discussed in section 5.3.3. These three variables are quantified on the basis of index numbers with the reference year of 2006. (Forecasted) statistics on these index numbers were found in the Dutch transport policy paper (Dutch Ministry of Transport, Public Works and Water Management and Dutch Ministry of Housing, Spatial Planning and the Environment, 2004) and showed that the current traffic situation corresponds with an index number of 140. This index number is not 100 as one would expect, because in the policy paper, the desired (lower) traffic statistics for 2020 are set at an index number of 100 and the current traffic situation is adjusted correspondingly. For the scenario analysis it is assumed that the social need can be low or decreasing and high or increasing. On a scale ranging from 100 to 200, it is assumed that low/decreasing equals an index number of 120 and that high/increasing corresponds with an index number of 200.

Table 6.4: social need of SA systems

Scenario	***Index***
Reference (2006)	140
Low/decreasing	120
High/increasing	200

6.3.4 System acceptance

'Are people positive or negative towards ADA systems?' is a question that had and still has a lot of attention in pilots and surveys with regards to various ADA systems. These surveys provided insights in the opinion of users towards mandatory or voluntary use of Intelligent Speed Adaptation (Theorin, 2002; Biding, 2002; Cuypers, 2004), their opinion towards the usefulness and satisfaction with regard to a Congestion Assistant (Van Driel and Van Arem, 2006) or the users' opinion about Adaptive Cruise Control and Stop&Go with regard to comfort and safety (McDonald et al. 2004). On the basis of the results of these surveys assumptions are made for the acceptance *(A_t)* of IRSA systems and the CA. The results are presented in Table 6.5.

Table 6.5: system acceptance (A_t)

System	***Acceptance – Low***	***Acceptance – Moderate***	***Acceptance – High***
IRSA – Advisory	*37.50 %*	**75 %**	*95 %*
IRSA – Intervening	*30 %*	**60 %**	*75 %*
IRSA – Controlling	*30 %*	**40 %**	*50 %*
Congestion Assistant	*25 %*	**50 %**	*62.50 %*

In every scenario the system acceptance can be 'high', 'moderate' or 'low'. It is assumed that the current situation (2006), on which the assumptions are based, correspond with 'moderate' system acceptance. For 'low' system acceptance the moderate values have been multiplied by 0.5 and for 'high' system acceptance the multiplier was 1.25.

6.3.5 System availability

Whether a system is available at a certain moment in time and if this system is available in all market segments differs per scenario. In general a step by step introduction of the different system variants is assumed. Also the introduction of systems in the three market segments is expected to be step by step. Starting in 2006 this means that it takes at least two time steps before all IRSA system variants are available or before one system variant is available in all market segments.

6.4 Defining relations

To enable making calculations with the scenario model the relations between the scenario and output variables were defined. This section describes the method and assumptions on which these relations are built.

Due to the limited knowledge about the relations between the scenario variables and the penetration rate of the system these relations are assumed to be linear. It has to be noted that these relations might be inaccurate and not describe reality as it is. Nevertheless, this seems the most accurate approach with the knowledge at hand.

All relations between the scenario variables and the penetration rate of the system are of the same form presented in equation 6.2.

$$P(v) = a_v * v + P(0) \tag{6.2}$$

In which P penetration rate of the system
v scenario variable
a_v parameter for scenario variable v

This approach leads to four equations, one for each scenario variable: price of the system ($P_{c,t}$), purchasing power ($P_{g,t}$), social need ($P_{n,t}$) and system acceptance ($P_{a,t}$) as discussed in the sections 6.4.1 till 6.4.4. These equations represent the individual relations between the scenario variables and the penetration rate. The next step is to define an equation for the penetration rate of the system as a function of *all* scenario variables together. This equation is presented in 6.3.

$$P_t = P_{\max,t} * P_{factors,t} \tag{6.3}$$

In which:
$P_{max,t}$ number of vehicles possible to be equipped with the system at time t

$$P_{factors,t} = (P_{c,t} + P_{g,t} + P_{n,t} + P_{a,t}) / 4 \tag{6.4}$$

In which: $P_{factors,t}$ value between 0 and 1 representing all scenario variables
$P_{c,t}$ penetration rate of the system as a function of the price of the system
$P_{g,t}$ penetration rate of the system as a function of the purchasing power
$P_{n,t}$ penetration rate of the system as a function of the social need
$P_{a,t}$ penetration rate of the system as a function of the system acceptance

With regard to $P_{factors}$, all relations between the scenario variables and the penetration rate of the system are of the same form, the outcome of these relations can be averaged to obtain the penetration rate of the system as a function of all scenario variables. This is presented in equation 6.4. The outcome of this equation is a value between 0 and 1 representing the penetration rate of the system in percents divided by one hundred. Multiplying this value with the number of vehicles possible to be equipped with the system results in the actual penetration rate of the system. Below the relations between the scenario variables and the penetration rate of the system are discussed in detail.

6.4.1 Price of the system

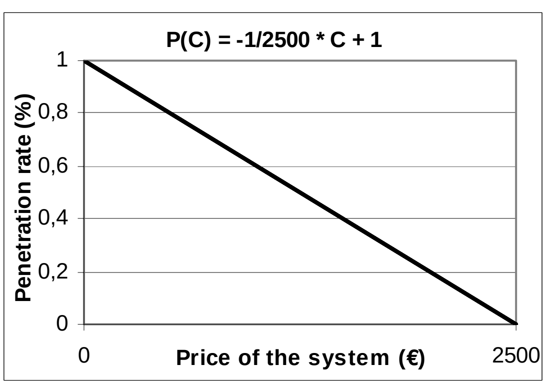


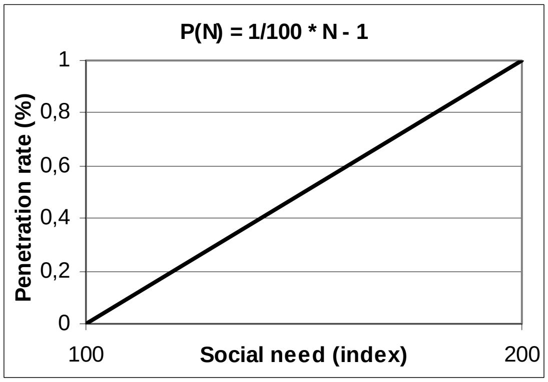
Figure 6.3: penetration rate as a function of the price of the system

It is assumed that the penetration rate of the system is 100 percent if the system is free and 0 percent if the price of the system equals the current cost price of the system *(c_c)*. It has to be noted that the cost price of the system differs per system variant. Equation 6.5 shows the relation between the penetration rate of the system *($P_{c,t}$)* and the price of the system.

$$P_{c,t} = -\frac{1}{c_c} * C_t + 1 \tag{6.5}$$

In figure 6.3 the equation is applied for IRSA controlling and the CA.

6.4.2 Social need



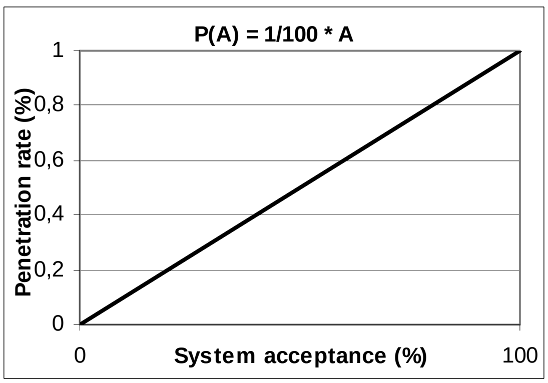
It is assumed that the penetration rate of the system is 100 percent if the social need *(N_t)* increases to $N = 200$ and 0 percent if there is no social need ($N = 100$). Equation 6.6 shows the relation between the penetration rate of the system *($P_{n,t}$)* and the social need.

$$P_{n,t} = \frac{1}{100} * N_t - 1 \qquad (6.6)$$

In figure 6.4 this relation is presented graphically.

Figure 6.4: penetration rate as a function of the social need

6.4.3 System acceptance



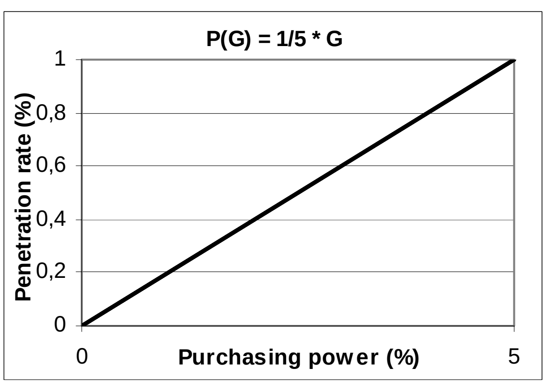
It is assumed that the penetration rate of the system is 100 percent if the system acceptance *(A_t)* is 100 percent and 0 percent if the system acceptance is 0 percent. Equation 6.7 shows the relation between the penetration rate of the system *($P_{a,t}$)* and the system acceptance.

$$P_{a,t} = \frac{1}{100} * A_t \qquad (6.7)$$

In figure 6.5 this relation is presented graphically.

Figure 6.5: penetration rate as a function of the system acceptance

6.4.4 Purchasing power



It is assumed that the penetration rate of the system is 100 percent if the growth of the purchasing power *(G_t)* is 5 percent (*G = 5*) and 0 percent if the growth of the purchasing power is 0 percent. Equation 6.8 shows the relation between the penetration rate of the system *($P_{g,t}$)* and the growth of the purchasing power.

$$P_{g,t} = \frac{1}{5} * G_t \qquad (6.8)$$

In figure 6.6 this relation is presented graphically.

Figure 6.6: penetration rate as a function of the purchasing power

6.4.5 System availability

System availability *(U_t)* is presented by a binary variable; a variable that can be 0 or 1. If a system variant is assumed to be available in a specific market segment the variable has to be set to 1. ‘0’ means that a system variant is not available. As a result of the chosen step by step development as discussed in the sections 5.3.5 and 6.3.5, it is only necessary to define when IRSA Advisory becomes available in the three market segments and when the other system variants are available. With this information the scenario model determines the system availability for every time step, market segment and system variant.

6.4.6 Government regulation

Like system availability, government regulation *($P_{r,t}$)* is presented by a binary variable, that can be 0 or 1. The presence of government regulation is described by '1', with the results that all scenario variables besides system availability are overruled and the penetration rate of the system reaches its maximum. As discussed previously, it is questionable whether this assumption is realistic, but due to its impact certainly interesting to examine.

6.5 Initial values of scenario variables

Using the scenario model for scenario analysis requires the following input from the user of the model for every scenario:

- The user has to define the percentage of cost savings as the result of economy of scope.
- The user has to define the percentage of cost savings as the result of financial incentives.
- The user has to define the percentage growth of the purchasing power.
- The user has to define the availability of IRSA Advisory in all market segments.
- The user has to define the availability of all system variants.
- The user has to define the presence of government regulation.
- The user has to define the system acceptance of all system variants.
- The user has to define the social need.

By varying the variable settings of the scenario model the user has the ability to formulate any desired scenario. This chapter has provided the reader with suggestions for all input variables. To start with, Table 6.6 presents an overview of the suggested variables settings for the four deployment scenarios described in chapter 5. In the following chapter the consequences of the scenarios and the scenario model itself are evaluated.

Table 6.6: suggested variable settings

Variable	***Scenario 1***	***Scenario 2***	***Scenario 3***	***Scenario 4***
Market organisation	*Individual*	*Individual*	*Collective*	*Collective*
Market development	*Stable*	*Growth*	*Stable*	*Growth*
Price reduction through cooperation	0	0	20	20
Price reduction through incentives	0	50	50	0
Growth of purchasing power	1	5	1	5
Availability IRSA Adv. in high-end segment	2006	2006	2006	2006
Availability IRSA Adv. in mid range segment	-	2010	2015	2010
Availability IRSA Adv. in low-end segment	-	2015	2025	2015
Availability – IRSA Advisory	2006	2006	2006	2006
Availability – IRSA Intervening	2015	2010	2010	2006
Availability – IRSA Controlling	2025	2015	2020	2010
Availability – Congestion assistant	2025	2015	2020	2010
Government regulation	no	yes	no	no
Initial acceptance IRSA – Advisory	37.50	56.25	75	95
Initial acceptance IRSA – Intervening	30	45	60	75
Initial acceptance IRSA – controlling	20	30	40	50
Initial acceptance – Congestion ass.	25	37.50	50	62.5
Social need	120	200	120	200

7 Model analysis and results

7.1 Introduction

The previous two chapters of this report produced four quantified scenarios for the deployment of SA systems and a scenario model to examine the consequences of these scenarios. In this chapter the scenario model and the model results are analysed and discussed. The objective of this analysis is to examine the behaviour of the model; whether the model works as intended, the sensitivity of the model and the model results for the four scenarios. The first two steps of this objective are necessary steps before the model has demonstrated to be usable for the calculation of scenarios.

The structure of this section is as follows. First the model is tested on the basis of several hypotheses which have to be satisfied. This model testing is discussed in section 7.2. Next, a sensitivity analysis is carried out to determine the sensitivity of the model outcome through variation of variables. The findings of the sensitivity analysis are discussed in section 7.3. Once the scenario model works as intended the model is used to evaluate the consequences of the deployment scenarios for SA systems. These consequences are discussed in section 7.4.

7.2 Model testing

The objective of model testing is to verify whether the model works as intended; whether the model contains errors (Kolkman, 2001). Normally, a model would be tested or calibrated in comparison with a reference or a well known standard. Due to the lack of such a reference for most model characteristics the model is tested on the basis of hypotheses. These hypotheses describe the intended behaviour of the model as a result of the model characteristics or variation of variables and parameters. During the building of the model these hypotheses were formulated on the basis of findings from the previous research phases; interviews, literature review and scenario development. In this building phase the hypotheses were used to define what the model *should* do, here they are used to evaluate what the model *does do* (to verify if the model works as intended). The following hypotheses are used for this evaluation. The first hypothesis is explained here, the other hypotheses are explained in appendix D. For all evaluations specific default settings are used, which are described in section 7.3.1.

- The penetration rate of the system increases as the scenario variables increase.

  In section 6.4 it was shown that the relations between the scenario variables and the penetration rate of the system are summarised by $P_{factors}$. This means that when the scenario variables increase, $P_{factors}$ increases and thus the penetration rate of the system should increase. In Table 7.1 it is demonstrated that the behaviour of the model satisfies this hypothesis; that the penetration rate of the system increases when the scenario variables increase.

  Table 7.1: penetration rate of the system as a function of the scenario variables ($P_{factors}$)

	Penetration rate of the system				
$P_{factors}$	**2006**	**2010**	**2015**	**2020**	**2025**
0.0	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %
0.25	0.0 %	1.8 %	6.7 %	12.2 %	16.7 %
0.50	0.0 %	3.6 %	13.4 %	24.4 %	33.4 %
0.75	0.0 %	5.4 %	20.1 %	36.5 %	50.1 %
1.00	0.0 %	7.3 %	26.8 %	48.7 %	66.9 %

- The penetration rate of the system develops differently for the different system variants. For example, the penetration rate of IRSA advisory increases fastest and the penetration rate of IRSA controlling increases slowest. Explanatory variables for the differences between system variants are system acceptance, system availability and the impact of the system.

- If government regulation is present, which means that this variable is set to '1', other scenario variables besides system availability are overruled and the penetration rate of the system reaches its maximum (which is equal to the percentage of new vehicles since the system is available).

- When systems become available in a new market segment (starting with the high-end segment), only IRSA advisory is available directly. It lasts one time step before IRSA intervening becomes available and two time steps for IRSA controlling and the Congestion Assistant. Once a system is available in the high-end market segment it lasts one time step before the system is available in the mid-range segment and two time steps before the system is available in the low-end segment.

- Initially, all scenario variables have equal weights; none should be dominant.

By varying the settings of the model variables the behaviour of the model was examined and the hypotheses were evaluated. The structure of the model was found correct, but the mathematical formulations required some fine tuning mostly concerning plusses and minuses which were mixed up, forgotten brackets and cross-references to wrong cells in the Excel-sheet. Finally, it could be concluded that the model worked as intended and could be used for a more detailed sensitivity analysis.

7.3 Sensitivity analysis

The objective of the sensitivity analysis is to determine the sensitivity of the model outcome through variation of variables (Kolkman, 2001). Outcomes are set to be sensitive to variations of variables if a small change in a variable results in relatively large changes in the outcomes (Heylighen, 2000). The results of the sensitivity analysis provide insight into the complexity, behaviour and sensitive factors of the model. If necessary these results can be used to adjust the model.

The model consists of a number of numerical variables and a number of binary variables. In this analysis the binary variables are not considered because they only activate or deactivate a part of the model and do not influence the model behaviour. The numerical variables considered in this analysis are all the variables that have to be set by the user of the model for every scenario and thus will differ under different conditions. All these variables are scenario variables or sub-variables: economy of scope, financial incentives, purchasing power, system acceptance and social need.

The results of the sensitivity analysis are obtained after the model was adjusted on several places. For example, the first results of the sensitivity analysis indicated that the equations of the price of the system and the social need had to be changed. With regard to the price of the system the variable 'production scale' was too dominant and in the case of social need values below zero could be reached, which means that the penetration rate could be negative. Both errors could be solved by defining two boundary conditions: 'social need values ≥ 0' and 'cost reduction through production scale ≤ 75 %'.

7.3.1 Results

In the default situation of the sensitivity analysis all numerical variables are set to their median value and all binary variables are set to '1'. From here the numerical variables are varied one by one with plus 10 and minus 10 percent. All other settings are kept constant. Table 7.2 shows which values are used for the variables which are varied.

Table 7.2: variable values for sensitivity analysis

Variable	**Median -10%**	**Median value**	**Median +10%**
Economy of scope	9 %	***10 %***	11 %
Financial incentives	22.5 %	***25 %***	27.5 %
Purchasing power	2.25 %	***2.5 %***	2.75 %
System acceptance	45 %	***50 %***	55 %
Social need	145	***150***	155

For all variables the same steps are performed. First the reference situation, which is the penetration rate of the system as the result of the default settings, is presented (see Table 7.3a). Next the penetration rate of the system is calculated by varying one of the variables with plus or minus 10 percent. Table 7.3b and 7.3c show the penetration rate of the system as the result of a plus and minus 10 percent change of the system acceptance. The results of changes in the other variables are presented in appendix E.

Table 7.3a-c: penetration rate of the system with system acceptance of 50, 45 and 55 percent

a. Penetration rate – ***System acceptance 50%***	**2006**	**2010**	**2015**	**2020**	**2025**
IRSA – Advisory	0 %	3.35 %	12.6 %	23.1 %	31.9 %
IRSA – Intervening	0 %	3.35 %	12.5 %	22.6 %	30.8 %
IRSA – Controlling	0 %	3.35 %	12.3 %	21.6 %	28.7 %
Congestion Assistant	0 %	3.35 %	12.4 %	22.4 %	30.3 %

b. Penetration rate – ***System acceptance 45%***	**2006**	**2010**	**2015**	**2020**	**2025**
IRSA – Advisory	0 %	3.26 %	12.2 %	22.5 %	31.0 %
IRSA – Intervening	0 %	3.26 %	12.1 %	22.0 %	30.0 %
IRSA – Controlling	0 %	3.26 %	11.9 %	21.0 %	27.9 %
Congestion Assistant	0 %	3.26 %	12.1 %	21.7 %	29.5 %

c. Penetration rate – ***System acceptance 55%***	**2006**	**2010**	**2015**	**2020**	**2025**
IRSA – Advisory	0 %	3.44 %	12.9 %	23.8 %	32.8 %
IRSA – Intervening	0 %	3.44 %	12.8 %	23.2 %	31.7 %
IRSA – Controlling	0 %	3.44 %	12.6 %	22.2 %	29.6 %
Congestion Assistant	0 %	3.44 %	12.8 %	23.0 %	31.2 %

Model sensitivity is measured by comparing the percentage change of one of the variables by the percentage change of the model output; the penetration rate of the system. Based on the Tables 7.3b and 7.3c the Tables 7.4a and 7.4b show the percentage change of the penetration rate of the system through variation of system acceptance. The numbers are calculated on the basis of equation 7.1.

$$\Delta P(v) = ((P(v_{\mu \pm 10\%}) - P(v_{\mu})) / P(v_{\mu}) \quad (7.1)$$

In which: *$P(v_{u\pm10\%})$* penetration rate as the result of variation of one scenario variable
$P(v_u)$ penetration rate as the result of median scenario variables

If the percentage change of the model output exceeds the percentage variation of the variable (which is ten percent) the model is said to be sensitive for changes in this particular variable. This may mean that this variable has to be determined very accurately or that the model might be redesigned for low sensitivity (Heylighen, 2000).

Table 7.4a and 7.4b: change in penetration rate of the system with system acceptance of 45 and 55 percent compared to system acceptance of 50 percent

a. Penetration rate – *System acceptance 45%*	**2006**	**2010**	**2015**	**2020**	**2025**
IRSA – Advisory	0 %	-2.74 %	-2.74 %	-2.75 %	-2.76 %
IRSA – Intervening	0 %	-2.74 %	-2.74 %	-2.76 %	-2.78 %
IRSA – Controlling	0 %	-2.74 %	-2.74 %	-2.77 %	-2.82 %
Congestion Assistant	0 %	-2.74 %	-2.74 %	-2.76 %	-2.79 %

b. Penetration rate – *System acceptance 55%*	**2006**	**2010**	**2015**	**2020**	**2025**
IRSA – Advisory	0 %	2.74 %	2.74 %	2.75 %	2.76 %
IRSA – Intervening	0 %	2.74 %	2.74 %	2.76 %	2.78 %
IRSA – Controlling	0 %	2.74 %	2.74 %	2.77 %	2.82 %
Congestion Assistant	0 %	2.74 %	2.74 %	2.76 %	2.79 %

Table 7.5 presents the percentage change of the penetration rate of the system as the result of variation of all five variables. Due to two causal loops in the model, which are discussed in the following section, the change of the penetration rate of the system differs per system variant and per time step. Therefore, Table 7.5 presents a range of the possible change of the penetration rate of the system.

Table 7.5: change in penetration rate of the system trough variation of variables by +/- 10 percent

Variable	**Change penetration rate *variable – 10%***	**Change penetration rate *variable + 10%***
Economy of scope	-0.32 - -0.40	0.32 - 0.40
Financial incentives	-0.97 - -1.19	0.97 - 1.19
Purchasing power	-2.74 - -2.82	2.74 - 2.82
System acceptance	-2.74 - -2.82	2.74 - 2.82
Social need	-2.36 - -2.74	2.34 - 2.74

A number of things can be concluded from these results. First of all it can be concluded that the scenario model is not overly sensitive to variation of one of the variables, because *$\Delta P(v)$* < 10%. Since the values of the variables cannot be determined very accurately due to the lack of available data, the insensitivity of the scenario model prevents a large inaccuracy in the outcome.

Secondly, the results show that the model is the least sensitive to changes in price-related variables (economy of scope and financial incentives) compared to the other variables. This can easily be explained by the fact that economy of scope and financial incentives are sub-variables of the scenario variable price of the system and that the other variables are scenario variables themselves. The model sensitivity through variation of purchasing power, system acceptance and social need are logic and can be explained when one takes a closer look at the construction of the model.

As can be gathered from equations 7.2 and 7.3, which were already discussed in chapter 6, the scenario variables all determine ¼th of the penetration rate of the system. Due to the linearity of the model this means that a 10 percent change in one of the scenario variables leads to a 2.5 percent change in the penetration rate of the system. However, due to the presence of two causal loops, which are discussed in the following section, the model is not entirely linear. Therefore, the change in the penetration rate of the system should be 2.5 percent plus or minus the influence of the causal loops. Similar values are found for purchasing power, system acceptance and social need as presented in Table 7.5.

$$P(v) = a_v * v + P(0) \tag{7.2}$$

In which P_x penetration rate of the system
v scenario variable
a_v parameter for scenario variable v

$$P_t = P_{\max,t} * P_{factors,t} \tag{7.3}$$

In which:
$P_{max,t}$ number of vehicles possible to be equipped with the system at time t

$$P_{factors,t} = (P_{c,t} + P_{g,t} + P_{n,t} + P_{a,t}) / 4 \tag{7.4}$$

In which: $P_{factors,t}$ value between 0 and 1 representing all scenario variables
$P_{c,t}$ penetration rate of the system as a function of the price of the system
$P_{g,t}$ penetration rate of the system as a function of the purchasing power
$P_{n,t}$ penetration rate of the system as a function of the social need
$P_{a,t}$ penetration rate of the system as a function of the system acceptance

With regard to the price-related variables equation 7.5 shows that the price of the system (C_t) is multiplied by factors concerning three sub-variables: economy of scope ($c_{e,t}$), financial incentives ($c_{i,t}$) and production scale ($c_{s,t}$).

$$C_t(c_c, c_{e,t}, c_{i,t}, c_{s,t}) = c_c * \frac{(100 - c_{e,t})}{100} * \frac{(100 - c_{i,t})}{100} * \frac{(100 - c_{s,t})}{100} \tag{7.5}$$

The result of this multiplication is that a change in one of the three sub-variables is partly cancelled out; a 10 percent change in $c_{e,t}$, $c_{i,t}$ or $c_{s,t}$ does not lead to a 10 percent change in C_t. Therefore it is logical that the model is much less sensitive for changes in one of these variables. If all three sub-variables are changed at the same time the sensitivity is expected to be similar to the sensitivity of the other scenario variables.

7.3.2 Causal loops

What attracts attention are the differences of the sensitivity between the system variants and the time steps. Although all relations in the model are assumed linear, the model as a whole does not seem to be linear at all. These results however, can easily be explained by two causal loops in the structure of the model. In Figure 7.1, the structure of the model is presented and the two causal loops of the model are highlighted with the dotted lines.

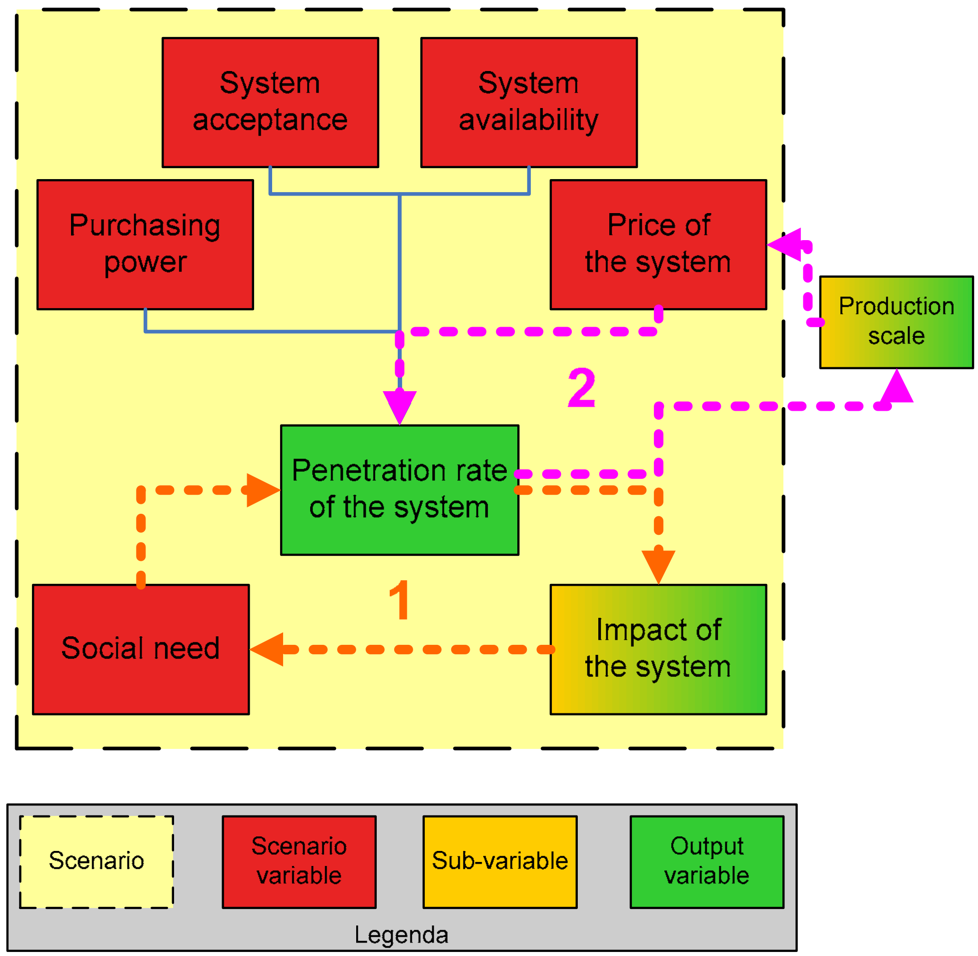


Figure 7.1: causal loops in scenario model

Causal loop 1 has a dimming effect on the development of the penetration rate of the system, which can be explained as follows. As the penetration rate of the system increases, the impact of the system increases, and the social need decreases. Through lower social need the demand for SA systems decreases and thus leads to a lower penetration rate.

On the other hand, causal loop 2 has a stimulating effect on the development of the penetration rate of the system, which can be explained as follows. As the penetration rate of the system increases, the production scale increases, and the price of the system decreases. A lower price of the system increases the demand for SA systems and thus leads to a higher penetration rate.

Both causal loops affect the outcome of the each time cycle as was briefly discussed in section 6.2.3. The contribution of causal loop 2 is straightforward and equal for all system variants. With regard to causal loop 1 there are differences between the system variants due to other expected impacts of the system variants. For example, it is assumed that the impact of controlling system variants is higher than the impact of intervening system variants and that the impact of intervening system variants is higher than the impact of advisory system variants. As a result, a higher impact of the system leads to a stronger decrease of the social need and thus throughout time in a lower penetration rate of the system in comparison with other system variants. From this and the results in Table 7.5 it can be concluded that the model is more sensitive for parameter settings representing high impact (as with IRSA Controlling) than for settings representing low impact (as with IRSA Advisory).

7.3.3 Conclusions sensitivity analysis

Variation of the variables economy of scope, financial incentives, purchasing power, system acceptance and social need by plus and minus 10 percent indicated that the scenario model is not overly sensitive for changes in these variables. Two causal loops in the structure of the model explain the differences in sensitivity between the system variants and time steps. The analyses provided insight in the complexity and behaviour of the model and showed that all findings are logical and explainable. After the model was improved by some adjustments the scenario model was found usable for scenario analysis.

7.4 Model results

In this section the model outcome of the four scenarios for the development of the penetration rate of SA systems is presented and discussed. The model outcome is obtained from the model input for the scenarios presented in Table 7.6. The results presented here are a quantitative representation of the four scenarios described in chapter 5. Figure 7.2 shows the development of the penetration rate of the four system variants for all scenarios. In appendix F these results are also presented per scenario and per system variant. This appendix also presents tables of the penetration rates presented in the figures, and tables of the development of the price and the social need per scenario.

Table 7.6: values scenario variables per scenario

Variable	***Scenario 1***	***Scenario 2***	***Scenario 3***	***Scenario 4***
Market organisation	*Individual*	*Individual*	*Collective*	*Collective*
Market development	*Stable*	*Growth*	*Stable*	*Growth*
Price reduction through cooperation	0	0	20	20
Price reduction through incentives	0	50	50	0
Growth of purchasing power	1	5	1	5
Availability IRSA Adv. in high-end segment	2006	2006	2006	2006
Availability IRSA Adv. in mid-range segment	-	2010	2015	2010
Availability IRSA Adv. in low-end segment	-	2015	2025	2015
Availability – IRSA Advisory	2006	2006	2006	2006
Availability – IRSA Intervening	2015	2010	2010	2006
Availability – IRSA Controlling	2025	2015	2020	2010
Availability – Congestion assistant	2025	2015	2020	2010
Government regulation	no	yes	no	no
Initial acceptance IRSA – Advisory	37.50	56.25	75	95
Initial acceptance IRSA – Intervening	30	45	60	75
Initial acceptance IRSA – controlling	20	30	40	50
Initial acceptance – Congestion ass.	25	37.50	50	62.5
Social need	120	200	120	200

Below, the results from the scenario model and the differences between the scenarios are discussed. This discussion focuses on the key drivers and barriers of the development of the penetration rate of SA systems. Most of all it is tried to present an overall picture about what possibly *can happen.*

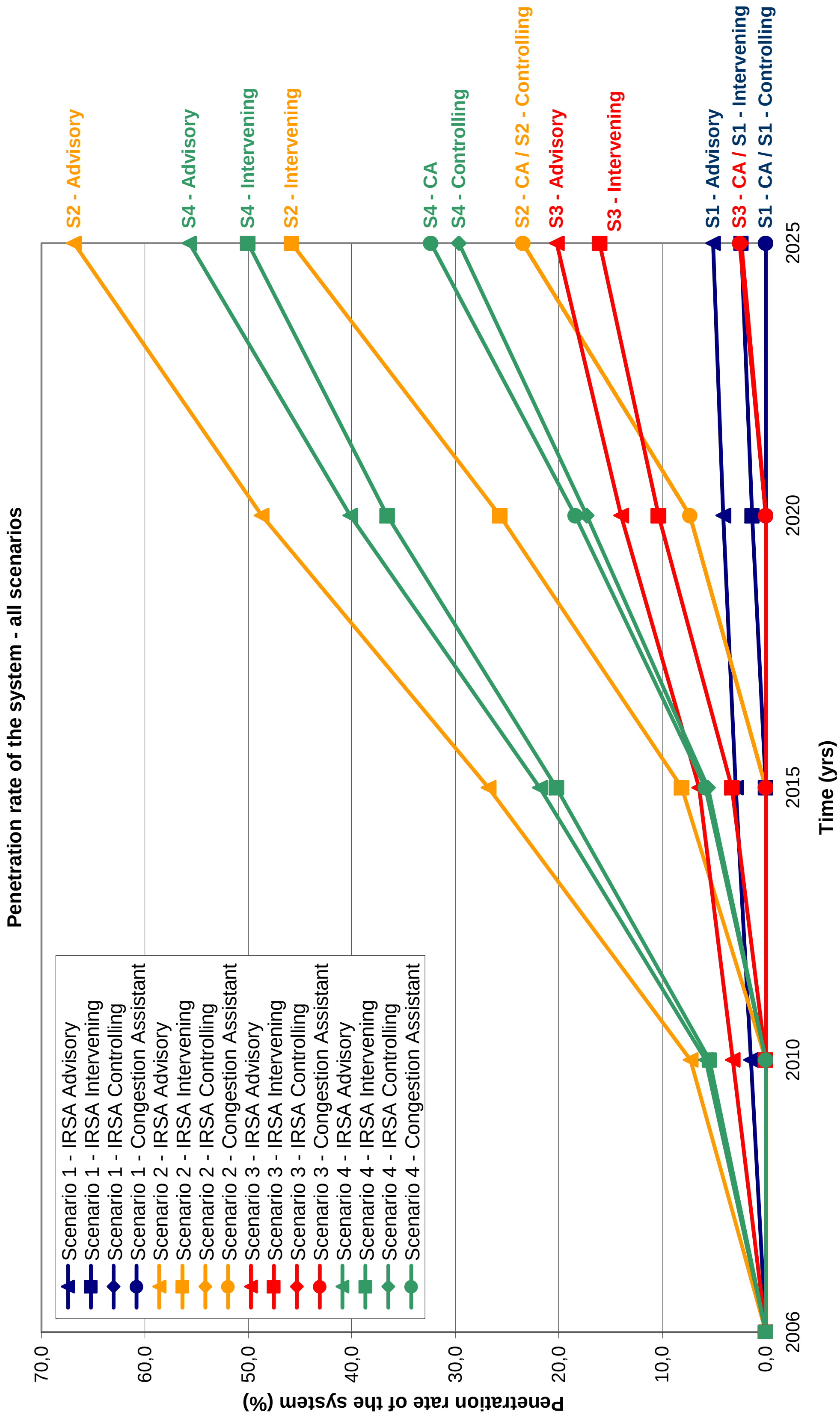


Figure 7.2: results of the scenario model

- Clearly, in scenario 1 the penetration rates of SA systems develop the least. This can easily be explained by the high price of the systems, low growth of the purchasing power, poor system availability, low system acceptance and low social need. In summary, there is no technology push as the result of an individually organised market and there is no market demand either. With regard to the deployment of SA systems this scenario is not very promising.

- In the scenarios 2 and 4 the penetration rates of SA systems develop the most. In the case of scenario 2 this can be explained by the presence of government regulation. The combination of technology push as the result of a collectively organised market and the presence of high market demand make scenario 4 very successful with regard to the deployment of SA systems. The differences between the system variants are the result of the system availability in the three market segments. With regard to scenario 4 also the differences in system acceptance are of influence. In scenario 2, system acceptance (and the other scenario variables besides system availability) is overruled by government regulation.

- Scenario 3 is a hybrid between the scenarios 1 and 4. On the one hand there is a technology push as the result of a collectively organised market, but on the other hand there is no strong market demand. Throughout time, IRSA Advisory and IRSA Intervening reach reasonable penetration rates, but IRSA Controlling and the CA lag behind.

- In general, what can be seen is that under specific market conditions considerable penetration rates of up to 50 percent or more can be reached. Specifically the penetration rates of IRSA Advisory and IRSA Intervening, which can be available soon and are reasonably well accepted, can develop fast. The penetration rates of IRSA Controlling and the CA develop much slower and do not seem to reach penetration rates higher than 20 percent within the next twenty years.

In summary, two key drivers of the development of the penetration rate of SA systems are found: government regulation and cooperation between the government and the car manufacturers. With regard to the user, system acceptance, social need and financial factors like purchasing power and financial incentives can make a significant difference. Especially IRSA Advisory and IRSA Intervening seem to have large potential within the next 20 years. Generally, IRSA Controlling and the CA lag behind and the differences in penetration rate between both systems are negligible. The differences between IRSA Advisory and Intervening and IRSA Controlling and the CA can easily be explained because the last two are more expensive, less accepted and available at a later stage.

On the basis of the findings from the interviews, literature review and scenario development it can be concluded that the scenarios 3 and 4 are most likely. First of all, it is expected that the government and car manufactures will cooperate more within the next couple of years, which leads to a more organised market. This supposition makes scenario 1 unlikely. Furthermore, government regulation was found unrealistic, which makes scenario 2 unlikely. Nevertheless, it has to be noted that government regulation is a very effective tool to guarantee high penetration rates of a particular system. Although the scenarios 3 and 4 both seem plausible it can be suggested that scenario 4 is too opportunistic and scenario 3 too conservative. Most plausible seems a hybrid between both scenarios, making the scenarios 3 and 4 the two outer limits of what might realistically happen.

In chapter 8 the approach and the validity of the results of the scenario analysis are discussed. It is discussed what consequences the choices that were made have had and what the results of the analysis would have been if other choices were made. Section 8.4 concludes with the presentation of a possible deployment strategy based on the findings of this analysis. Finally, the conclusions and recommendations for future analysis are presented in chapter 9.

8 Discussion

8.1 Introduction

In the previous chapter the scenario model was tested, a sensitivity analysis was carried out and the model results of the four scenarios for the deployment of SA systems were presented and discussed. This chapter focuses on the validity of the results by evaluating the scenario model and the model results and by means of reflection of the research approach. Finally, based on the judgments of the author, a possible deployment strategy is suggested.

8.2 Model validity and model results

In every analysis choices are made; an approach is chosen, assumptions are made and boundary conditions are formulated. Normally, such choices are well considered and assumed to be the best solution under the present research conditions. If well considered, these choices are not wrong, but for a correct interpretation of the results of an analysis, one has to take these choices into account and understand what consequences they may have.

The objective of this section is to understand the consequences of the choices made in this analysis and discuss the validity of the analysis results. Dee (in Kolkman, 2003) defined validation of a model as '*the process of formulating and substantiating explicit claims about the applicability and accuracy of computational results with reference to the intended purposes of the model as well as to the natural system it represents*'. Within this broad definition the scope of this section is to perform a theoretical analysis of the model assumptions. Below, the model assumptions and some other points for discussion are evaluated.

- The handled approach has resulted in a theoretical description of four plausible deployment scenarios for SA systems and a scenario model that enables a quantitative evaluation of the consequences of deployment scenarios. With lots of possibilities at hand, the strength of the approach was to make choices, mark out the research scope and carry out analyses from there. Ideally, a more advanced transport model would be used to integrate network analysis and evaluate the impact SA systems on its environment; the transportation system. The scenario model performs best for analyses on a macroscopic level, for example for the analysis of an overall picture of the deployment of SA systems. Through the consideration of multiple scenarios, the market mechanisms of deployment can be explored and evaluated to formulate effective deployment strategies.

- Due to time limitations the analysis has only focussed on the most critical factors with regard to the deployment of SA systems. Furthermore, only three stakeholders were considered. Taking into account other factors and stakeholders can have a significant influence on the outcome of the analysis and possibly improve the accuracy of the scenario model. Undesirably, as a result, the model can become more complex and less understandable too. From this it can be concluded that it is difficult to build a model that is both complete and understandable at once. Moreover, the apparent endless number of factors and the considerable number of stakeholders involved always bring along a certain level of uncertainty which cannot be predicted or modelled.

- With regard to deployment a rational economic approach was applied. Scientifically this approach is very convenient, because it is straightforward. However, the validity of the approach can be questioned. Many scientists will agree that people often do not handle in accordance with rationality, certainly not when the car is concerned. For example, traffic demand is known to be insensitive to an increase of the oil price, while economic rationality assumes that traffic demand will decrease. In summary, human rationality is very complex and unpredictable and a specialism of its own. Therefore, economic rationality was assumed in this research, regardless of the limitations on (results of) the analysis.

- The assumed conditions and the model assumptions suppose an ideal world in which problems like the liability issue are assumed to be solved. These assumptions might result in an overestimation of the developments of the deployment of SA systems. It is suggested that these assumed scenario conditions, which are discussed in section 5.2.2, first should be created before SA systems can ever by successful. The model assumptions, which are summarised in section 6.2, are selected in order to limit the complexity of the model and leave human irrationality out of consideration as much as possible.

- The scenario model as presented in this report and the values used to quantify the scenario variables are a 'static' representation of the current situation. The question is whether the factors, relations and assumptions made now are still applicable for the situation in ten years. It is likely that the importance of deployment factors, the relations between these factors and values of scenario variables change throughout time, which might change the outcome of the scenarios radically. However, due to the lack of information concerning these possible changes they are not considered. Again, this is not wrong, but it is necessary to understand the consequences. As discussed in chapter 3 it has to be noted that scenario analysis involves a considerable amount of uncertainty and describes the outer limits of what realistically <u>*can happen*</u>. On itself, the process of carrying out a scenario analysis is a useful exercise. The reader is left with an option to judge and choose for himself the most plausible path of events within the limits set by the scenarios. At this moment in time, static representations are the most plausible of what realistically can happen.

- A model can be defined as '*an object or concept that is used to represent something else. It is reality scaled down and converted to a form we can comprehend*' (Meijer in Kolkman, 2003). Basically, a model is a simplification of a part of reality based on the knowledge available, with the possibility that this knowledge might be inaccurate or insufficient. With regard to the scenario model, the values of the scenario variables and the relations among the scenario variables and output variables could not always be founded with academic literature sources or deterministic figures. At this time most relations and values are 'a best guess' and in most cases the most plausible choice under the circumstances. Obviously, the results of the scenario model would be more reliable if the input were more reliable. It is difficult to say how the results would change, since this strongly depends on the how the input changes.

- One of the factors which is not considered in the scenario model is the correlation between the developments of the different system variants. It is likely that once SA systems are introduced, new systems will benefit from the awareness, acceptance and market share created by the preceding system(s). In this way, systems like IRSA controlling and the CA are likely to benefit from their predecessors; IRSA advisory and IRSA intervening. Furthermore spin-offs are likely to result from the deployment of SA systems, which might be able to stimulate the development of ADA systems as a whole. In summary, if the first variants of SA systems begin to gain a significant market share, deployment can proceed much faster for the following system variants. From this perspective, it can be concluded that a turning point with regard to the deployment of SA systems has to be expected.

- To solve the traffic problems concerning traffic flow, traffic safety and vehicle emissions the government can choose from a number of measures. In this research alternative measures besides ADA systems were not considered, due to which it seems that there are no alternatives. Obviously, the consideration of the government not only involves whether to introduce ADA systems as a measure for traffic problems. Besides the factors discussed in this report the decision of the government will also be based on the objectives of current policies, political considerations and the seriousness of other (traffic) problems to be solved. Examination of this political field of forces is a specialism of its own and therefore not discussed elaborately in this analysis. Nevertheless, for future analysis it is recommended to examine the political consideration towards the introduction of ADA systems.

- First, the intention was to develop a scenario model specifically for SA systems. However, the rational economic approach has resulted in a model with a broad scope, which can be applied to various kinds of ADA systems. In this research the model is applied to SA system, but it can easily be applied to other systems.

The matters discussed above give an indication of the limitations of the scenario model and make clear that the analysis results should be interpreted with care before conclusions can be drawn. As discussed previously, the results present the outer limits of what realistically can happen and leave the reader with an option to judge and choose for himself the most plausible path within those limits. Although the scenario model presents exact numbers, these numbers, as well as the scenarios as a whole, should be interpreted comparatively (for example: in scenario 3 the penetration rates of the systems are higher than in scenario 1, but much lower than in scenario 4. This can be explained by differences in market organisation, government regulation, etc.).

It is difficult to say what the results of the analysis would have been if other conditions were opposed or other assumptions were made. Obviously, if more data would have been available to formulate the conditions and assumptions more precise, the model would have been more accurate. If the accuracy of the model improves more detailed analysis can be performed. However, on a macroscopic level the differences in the model results are expected to be marginal. Especially, since the sensitive analysis showed that the scenario model is not overly sensitive to variation of one of the variables. At this point, the current results are sufficient to obtain a first impression of future possibilities with regard to the deployment of SA systems.

8.3 Research approach

To formulate plausible deployment scenarios for Speed Assistance systems a scenario analysis was performed and a scenario model was developed. The applied approach involved four phases (see Figure 8.1) and is evaluated in this section. The objective of this section is to conclude to what extent the approach was useful.

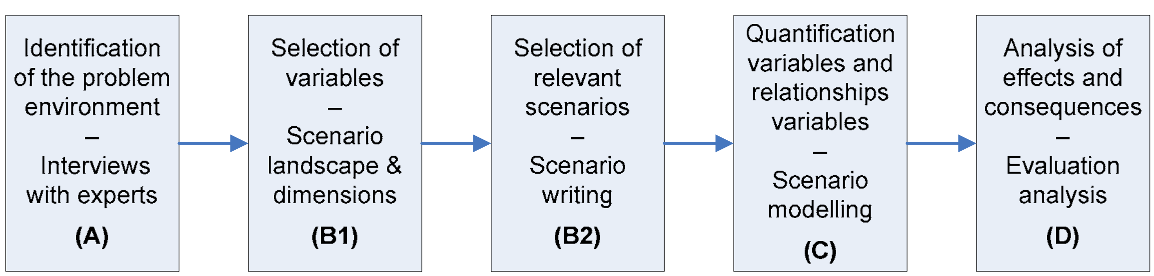


Figure 8.1: research approach

The first phase of the research concerned interviews with stakeholders and experts (A). The objective of the interviews was to identify the most critical factors with regard to the deployment of SA systems. It was assumed that experts and stakeholders know most about the current situation and recent developments. It was found that the interviews provided a lot of useful information in a relatively short period of time. The information was obtained by considering multiple perspectives and did not contain any contradictions. It was an unexpected surprise that the interviews were this productive. One aspect has to be noted with regard to the results of the interviews: where interviews are concerned a certain inaccuracy has to be considered due to personal interpretations by both the respondents and the interviewer. Asking respondents about ‘their opinion’ about a subject involves personal interpretation, which can lead to different answers from different respondents. Furthermore, the answers of the respondents are interpreted by the interviewer, who can also misinterpret the answers. This can lead to other conclusions than intended by the respondent. Besides verifying the answers with the respondents to prevent misinterpretations, the findings of the interviews were validated and extended by comparing the findings with findings from other studies found in literature. It this way the credibility and completeness of the results could be raised. The combination of interviews and literature review resulted in a good base for the scenario analysis.

The second of the research concerned scenario development, which included the construction of a scenario landscape and the writing of scenarios (B1 and B2). Processing the findings of the interviews and literature review into scenarios and eventually a scenario model was found to be very difficult, as the still large number of factors that could be taken into account were hard to overlook. A solution was found by defining the desired outcome of the analysis and work backwards from there instead of working chronologically. The scenario method of Svidén (1986) was found very helpful to define the area under investigation and use the scenario sketches as the basis for further scenario analysis. Most difficult with regard to scenario writing was not what to *include* in the scenarios, but what to *exclude* from the scenarios. To limit the size and complexity of the analysis it was necessary to limit the scope of the analysis. On the one hand it is clear that choices about what to exclude from the analysis are necessary, but on the other hand it is difficult to decide what to leave out despite the imperfection this will create. With regard to the latter, one has to consider that due to continuous developments a picture of the area under investigation can never be complete. In the end, it can be concluded that the approach used for scenario development resulted in four plausible scenarios of the deployment of SA systems and provided a good basis for scenario modelling.

The third phase of the research concerned the construction of the scenario model and the quantification of the scenarios (C). First, it was attempted to find a software tool to support the modelling process. Unfortunately, such a tool was not available. Alternatively, Microsoft Excel was used to construct the model. Two (not abnormal) difficulties were encountered in this phase; first of all, there was no manual available about how to construct a scenario model and secondly, there was hardly any information available about the relations between the variables of the model. Both limitations were handled by starting simple, assuming understandable relations as the result of logic reasoning and constructing a model that satisfies the research objective. The consequences of the limitations of the scenario model have already been discussed previously. What can be concluded is that with the use of the scenario model, a good picture can be obtained concerning the consequences of the coherence of scenario factors within the outer limits of what realistically can happen.

The fourth and final phase of the research concerned the analysis of the effects and consequences of each scenario. Basically, this step was straightforward; visualise the model outcome in figures and tables and discuss the result. The insights gained from the interviews and literature review are used to explain the results, to determine whether the results are plausible and to conclude which results are most likely. In this way a good base was laid for the discussion.

In conclusion, the scenario analysis described in this report is found sufficient to manage the considerable level of uncertainty concerning the deployment of SA system. Four plausible scenarios are formulated and by means of a scenario model the consequences of the scenarios were calculated. In the following section, based on the judgments of the author, a possible plausible path of events is suggested in terms of a deployment strategy.

8.4 Deployment strategy

A deployment strategy should create the necessary conditions for successful deployment of SA systems, describing a logical sequence of events in order to, starting from the present, create a desired future state. A deployment strategy should provide insight into the roles and responsibilities of the stakeholders, based on a clear vision of what to achieve. The deployment strategy discussed below corresponds with the hybrid of the two most likely scenarios; the scenarios 3 and 4.

An example of a clear vision is the vision of the Intelligent Car Initiative that attempts to move towards a new traffic situation which is smarter, safer and clearer than today (Reding, 2006). The visions of IRSA systems and the Congestion Assistant are clear as well. Their primary aim is to calmly reduce the speed of the traffic flow in specific situations to prevent the formation of shock waves due to abrupt braking manoeuvres and subsequently improve traffic safety, traffic flow and vehicle emissions. After the formulation of a clear vision, the next step of the deployment strategy should be to bring together all the stakeholders involved, clarify their benefits and develop a Code-of-Practice on which all stakeholders agree. The Code-of-Practice should describe the system specifications, provide guidelines for all stakeholders, distribute responsibilities and settle problems with regard to liability risk. Furthermore, much effort should be put in raising the political and public awareness and acceptance by launching pilots and promotion campaigns to present the potential of SA systems. Additionally, in the first phase of deployment, systems should be subsidised to compensate the high prices of the systems and get the market in motion. Alternatively, authorities could act as launching customers or SA systems could become mandatory for specific groups of drivers. The hypothesis is that once the market is in motion and considerable penetration rates are reached, the deployment of SA systems will develop further as the result of market forces.

From a more operational point of view, the respondents of the interviews suggested the following: given the uncertainties, the objective of the deployment strategy should be to promote the objective of the system (safety/road performance/comfort), start small and simple on specific locations (for instance around schools) or with specific groups (for instance young drivers) for which the system has benefits. New systems should be dressed up slowly as to allow the public to get used to the system. This is called market driven implementation. For the persons or locations selected, the effects of the system should be monitored (effectiveness, costs, etc.) and when something is not functioning as desired measures should be taken to solve the problem. Beforehand, it has to be examined which time scale is acceptable for monitoring and what good predefined criteria for monitoring are.

In conclusions, the importance of how systems are introduced should not be underestimated. Not only the public, but politicians as well, will expect an intelligent system, which is accurate, flawless and easy to operate. If the system fails these expectations, deployment can not succeed. Also critical are the business cases of the stakeholders, which all should be positive before deployment can succeed. Bringing together all the stakeholders involved is a good start to discuss this issues and create positive business cases for all.

9 Conclusions and recommendations

9.1 Conclusions

Despite the potential of most intelligent systems they are not yet on the market, and when they are, large scale deployment takes a long period of time due to several problems (Reding, 2006). The objective of this research was to obtain insight into the mechanisms of deployment by *formulating plausible deployment scenarios for Speed Assistance systems by means of scenario modelling and the development of a scenario model*. Scenarios are used to address the uncertainty of future developments by describing the outer limits of what realistically can happen, leaving the reader with an option to judge and choose for himself the most plausible path of events within those limits set by the scenarios. Speed Assistance systems is a generic term for three IRSA[5] variants Advisory, Intervening and Controlling and the Congestion Assistant. The primary aim of these systems is to calmly reduce the speed of the traffic flow to prevent the formation of shock waves due to abrupt braking manoeuvres and primary increase the traffic safety.

The remainder of the conclusions of this research are discussed on the basis of the research questions.

A. What are the most critical factors with regard to the deployment of SA systems?
Interviews among experts and stakeholders combined with a literature review have identified coordination and cooperation, vision and strategy, and awareness and acceptance as the most critical factors with regard to the deployment of Speed Assistance (SA) systems. It was found that these factors could be summarised by two overall deployment factors; *market development* (the development of market demand as the result of awareness and acceptance factors) and *market organisation* (market structure as the result of cooperation, coordination, vision and strategy).

B. How can deployment scenarios be developed on the basis of the critical deployment factors?
To define the area under investigation a set of rough scenario sketches was produced by means of a scenario landscape, using the two overall deployment factors as the dimensions of the landscape. The four quadrants of the scenario landscape resulted in a theoretical description of the following deployment scenarios:

- *Scenario 1 – Conservative*. This scenario is characterised by a stable market involving low social need, low growth of the purchasing power and low system acceptance. Due to the lack of a technology push there is neither a strong demand nor a strong supply, which results in poor development of the deployment of SA systems.

- *Scenario 2 – Regulation*. This scenario is characterised by a growing market involving high social need, high growth of the purchasing power and high system acceptance. Due to the lack of a technology push, the government acts as the manager of the social interest and regulates the market, which results in a strong development of the deployment of SA systems.

- *Scenario 3 – Free market*. This scenario is characterised by a stable market involving low social need, low growth of the purchasing power and initially, low system acceptance. Due to cooperation between the government and car manufacturers a strong technology push arises. As the result of promotion and pricing strategies the system acceptance increases and the deployment of SA systems starts to develop moderately.

[5] Integrated full-Range Speed Assistance

- *Scenario 4 – Progressive.* This scenario is characterised by a growing market involving high social need, high growth of the purchasing power and high system acceptance. Due to cooperation between the government and car manufacturers a strong technology push arises. The combination of strong demand and strong supply result in a strong development of the deployment of SA systems.

C. How can the mechanisms of deployment and the deployment scenarios be modelled?
The construction of a scenario model proved to be sufficient for a quantitative evaluation of the consequences of the deployment scenarios. A number of scenario variables and sub-variables describing the actual state of a scenario are input of the model and the penetration rate of the system is the model output.

D. What can be learned from the findings on plausible deployment factors?
The results showed that the penetration rate of SA systems increases most in the scenarios 2 and 4, that the penetration rate of SA systems develops the least in scenario 1, and that scenario 3 is a hybrid between the scenarios 1 and 4. From these results it can be concluded that the deployment of SA systems is subject to two key drivers: government regulation (scenario 2) and cooperation between the government and car manufacturers (scenarios 3 and 4). Additionally, with regard to the users, system acceptance, social need and financial factors like purchasing power and financial incentives can make a significant difference. In general it can be concluded that under specific market conditions penetration rates of up to 50 percent can be reached in 2025. Specifically, the penetration rates of the IRSA Advisory and IRSA Intervening variants can develop fast, but the penetration rates of the IRSA Controlling variant and the Congestion Assistant develop much slower. These differences can easily be explained because the IRSA Controlling variant and the CA are more expensive, less accepted and available at a later stage. On the basis of the findings from the interviews, literature review and scenario development it can be concluded that the scenarios 3 and 4 are most likely. Although these scenarios seem most plausible, it is likely to suggest that scenario 4 is too opportunistic and scenario 3 too conservative. Most plausible seems a hybrid between both scenarios, making the scenarios 3 and 4 the two outer limits of what realistically can happen.

Finally, a possible plausible path of events was suggested in terms of a deployment strategy. In summary, the necessary steps of the deployment strategy should successively be: formulation of a clear vision, bring together all the stakeholders involved, clarify the benefits of the stakeholders, develop a Code-of-Practice on which all stakeholders agree, raise public and political awareness and acceptance and finally guide the take-up of systems with subsidies or mandatory introduction.

In conclusion, scenario analysis and the development of a scenario model to formulate plausible deployment scenarios for Speed Assistance showed that the deployment of IRSA systems and the CA can be successful if specific scenario conditions are created. Much effort is necessary to create the desired scenario conditions, starting with bringing all stakeholders together. It is likely that cooperation among stakeholders is the first, and most necessary step towards a new traffic situation, which is smarter, safer and cleaner that of today.

9.2 Recommendations for further analysis

The following recommendations for further analysis can be made.

- The values of the scenario variables and the relation among the scenario variables and the output variables could not always be founded with academic literature sources or deterministic figures. Obviously, the results of the scenario model would be more reliable if the input were more reliable. Future work should improve the reliability of the data and thus the model.

- All variables in the scenario model are ‘static’ variables, based on the current situation. It is likely that the current situation changes throughout time, which might change the outcome of the scenarios radically. Future work should consider ‘dynamic’ variables improving the accuracy of the model.

- Due to time limitations the analysis only considered the most critical deployment factors and the three most important stakeholders. It is possible that the scenario model is more accurate if other factors and stakeholders are considered as well. Future work should extend the model with more factors, but prevent that the model becomes too complex and incomprehensible.

- In favour of the comprehensiveness of the scenarios a number of limitations were imposed. Future research should reconsider these limitations and if possible remove them by extending the scenario model.

- Due to practical reasons this research did not consider transport-related external developments. Future work should consider developments like an increasing oil price and the introduction of road pricing. Furthermore, other traffic management measures should be taken into account for a complete consideration of all alternatives.

- The focus of a deployment strategy for SA systems can vary in numerous ways, for example: road type (urban, rural, highways), communication (static, dynamic), target groups (professional drivers, young drivers, learning drivers, speed offenders, etc.), spatial differentiation (vulnerable areas, congested areas, hazardous areas, etc.) and differentiation in time (peak periods, school hours, etc.). Future work should explore the focus of deployment strategies on an operational level.

- The respondents of the interviews suggested that the deployment of SA systems can only be successful if there is a positive business case for all stakeholders. Future work should describe the business cases of all stakeholders and evaluate the cost and benefits of all scenarios. These insights can be used to bring stakeholders together, deal with conflicting interests and formulate more effective deployment strategies.

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Acronyms

ACC	Adaptive Cruise Control
ADA	Advanced Driver Assistance
AVG	Automated Vehicle Guidance
CA	Congestion Assistant
CACC	Co-operative Adaptive Cruise Control
CAS	Collision Avoidance System
CC	Cruise Control
CMS	Collision Mitigation System
CWS	Collision Warning System
HMI	Human Machine Interface
ICT	Information and Communication Technology
ISA	Intelligent Speed Adaptation
ITS	Intelligent Transport System
IRSA	Integrated full-Range Speed Assistance
LDW	Lane Departure Warning
R&D	Research & Development
SA	Speed Assistance
TA	Technology Assessment
V-V	Vehicle-Vehicle (communication)
V-I (I-V)	Vehicle-Infrastructure (communication)

Glossary

Code-of-Practice	A voluntary agreement on development guidelines between stakeholders.
Deployment factor	Barriers or stimulants with regard to the development of deployment.
Deployment strategy	A sequence of events and necessary actions to create a desired future stated defining the roles, tasks and responsibilities of all stakeholders involved.
Deployment	-*or implementation*- The whole of the initial market phase of the development of a product-market combination and the development of market penetration.
Launching costumer	The first consumer or group of consumers which buys and uses a product and so form the basis of wide implementation of the product.
Level of support	The level in which a system takes over the tasks of the driver. These levels can be ‘advisory’, ‘intervening’ and ‘controlling’.
Market pull	Technology developments and market introduction of new technologies to meet a market need. A market pull is ‘consumer-driven’.

Penetration rate of the system	The percentage of vehicles equipped with a system.
Platooning	The technique of coupling 2 or more vehicles together electronically to form a train.
Scenario analysis	Method to address uncertainty about the future and describe possible future developments based on explicit assumptions.
Scenario model	Schematic or mathematical presentation of a scenario. A mathematical presentation enables calculations.
Scenario variable	Typical 'state' variable that describes the actual scenario, which should be sufficient to induce likely values for the output variables.
Scenario	An integrated description of a future state of society or special parts of it, and a plausible sequence of events leading to this future state, without the necessity of including statements on the probability of those events.
String stability	The homogeneity of a chain of vehicles. An instable string continuously stretches out and shrinks again.
Technology push	Stimulation of a market as the result of the development, production and introduction of new technologies. A technology push is 'producer-driven'.

Appendix A: Roadmaps

The technology roadmaps discussed in this section are developed by the industry or in (European) projects. Technology roadmaps discuss either; the moment of technological availability of ADA systems, when a manufacturer can offer a new ADA system, the timing of the launch on the global market or the time when an ADA system has reached a minimum deployment rate. In most cases, roadmaps refer to the time when a manufacturer starts series production of an ADA system for the market of interest.

ADASE (2000/2004)

The ADASE (Advanced Driver Assistance Systems for Europe) project aimed at paving the road for the introduction of the ADA systems for passenger cars in Europe by coordinating existing studies, developing scenarios for the introduction of these systems and initiating new innovative European projects (Zwaneveld et al. 1999).

The introduction of new ADA systems is characterized by an evolutionary or step-by-step introduction and development of these systems. Each step enables the next step on the roadmap. This is due to the limitations of technology, the users and the costs. An evolutionary introduction will allow the users to understand the reactions of ADA systems better, gain experience and confidence, and so raise the acceptance of these new systems. Where the costs are concerned, no supplier is going to offer a new ADA system if no customer is willing to pay for a too expensive service.

In Zwaneveld et al. (1999), the evolutionary roadmap of ADA systems with corresponding technological challenges of the ADASE1 project is presented in Figure A.1.

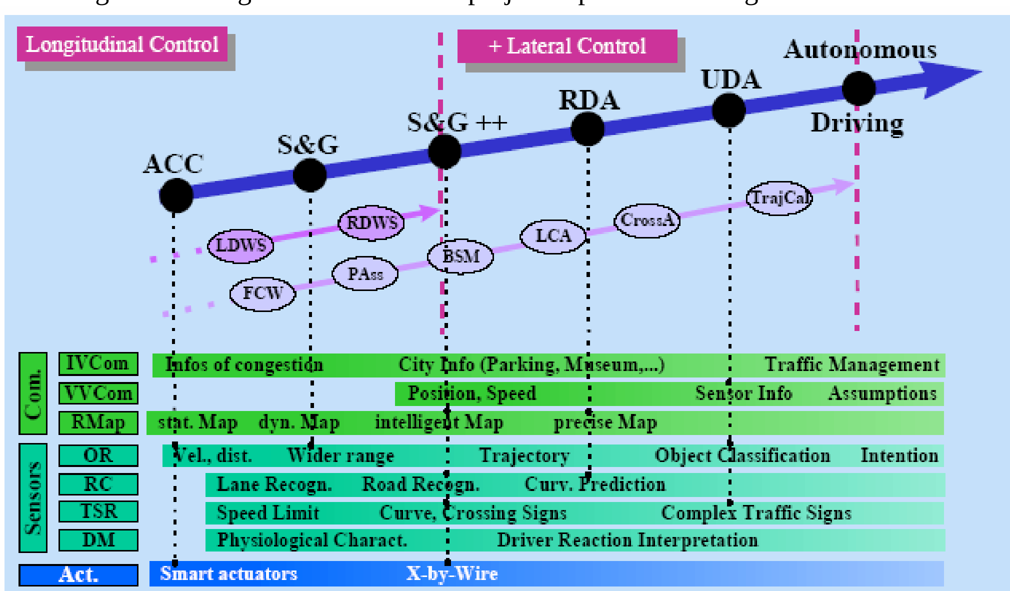


Figure A.1: evolutionary roadmap of ADA systems with corresponding technological challenges

In 2004 the ADASE roadmap was updated. The technological focus was extended in many other aspects of driver assistance like legal aspects, political and societal aspects, etc. In each case the complexities of the system concerning these aspects are shown by the size of the dots. The overall consideration of all these aspects and the functionality of the systems should lead to an assessment of the estimated safety benefit. The roadmap of the ADASE2 project is presented in Figure A.2.

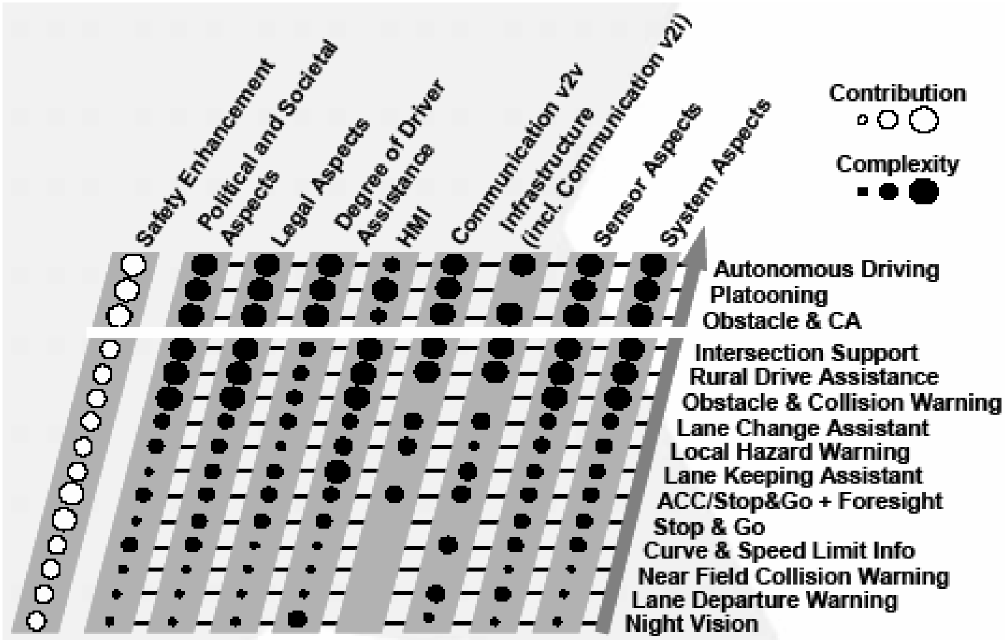


Figure A.2: ADASE2 roadmap

ATZ/Response2 (2003)

The aim of the RESPONSE2 project was to support functions for facilitation the market introduction of ADA systems. In a presentation discussing the scope of the RESPONSE2 project, Schollinski (2004) presented the 'driver assistance roadmap' of the Automobiltechnische Zeitschrift (ATZ). The ATZ roadmaps is presented in Figure A.3.

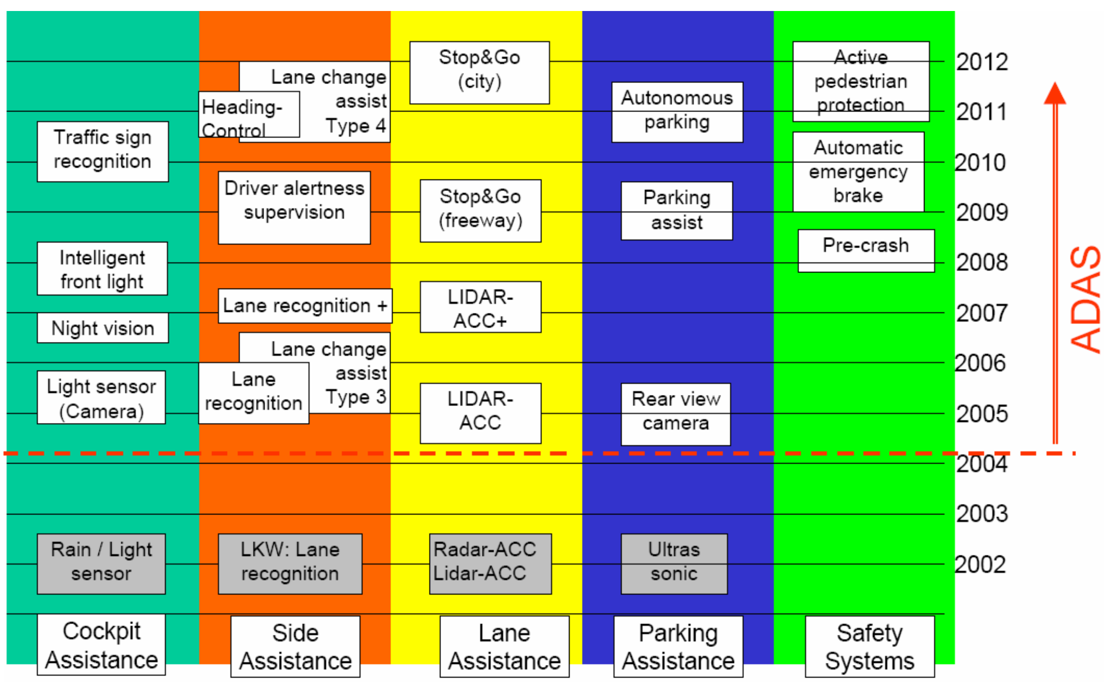


Figure A.3: Automobiltechnische Zeitschrift (ATZ) roadmap

MONET (2003)

The MONET project describes the automotive technical roadmap for the application of model-based systems and qualitative reasoning techniques in the automotive industry (MONET, 2003). Changes in technology over the next ten years have been included or excluded in this document on the grounds of whether model-based reasoning can assist in the aim of supporting the development of such technologies. Where that is not the case, the technology is not included in this roadmap, how significant it might be to the automotive community in general. The MONET roadmap is presented in Figure A.4.

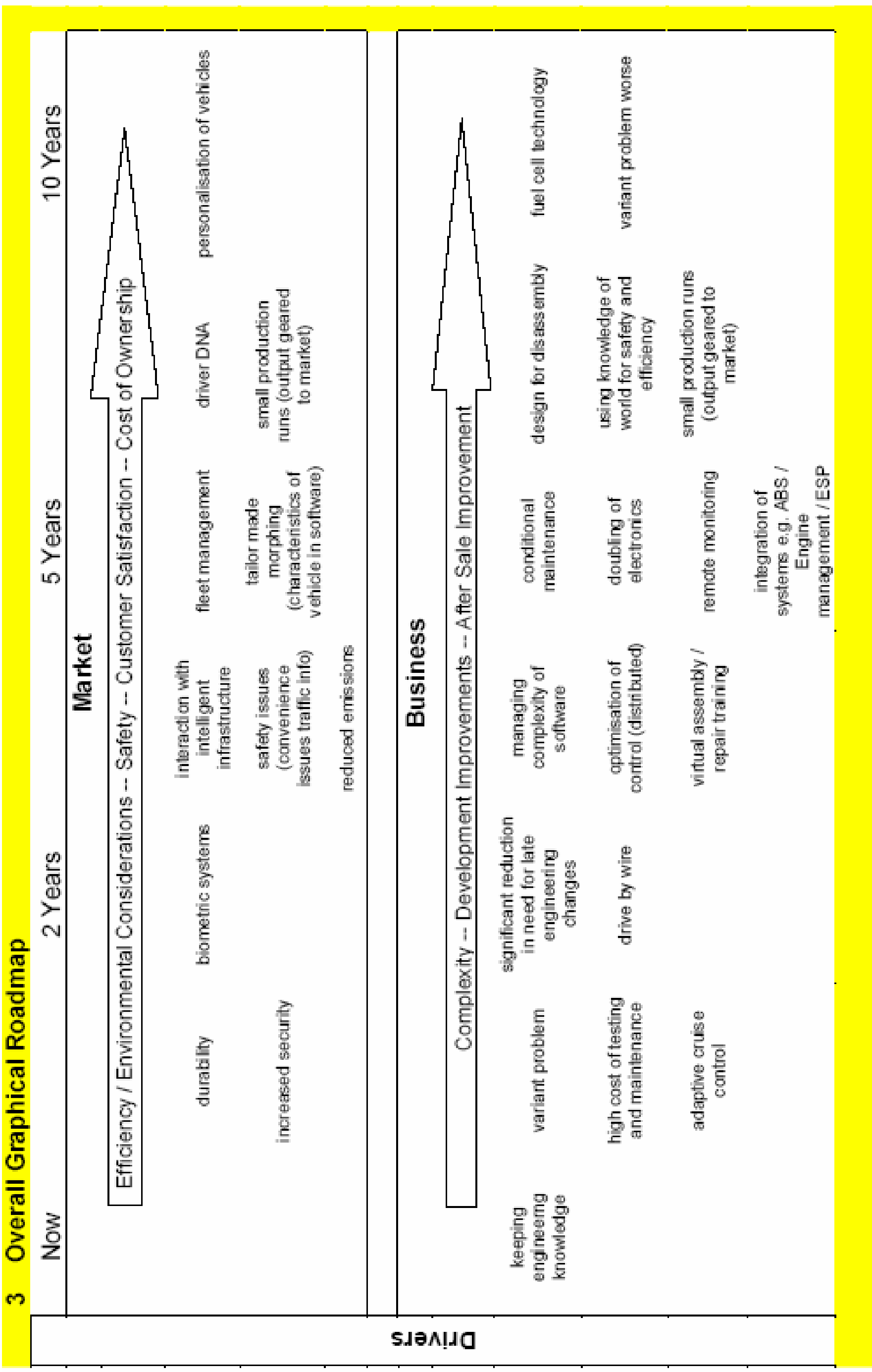


Figure A.4: MONET Automotive technology roadmap

SEiSS (2000/2004)

In the final report of the SEiSS (Socio Economic Impact of Intelligent Safety Systems) project two roadmaps are discussed (Abele et al, 2005). The objectives of the project were to provide factors for estimating the socio-economic benefits resulting from the introduction of Intelligent Vehicle Safety Systems and to identify the major indicators influencing market deployment and develop deployment scenarios for selected technologies/regions.

Figure A.5 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 & Go functionality based on additional sensor input (near area) and advanced actuation mechanisms (electro hydraulic braking). Technologies (grey) are invisible for the driver and functions (coloured) are directly related to the vehicle and the driver.

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.

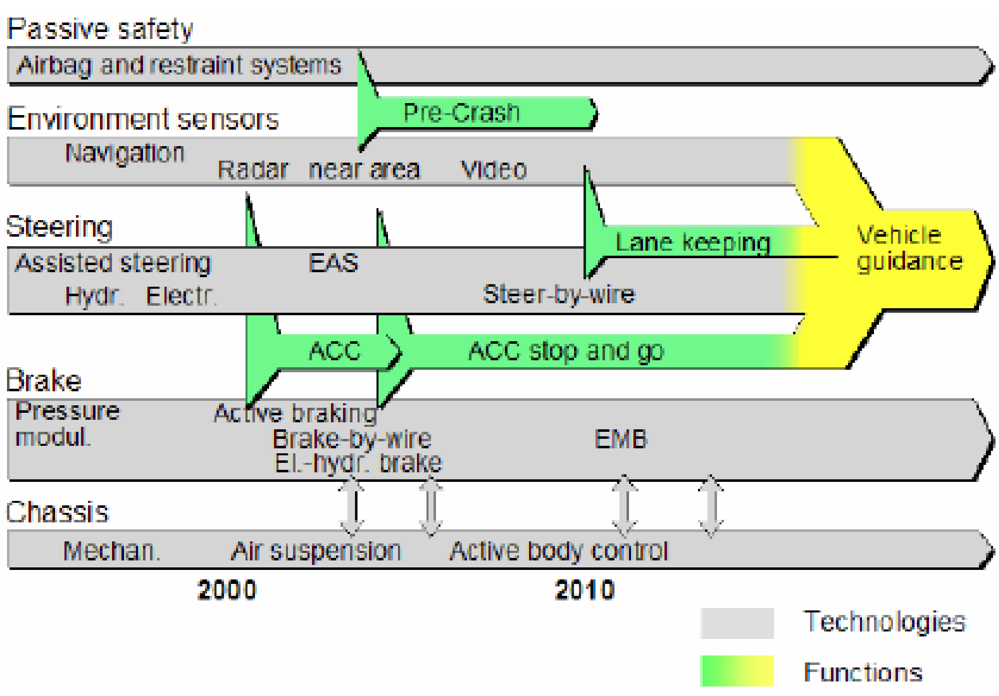


Figure A.5: Connected technology and ADAS roadmap (based on Robert Bosch GmbH)

Figure A.6 introduces the Intelligent Vehicle Safety System roadmap of the SEiSS project. 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.

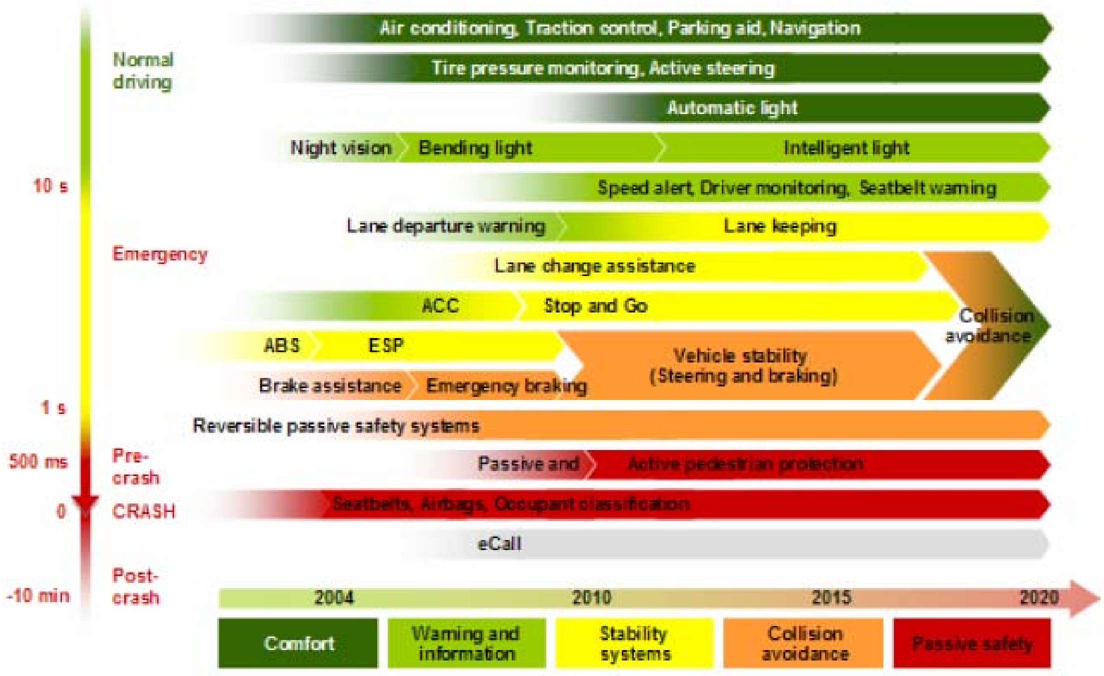
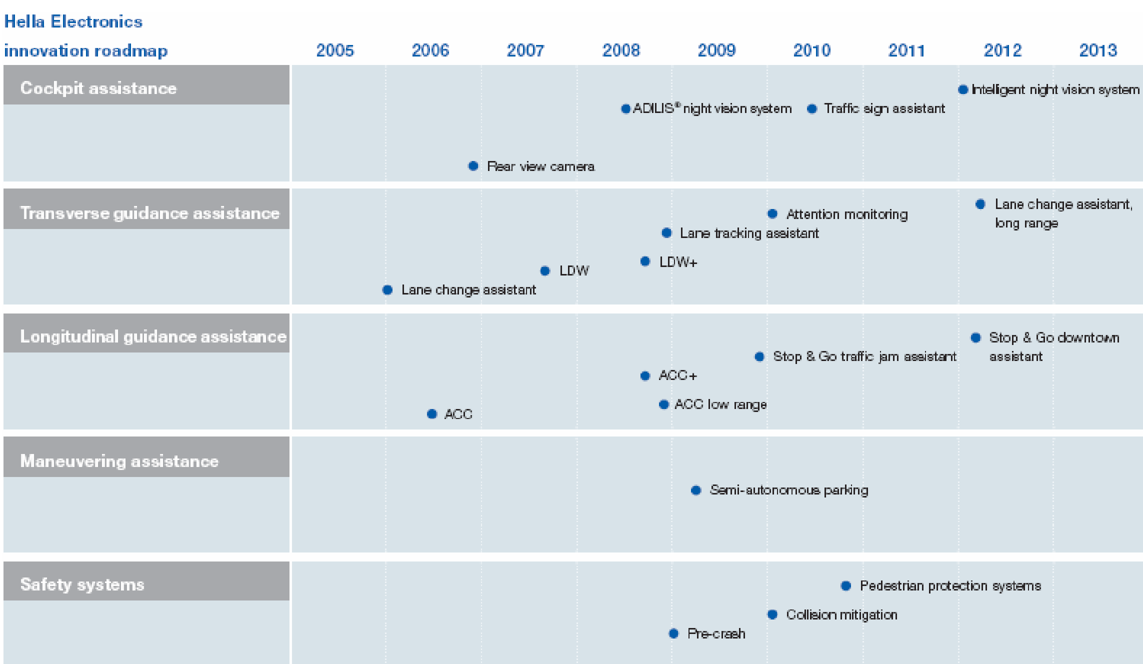


Figure A.6: SEiSS roadmap

Hella technology innovation roadmap (2005)

The supply of lights and electronics for the automotive industry and the supply of automotive products for the aftermarket and garages are the core business fields of Hella (Hella, 2005). Hella took preparatory steps for the next generation of driver assistance systems, in accordance with the roadmap agreed with their customers. The Hella roadmap is presented in Figure A.7.



Definitions of abbreviations:
ACC: Adaptive Cruise Control ACC+: Adaptive Cruise Control in conjunction with lane departure warning LDW: Lane departure warning RFK: Rear view camera SWA: Lane change assistant

Figure A.7: Hella technology innovation roadmap

SpeedAlert (2005)

SpeedAlert is a multi-sector initiative of a consortium including key public and private stakeholders, which have contributed their expertise in combining transport policy and industry perspectives to maximise concrete and exploitable results supporting future EU-wide implementation (ERTICO, 2005). The main results of SpeedAlert include a roadmap for deployment taking into account user needs, technical feasibility and available solutions. The SpeedAlert roadmap is given in Figure A.8.

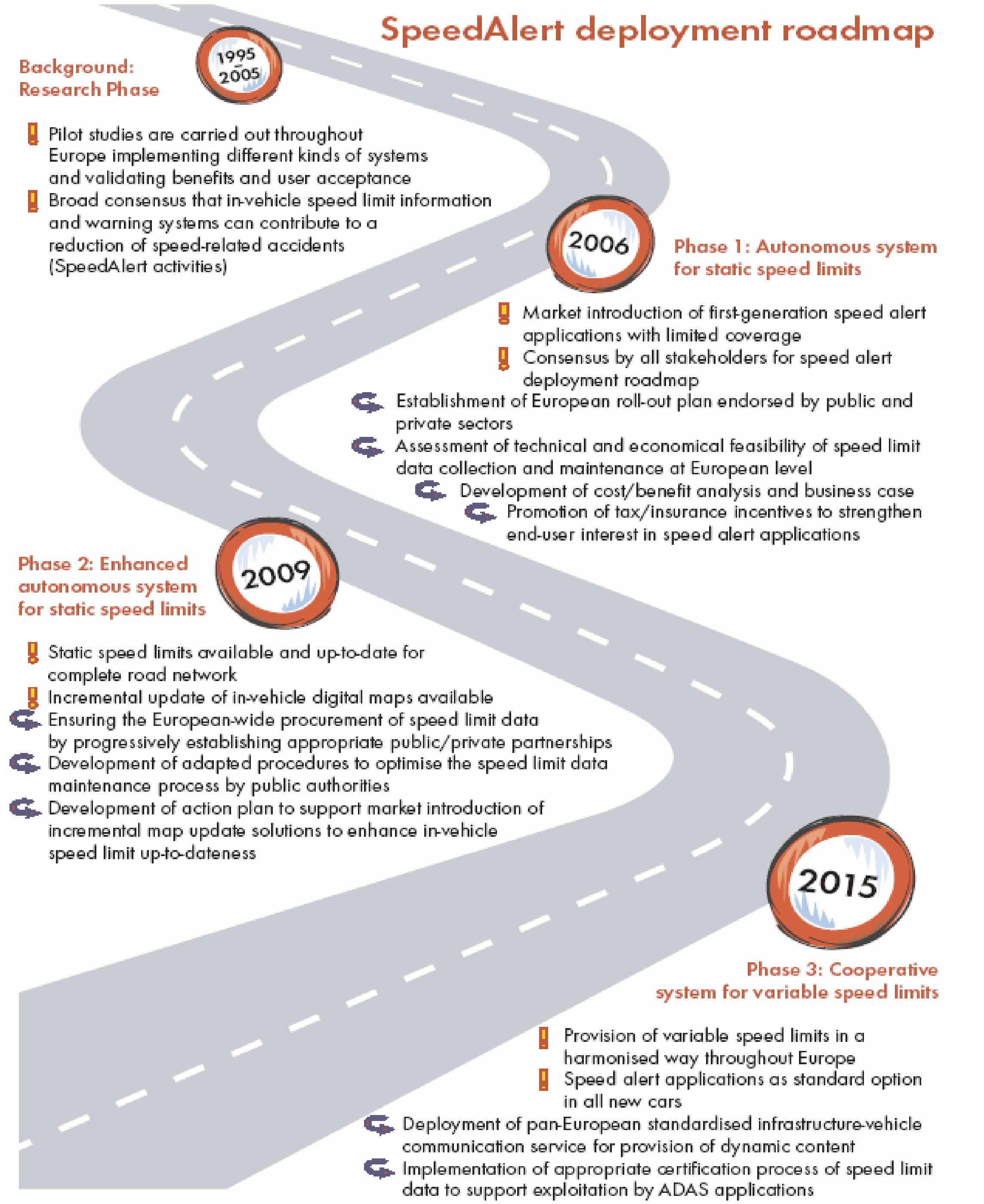


Figure A.8: SpeedAlert roadmap

9.2.1 Richard Bishop – AVV (2005)

In 2005 Richard Bishop developed a potential roadmap for European product introduction which he presented at the Dutch Ministry of Transport. The roadmap is presented in Figure A.9.

Potential roadmap for European product introduction									
	Now	2006	2007	2008	2009	2010	2012	2015	2020+
Electronic Stability Program									
Adaptive Cruise Control									
Lane Departure Warning									
Low Speed Following									
Short Range Obstacle Detection/Blind Spot									
Collision Mitigation Braking									
Lane Keeping Assist									
Curve Speed Warning									
Drowsy Driver Detection									
Pedestrian Detection									
V-V Communications									
V-R Communications									
Extensive Information based on Floating Car Data									
Cooperative Intersection Collision Avoidance									
Cooperative Adaptive Cruise Control									
Low Speed Automation (congested traffic)									
Automated Vehicles									

Figure A.9: Roadmap Richard Bishop

Appendix B: Questionnaire interviews

Interview deployment issues speed support systems

By: Jaap Vreeswijk; Student University of Twente, Trainee TNO Mobility and Logistics

The research objective of my Master-thesis is: *Provide insight in the meaning of development scenarios for stakeholders, the market position and the market perspective of speed support systems by processing relations between factors of influence in a scenario model.* In summary, I would like to make an overview of the factors affecting the development and implementation of speed support systems. With the development of a scenario model I will try to find relations between these factors and find possible deployment scenarios. The final objective of the research is to visualise the costs and benefits of deployment scenarios of speed support systems for stakeholders.

In order to make this research feasible I have to limit the number of factors by distinguishing main issues from minor issues. Most important are the critical issues of the implementation process. This separation can be done on the basis of experiences gained from development and implementation processes of driver support systems that are available on the market today.

Driver support systems that are currently available on the market and have something in common with speed support systems are (among others):

- Adaptive Cruise Control (ACC)
- Intelligent Speed Assistant (ISA)
- Lane Departure Warning System (LDWS)
- Low-speed ACC/Stop-and-go (Japan, Nissan/Toyota)

- Anti-lock braking system (ABS)
- Electronic Stability Program (ESP)

I hope you will participate in this interview, because I think that you have had valuable insights of the development and implementation process of one of the systems described above or of advanced driver assistance systems in general. Furthermore I expect that you are representative for one of the stakeholders (government, automobile industry, suppliers, interest groups, commercial) or are an expert in development and implementation processes. I would like to ask you to answer the questions from this point of view (system and your background) and besides looking backwards also reflect your experiences to possible future scenarios.

Implementation issues

For this interview I would like to discuss the most relevant implementation issues for speed support systems or advanced driver assistance systems in general. Below, some issues you could think of are given and explained by a few keywords.

- Technology availability (availability, technology breakthroughs)

- Road and information infrastructure need and availability (i.e. digital roadmap)

- Organisation requirements (responsibility, reliability)

- Regulatory requirements/barriers (quality requirement, responsibility, liability, timing of the updating, legal relevance)

- Business case/customer awareness and acceptance (development, actions, necessary conditions, future expectations)

- Feasible deployment strategy (strategies past/future, key issues, i.e. scale of implementation, mandatory/voluntary, etc.)

The objective of this interview is to get an idea of the importance of the issues regarding development and implementation. What I would like to know from the experts interviewed is what the development and implementation process of already introduced systems did look like. What were/are the critical issues? Feel free to focus on one or more of the possible implementation issues if you think these are most important. That is exactly what I am looking for!

Questions

- Can you specify the development and implementation process of the system in steps and describe the most relevant events within these steps?

- How much time did these steps cost, which steps were most time-consuming and which steps are expected to be accomplished quicker in the future?

- Which problems/obstacles/barriers came across during the development and implementation of the system and made the process slow down?

- Will these problems/obstacles/barriers form the same problem nowadays as they did in the past?

- Which events (like subsidy or a code-of-practise) are necessary and which events can we expect in the (near) future that will be of huge influence to the development and implementation process of speed support systems?

- From your stakeholder point of view, stimulating the development and implementation process or waiting and see how things take course, what considerations did or do you make? What is your attitude towards speed support systems and how is that attitude formed? (For instance; why are ABS and ESP implemented on a wide scale and systems like ISA and ACC not?).

- Based on your expertise and background, how would you characterise the ideal scenario that is most beneficial for your stakeholder group, the development and a wide implementation of speed support systems?

- Seen from your stakeholder position; what can be expected of future development and implementation processes of speed support systems?

- In conclusion, in order to make an overview of factors that influence the development and implementation of speed support systems and make a distinction between issues of major and issues minor importance; which aspects were and might still are most crucial for the development and implementation of the system, seen from your stakeholder-background point of view?

Appendix C: Interview participants

Richard Bishop	Bishop Consulting
Gerben Bootsma	Rijkswaterstaat, Ministry of Transport
Walter Hagleitner	ADAS Management Consulting
Peter Hendrickx	Groeneveld Transport Efficiency B.V.
Vincent Marchau	TU Delft
Peter Morsink	Stichting Wetenschappelijk Onderzoek Verkeersveiligheid (SWOV)
Jeroen Ploeg	TNO Automotive
Bart Swaans	Province of North-Brabant
Allard Zoutendijk	TNO Imaging Systems

Four of the interview participants could not be reached in time to give their permission for publication of their names. They are therefore not included in this list.

Appendix D: Model testing

- The penetration rate of the system increases as the scenario variables increase.

  In section 6.4 it was shown that the relations between the scenario variables and the penetration rate of the system are summarised by $P_{factors}$. This means that when the scenario variables increase, $P_{factors}$ increases and thus the penetration rate of the system should increase. In Table D.1 it is demonstrated that the behaviour of the model satisfies this hypothesis; that the penetration rate of the system increases when the scenario variables increase.

  Table D.1: penetration rate of the system as a function of the scenario variables ($P_{factors}$)

	Penetration rate of the system				
$P_{factors}$	**2006**	**2010**	**2015**	**2020**	**2025**
0.0	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %
0.25	0.0 %	1.8 %	6.7 %	12.2 %	16.7 %
0.50	0.0 %	3.6 %	13.4 %	24.4 %	33.4 %
0.75	0.0 %	5.4 %	20.1 %	36.5 %	50.1 %
1.00	0.0 %	7.3 %	26.8 %	48.7 %	66.9 %

- The penetration rate of the system develops differently for the different system variants. For example, the penetration rate of IRSA advisory increases fastest and the penetration rate of IRSA controlling increases slowest. Explanatory variables for the differences between system variants are system acceptance, system availability and the impact of the system.

  Table D.2 shows that, given the variables setting of scenario 4, the behaviour of the model satisfies this hypothesis; that the penetration rate of the system develops differently for the different system variants. A more detailed analysis of these differences is presented in section 7.4.

  Table D.2: penetration rate of the system in scenario 4

Penetration - Scenario 4	**2006**	**2010**	**2015**	**2020**	**2025**
IRSA - Advisory	0.0	5.8	21.8	40.2	55.7
IRSA - Intervening	0.0	5.4	20.2	36.6	50.1
IRSA - Controlling	0.0	0.0	5.6	17.3	29.7
Congestion Assistant	0.0	0.0	5.8	18.4	32.4

- If government regulation is present, which means that this variable is set to ‘1’, other scenario variables besides system availability are overruled and the penetration rate of the system reaches its maximum (which is equal to the percentage of new vehicles since the system is available). Therefore, $P_{factors}$ should be ‘1’ as a result of equation D.1.

$$P_{factors,t} = (P_{c,t} + P_{g,t} + P_{n,t} + P_{a,t})/4 + P_{gov} * (1 - ((P_{c,t} + P_{g,t} + P_{n,t} + P_{a,t})/4)) \quad \text{(D.1)}$$

In which:
- $P_{factors,t}$ value between 0 and 1 representing all scenario variables
- $P_{c,t}$ penetration rate of the systems as a function of the system price
- $P_{g,t}$ penetration rate of the system as a function of the purchasing power

$P_{n,t}$ penetration rate of the system as a function of the social need
$P_{a,t}$ penetration rate of the system as a function of the system acceptance

For the analysis of this hypothesis the variable settings of scenario 4 are used with the adaptation that all systems are available in all market segments in 2006. If all scenario variables are overruled the differences between the system variants should disappear. Furthermore, the penetration rates should be much higher, equalling the maximum penetration rate. The Tables D.3a and D.3b present the penetration rate of the system as the result of the scenario conditions described. In Table D.3a government regulation is excluded and in Table D.3b government regulation is included. From these tables is can be concluded that the behaviour of the model satisfies this hypothesis; that the scenario variables are overruled and the penetration rate of the system reaches is maximum in the presence of government regulation.

Table D.3a: penetration rate of the system without government regulation

Penetration - Scenario 4	**2006**	**2010**	**2015**	**2020**	**2025**
IRSA - Advisory	0.0	5.8	21.8	40.2	55.7
IRSA - Intervening	0.0	5.4	20.2	36.6	50.1
IRSA - Controlling	0.0	5.1	18.5	32.3	43.0
Congestion Assistant	0.0	5.2	19.3	34.5	46.9

Table D.3b: penetration rate of the system with government regulation

Penetration - Scenario 4	**2006**	**2010**	**2015**	**2020**	**2025**
IRSA - Advisory	0.0	7.3	26.8	48.7	66.9
IRSA - Intervening	0.0	7.3	26.8	48.7	66.9
IRSA - Controlling	0.0	7.3	26.8	48.7	66.9
Congestion Assistant	0.0	7.3	26.8	48.7	66.9

- When systems become available in a new market segment only IRSA advisory is available directly. It lasts one time step before IRSA intervening becomes available and two time steps for IRSA controlling and the Congestion Assistant.

For this analysis of this hypothesis the system availability is defined as follows:

Table D.4: system availability

Variable	***Scenario***
1st availability in high-end segment	2006
1st availability in middle-end segment	2010
1st availability in low-end segment	2015
Availability – IRSA Advisory	2006
Availability – IRSA Intervening	2010
Availability – IRSA Controlling	2015
Availability – Congestion assistant	2015

As a result of these variable settings, the scenario model defines the availability of IRSA Advisory, IRSA Intervening and IRSA Controlling and the Congestion Assistant as presented in the Tables D.5a, b and c. From these tables is can be concluded that the behaviour of the model satisfies this hypothesis; that all systems become available in the different market segment step-by step.

Table D.5a: availability of IRSA Advisory

Availability IRSA Advisory	**2006**	**2010**	**2015**	**2020**	**2025**
High-end segment	0	1	1	1	1
Mid-range segment	0	0	1	1	1
Low-end segment	0	0	0	1	1

Table D.5b: availability of IRSA Intervening

Availability IRSA Advisory	**2006**	**2010**	**2015**	**2020**	**2025**
High-end segment	0	0	1	1	1
Mid-range segment	0	0	0	1	1
Low-end segment	0	0	0	0	1

Table D.5c: availability of IRSA Controlling and the Congestion Assistant

Availability IRSA Advisory	**2006**	**2010**	**2015**	**2020**	**2025**
High-end segment	0	0	0	1	1
Mid-range segment	0	0	0	0	1
Low-end segment	0	0	0	0	0

- Initially, all scenario variables have equal weights; none should be dominant. This hypothesis is evaluated in section 7.3 of the report.

CIV

Appendix E: Sensitivity analysis

Economy of scope

Table E.1 a and b: penetration rate of the system with economy of scope of 10, 9 and 11 percent

a. Penetration rate – ***Economy of scope 10 %***	**2006**	**2010**	**2015**	**2020**	**2025**
IRSA – Advisory	0 %	3.35 %	12.6 %	23.1 %	31.9 %
IRSA – Intervening	0 %	3.35 %	12.5 %	22.6 %	30.8 %
IRSA – Controlling	0 %	3.35 %	12.3 %	21.6 %	28.7 %
Congestion Assistant	0 %	3.35 %	12.4 %	22.4 %	30.3 %

b. Penetration rate – ***Economy of scope 9 %***	**2006**	**2010**	**2015**	**2020**	**2025**
IRSA – Advisory	0 %	3.34%	12.5 %	23.0 %	31.8 %
IRSA – Intervening	0 %	3.34 %	12.4 %	22.5 %	30.7 %
IRSA – Controlling	0 %	3.34 %	12.2 %	21.5 %	28.6 %
Congestion Assistant	0 %	3.34 %	12.3 %	22.2 %	30.2 %

c. Penetration rate – ***Economy of scope 11 %***	**2006**	**2010**	**2015**	**2020**	**2025**
IRSA – Advisory	0 %	3.36 %	12.6 %	23.2 %	32.0 %
IRSA – Intervening	0 %	3.36 %	12.5 %	22.7 %	31.0 %
IRSA – Controlling	0 %	3.36 %	12.3 %	21.7 %	28.8 %
Congestion Assistant	0 %	3.36 %	12.5 %	22.4 %	30.4 %

Table E.2 a and b: change in penetration rate of the system with economy of scope of 9 and 11 percent compared to economy of scope of 10 percent

a. Penetration rate – ***Economy of scope 9 %***	**2006**	**2010**	**2015**	**2020**	**2025**
IRSA – Advisory	0 %	-0.379 %	-0.369 %	-0.343 %	0.324 %
IRSA – Intervening	0 %	-0.379 %	-0.369 %	-0.345 %	-0.328 %
IRSA – Controlling	0 %	-0.379 %	-0.369 %	-0.348 %	-0.336 %
Congestion Assistant	0 %	-0.379 %	-0.369 %	0.346 %	-0.330 %

b. Penetration rate – ***Economy of scope 11 %***	**2006**	**2010**	**2015**	**2020**	**2025**
IRSA – Advisory	0 %	0.379 %	0.368 %	0.343 %	0.324 %
IRSA – Intervening	0 %	0.379 %	0.368 %	0.344 %	0.327 %
IRSA – Controlling	0 %	0.379 %	0.369 %	0.347 %	0.335 %
Congestion Assistant	0 %	0.379 %	0.369 %	0.345 %	0.329 %

Financial incentives

Table E.3 a and b: penetration rate of the system with financial incentives of 25, 22.5 and 27.5 percent

a. Penetration rate – ***Financial incentives 25 %***	**2006**	**2010**	**2015**	**2020**	**2025**
IRSA – Advisory	0 %	3.35 %	12.6 %	23.1 %	31.9 %
IRSA – Intervening	0 %	3.35 %	12.5 %	22.6 %	30.8 %
IRSA – Controlling	0 %	3.35 %	12.3 %	21.6 %	28.7 %
Congestion Assistant	0 %	3.35 %	12.4 %	22.4 %	30.3 %

b. Penetration rate – ***Financial incentives 22.5 %***	**2006**	**2010**	**2015**	**2020**	**2025**
IRSA – Advisory	0 %	3.31 %	12.5 %	22.9 %	31.6 %
IRSA – Intervening	0 %	3.31 %	12.4 %	22.4 %	30.5 %
IRSA – Controlling	0 %	3.31 %	12.1 %	21.4 %	28.5 %
Congestion Assistant	0 %	3.31 %	12.3 %	22.1 %	30.0 %

c. Penetration rate – ***Financial incentives 27.5 %***	**2006**	**2010**	**2015**	**2020**	**2025**
IRSA – Advisory	0 %	3.39 %	12.7 %	23.4 %	32.2 %
IRSA – Intervening	0 %	3.39 %	12.6 %	22.8 %	31.1 %
IRSA – Controlling	0 %	3.39 %	12.4 %	21.8 %	29.0 %
Congestion Assistant	0 %	3.39 %	12.6 %	22.6 %	30.6 %

Table E.4 a and b: change in penetration rate of the system with financial incentives of 22.5 and 27.5 percent compared to financial incentives of 25 percent

a. Penetration rate – ***Financial incentives 22.5%***	**2006**	**2010**	**2015**	**2020**	**2025**
IRSA – Advisory	0 %	-1.19 %	-1.11 %	-1.03 %	-0.97 %
IRSA – Intervening	0 %	-1.19 %	-1.11 %	-1.04 %	-0.99 %
IRSA – Controlling	0 %	-1.19 %	-1.11 %	-1.05 %	-1.01 %
Congestion Assistant	0 %	-1.19 %	-1.11 %	-1.04 %	-0.99 %

b. Penetration rate – ***Financial incentives 27.5 %***	**2006**	**2010**	**2015**	**2020**	**2025**
IRSA – Advisory	0 %	1.19 %	1.10 %	1.03 %	0.97 %
IRSA – Intervening	0 %	1.19 %	1.10 %	1.03 %	0.98 %
IRSA – Controlling	0 %	1.19 %	1.11 %	1.04 %	1.00 %
Congestion Assistant	0 %	1.19 %	1.10 %	1.03 %	0.99 %

Purchasing power

Table E.5 a and b: penetration rate of the system with purchasing power of 2.5, 2.25 and 2.75 percent

a. Penetration rate – ***Purchasing power 2.5 %***	**2006**	**2010**	**2015**	**2020**	**2025**
IRSA – Advisory	0 %	3.35 %	12.6 %	23.1 %	31.9 %
IRSA – Intervening	0 %	3.35 %	12.5 %	22.6 %	30.8 %
IRSA – Controlling	0 %	3.35 %	12.3 %	21.6 %	28.7 %
Congestion Assistant	0 %	3.35 %	12.4 %	22.4 %	30.3 %

b. Penetration rate – ***Purchasing power 2.25 %***	**2006**	**2010**	**2015**	**2020**	**2025**
IRSA – Advisory	0 %	3.26 %	12.2 %	22.5 %	31.0 %
IRSA – Intervening	0 %	3.26 %	12.1 %	22.0 %	30.0 %
IRSA – Controlling	0 %	3.26 %	11.9 %	21.0 %	27.9 %
Congestion Assistant	0 %	3.26 %	12.1 %	21.7 %	29.5 %

c. Penetration rate – ***Purchasing power 2.75 %***	**2006**	**2010**	**2015**	**2020**	**2025**
IRSA – Advisory	0 %	3.44 %	12.9 %	23.8 %	32.8 %
IRSA – Intervening	0 %	3.44 %	12.8 %	23.2 %	31.7 %
IRSA – Controlling	0 %	3.44 %	12.6 %	22.2 %	29.6 %
Congestion Assistant	0 %	3.44 %	12.8 %	23.0 %	31.2 %

Table E.6 a and b: change in penetration rate of the system with purchasing power of 2.25 and 2.75 percent compared to purchasing power of 2.5 percent

a. Penetration rate – ***Purchasing power 2.25%***	**2006**	**2010**	**2015**	**2020**	**2025**
IRSA – Advisory	0 %	-2.74 %	-2.74 %	-2.75 %	-2.76 %
IRSA – Intervening	0 %	-2.74 %	-2.74 %	-2.75 %	-2.78 %
IRSA – Controlling	0 %	-2.74 %	-2.74 %	-2.77 %	-2.82 %
Congestion Assistant	0 %	-2.74 %	-2.74 %	-2.76 %	-2.79 %

b. Penetration rate – ***Purchasing power 2.75 %***	**2006**	**2010**	**2015**	**2020**	**2025**
IRSA – Advisory	0 %	2.74 %	2.74 %	2.75 %	2.76 %
IRSA – Intervening	0 %	2.74 %	2.74 %	2.75 %	2.78 %
IRSA – Controlling	0 %	2.74 %	2.74 %	2.77 %	2.82 %
Congestion Assistant	0 %	2.74 %	2.74 %	2.76 %	2.79 %

Social need

Table E.7 a and b: penetration rate of the system with social need of 150, 145 and 165 percent

a. Penetration rate – *Social need 150 %*	**2006**	**2010**	**2015**	**2020**	**2025**
IRSA – Advisory	0 %	3.35 %	12.6 %	23.1 %	31.9 %
IRSA – Intervening	0 %	3.35 %	12.5 %	22.6 %	30.8 %
IRSA – Controlling	0 %	3.35 %	12.3 %	21.6 %	28.7 %
Congestion Assistant	0 %	3.35 %	12.4 %	22.4 %	30.3 %

b. Penetration rate – *Social need 145 %*	**2006**	**2010**	**2015**	**2020**	**2025**
IRSA – Advisory	0 %	3.26 %	12.2 %	22.5 %	31.1 %
IRSA – Intervening	0 %	3.26 %	12.2 %	22.0 %	30.1 %
IRSA – Controlling	0 %	3.26 %	12.0 %	21.1 %	28.1 %
Congestion Assistant	0 %	3.26 %	12.1 %	21.8 %	29.5 %

c. Penetration rate – *Social need 155 %*	**2006**	**2010**	**2015**	**2020**	**2025**
IRSA – Advisory	0 %	3.44 %	12.9 %	23.7 %	32.8 %
IRSA – Intervening	0 %	3.44 %	12.8 %	23.2 %	31.6 %
IRSA – Controlling	0 %	3.44 %	12.6 %	22.1 %	29.4 %
Congestion Assistant	0 %	3.44 %	12.8 %	22.9 %	31.1 %

Table E.8 a and b: change in penetration rate of the system with social need of 145 and 155 percent compared to social need of 150 percent

a. Penetration rate – *Social need 145 %*	**2006**	**2010**	**2015**	**2020**	**2025**
IRSA – Advisory	0 %	-2.74 %	-2.71 %	-2.67 %	-2.65 %
IRSA – Intervening	0 %	-2.74 %	-2.69 %	-2.61 %	-2.55 %
IRSA – Controlling	0 %	-2.74 %	-2.63 %	-2.47 %	-2.36 %
Congestion Assistant	0 %	-2.74 %	-2.68 %	-2.57 %	-2.50 %

b. Penetration rate – *Social need 155 %*	**2006**	**2010**	**2015**	**2020**	**2025**
IRSA – Advisory	0 %	2.74 %	2.71 %	2.67 %	2.64 %
IRSA – Intervening	0 %	2.74 %	2.69 %	2.60 %	2.55 %
IRSA – Controlling	0 %	2.74 %	2.63 %	2.46 %	2.34 %
Congestion Assistant	0 %	2.74 %	2.67 %	2.57 %	2.50 %

Appendix F: Model results

Penetration rates, prices of the systems and social need per scenario

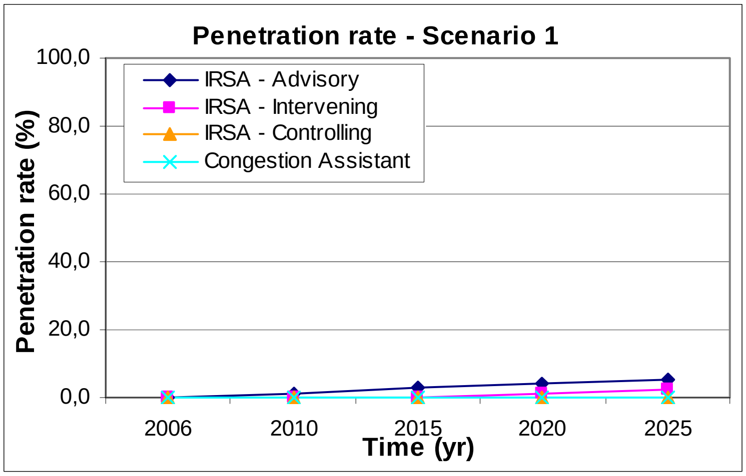


Figure and Table F.1: penetration rate of IRSA and the Congestion Assistant in scenario 1

Penetration - Scenario 1	**2006**	**2010**	**2015**	**2020**	**2025**
IRSA - Advisory	0.0	1.4	2.9	4.1	5.1
IRSA - Intervening	0.0	0.0	0.0	1.3	2.4
IRSA - Controlling	0.0	0.0	0.0	0.0	0.0
Congestion Assistant	0.0	0.0	0.0	0.0	0.0

Table F.2: price of IRSA and the Congestion Assistant in scenario 1

System price - Scenario 1	**2006**	**2010**	**2015**	**2020**	**2025**
IRSA - Advisory	€ 750	€ 739	€ 728	€ 719	€ 712
IRSA - Intervening	€ 1.500	€ 1.500	€ 1.500	€ 1.480	€ 1.464
IRSA - Controlling	€ 2.250	€ 2.250	€ 2.250	€ 2.250	€ 2.250
Congestion Assistant	€ 2.500	€ 2.500	€ 2.500	€ 2.500	€ 2.500

Table F.3: social need in scenario 1

Social need - Scenario 1	**2006**	**2010**	**2015**	**2020**	**2025**
Reference	*120*	*120*	*120*	*120*	*120*
IRSA - Advisory	120	120	119	119	118
IRSA - Intervening	120	120	120	120	119
IRSA - Controlling	120	120	120	120	120
Congestion Assistant	120	120	120	120	120

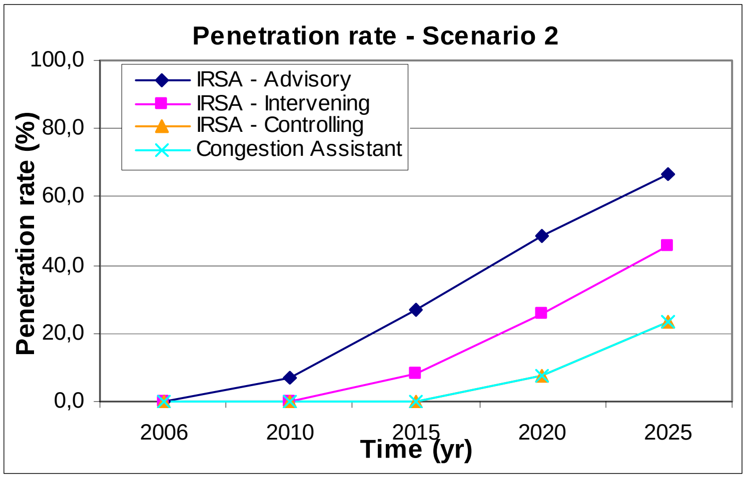


Figure F.2 and Table F.4 : penetration rate of IRSA and the Congestion Assistant in scenario 2

Penetration - Scenario 2	**2006**	**2010**	**2015**	**2020**	**2025**
IRSA - Advisory	0.0	7.3	26.8	48.7	66.9
IRSA - Intervening	0.0	0.0	8.1	25.7	45.8
IRSA - Controlling	0.0	0.0	0.0	7.3	23.5
Congestion Assistant	0.0	0.0	0.0	7.3	23.5

Table F.5: price of IRSA and the Congestion Assistant in scenario 2

System price - Scenario 2	**2006**	**2010**	**2015**	**2020**	**2025**
IRSA - Advisory	€ 375	€ 348	€ 275	€ 192	€ 124
IRSA - Intervening	€ 750	€ 750	€ 689	€ 557	€ 406
IRSA - Controlling	€ 1.125	€ 1.125	€ 1.125	€ 1.042	€ 861
Congestion Assistant	€ 1.250	€ 1.250	€ 1.250	€ 1.158	€ 956

Table F.6: social need in scenario 2

Social need - Scenario 2	**2006**	**2010**	**2015**	**2020**	**2025**
Reference	*200*	*200*	*200*	*200*	*200*
IRSA - Advisory	200	200	195	184	180
IRSA - Intervening	200	200	200	188	169
IRSA - Controlling	200	200	200	200	178
Congestion Assistant	200	200	200	200	186

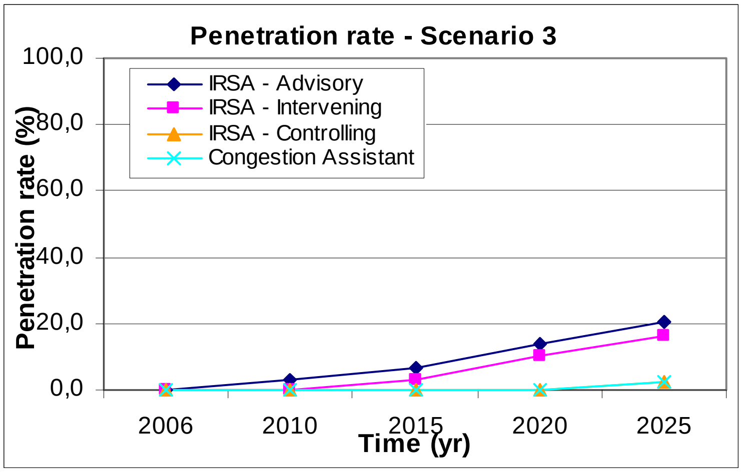


Figure F.3 and Table E.7: penetration rate of IRSA and the Congestion Assistant in scenario 3

Penetration - Scenario 3	**2006**	**2010**	**2015**	**2020**	**2025**
IRSA - Advisory	0.0	3.2	6.4	14.0	20.2
IRSA - Intervening	0.0	0.0	3.3	10.4	16.1
IRSA - Controlling	0.0	0.0	0.0	0.0	2.4
Congestion Assistant	0.0	0.0	0.0	0.0	2.5

Table F.8: price of IRSA and the Congestion Assistant in scenario 3

System price - Scenario 3	**2006**	**2010**	**2015**	**2020**	**2025**
IRSA - Advisory	€ 300	€ 290	€ 281	€ 258	€ 239
IRSA - Intervening	€ 600	€ 600	€ 580	€ 538	€ 504
IRSA - Controlling	€ 900	€ 900	€ 900	€ 900	€ 879
Congestion Assistant	€ 1.000	€ 1.000	€ 1.000	€ 1.000	€ 975

Table F.9: social need in scenario 3

Social need - Scenario 3	**2006**	**2010**	**2015**	**2020**	**2025**
Reference	*120*	*120*	*120*	*120*	*120*
IRSA - Advisory	120	120	119	117	114
IRSA - Intervening	120	120	120	117	111
IRSA - Controlling	120	120	120	120	120
Congestion Assistant	120	120	120	120	120

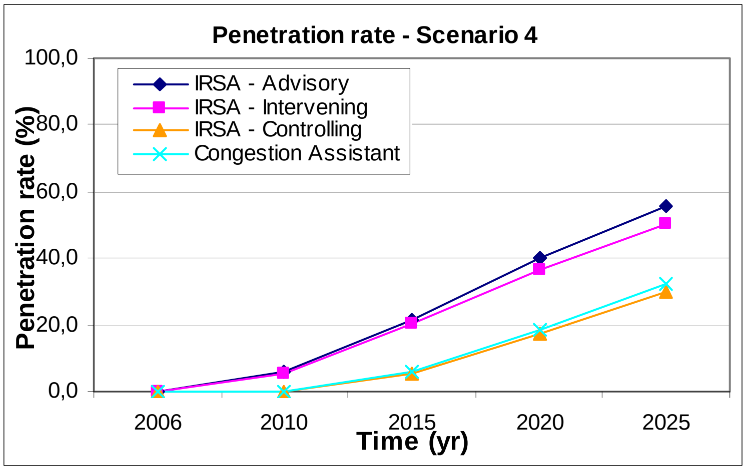


Figure F.4 and Table F.10: penetration rate of IRSA and the Congestion Assistant in scenario 4

Penetration - Scenario 4	**2006**	**2010**	**2015**	**2020**	**2025**
IRSA - Advisory	0.0	5.8	21.8	40.2	55.7
IRSA - Intervening	0.0	5.4	20.2	36.6	50.1
IRSA - Controlling	0.0	0.0	5.6	17.3	29.7
Congestion Assistant	0.0	0.0	5.8	18.4	32.4

Table F.11: price of IRSA and the Congestion Assistant in scenario 4

System price - Scenario 4	**2006**	**2010**	**2015**	**2020**	**2025**
IRSA - Advisory	€ 600	€ 565	€ 469	€ 359	€ 266
IRSA - Intervening	€ 1.200	€ 1.135	€ 957	€ 761	€ 599
IRSA - Controlling	€ 1.800	€ 1.800	€ 1.700	€ 1.489	€ 1.266
Congestion Assistant	€ 2.000	€ 2.000	€ 1.883	€ 1.632	€ 1.352

Table F.12: social need in scenario 4

Social need - Scenario 4	**2006**	**2010**	**2015**	**2020**	**2025**
Reference	*200*	*200*	*200*	*200*	*200*
IRSA - Advisory	200	200	196	186	181
IRSA - Intervening	200	200	192	174	163
IRSA - Controlling	200	200	200	183	154
Congestion Assistant	200	200	200	189	170

Penetration rates of IRSA and the Congestion Assistant per system

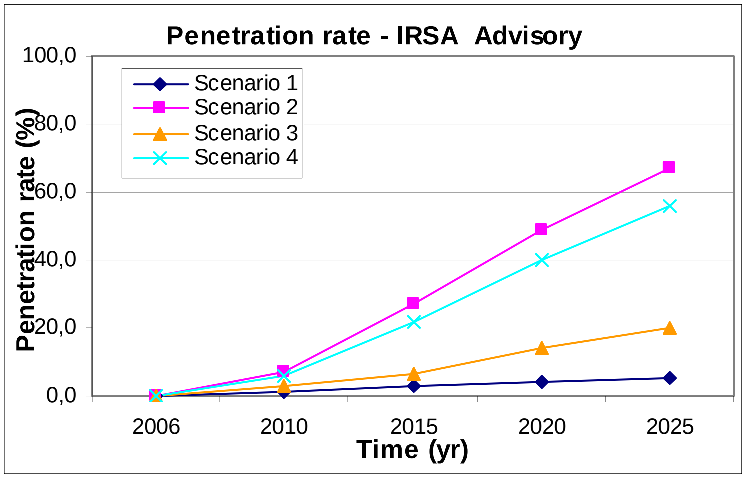


Figure F.5 and Table F.13: penetration rate of IRSA Advisory in four scenarios

Penetration - IRSA - Advisory	2006	2010	2015	2020	2025
Scenario 1	0,0	1,4	2,9	4,1	5,1
Scenario 2	0,0	7,3	26,8	48,7	66,9
Scenario 3	0,0	3,2	6,4	14,0	20,2
Scenario 4	0,0	5,8	21,8	40,2	55,7

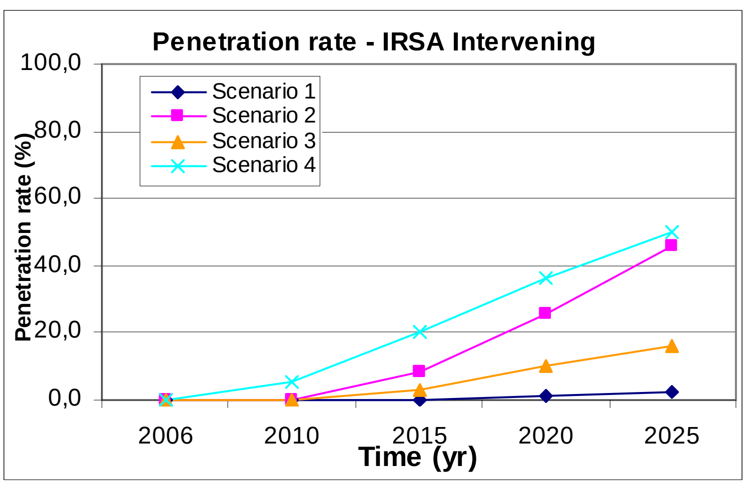


Figure F.6 and Table F.14: penetration rate of IRSA Intervening in four scenarios

Penetration - IRSA - Intervening	2006	2010	2015	2020	2025
Scenario 1	0.0	0.0	0.0	1.3	2.4
Scenario 2	0.0	0.0	8.1	25.7	45.8
Scenario 3	0.0	0.0	3.3	10.4	16.1
Scenario 4	0.0	5.4	20.2	36.6	50.1

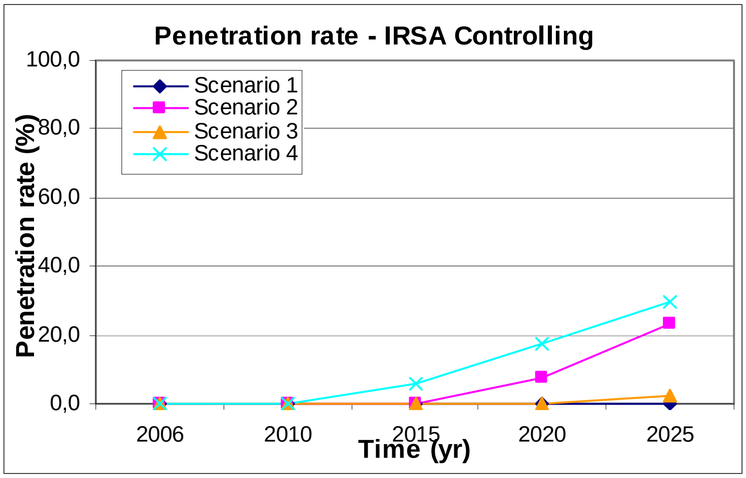


Figure F.7 and Table F.15: penetration rate of IRSA Controlling in four scenarios

Penetration - IRSA - Controlling	2006	2010	2015	2020	2025
Scenario 1	0.0	0.0	0.0	0.0	0.0
Scenario 2	0.0	0.0	0.0	7.3	23.5
Scenario 3	0.0	0.0	0.0	0.0	2.4
Scenario 4	0.0	0.0	5.6	17.3	29.7

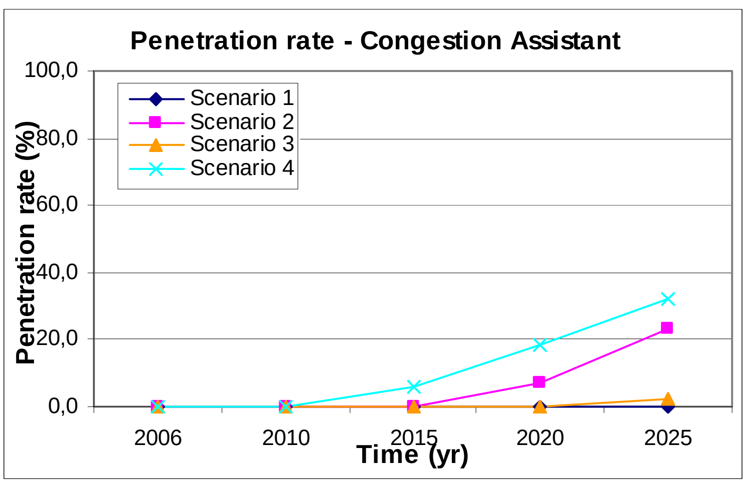


Figure F.8 and Table F.16: penetration rate of the Congestion Assistant in four scenarios

Penetration - Congestion Assistant	2006	2010	2015	2020	2025
Scenario 1	0.0	0.0	0.0	0.0	0.0
Scenario 2	0.0	0.0	0.0	7.3	23.5
Scenario 3	0.0	0.0	0.0	0.0	2.5
Scenario 4	0.0	0.0	5.8	18.4	32.4