Getting ADAS on the Road

Actors' Interactions in Advanced Driver Assistance Systems Deployment

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Preface

After finishing my studies in Civil Engineering in 2004, I took some time off to think what I wanted to do next. Working on my final research project had been so much fun that I could not imagine what would be the nicest job to do afterwards. In the end, the answer was straightforward, continue doing research, preferably on a PhD project. Fortunately, there was a PhD position available at the Transport and Logistics section of the TU Delft, for which I was accepted. The subject was almost a seamless follow-up on my final research project, featuring Advanced Driver Assistance Systems and Actors.

Those are the facts that led to this PhD thesis. But what can be much more fascinating than facts are stories. That is why I would like to tell you a brief story about how I ended up doing this research, focusing on the role transport technology played in my education and career. While my research had to do with automobility, it seems that the choices I made, that finally led to this thesis, had a lot to do with aviation. Getting curious? Read on!

One of the first occasion in which I got in touch with transport technology was when I was two years old and on my way to a summer holiday in Spain. I don't remember anything of it, but it is said that I was singing on the airplane. My parents did not own a car, were not looking forward to long journeys by bus or train, and air travel was not too expensive, so our main mode for holiday travel was flying. At least, that is how they rationalized it: I am pretty sure that their (and particularly my father's) fascination for aviation played a large role in their decision. During holidays and weekends we often cycled to the runways of Schiphol Airport, and closely watched airplanes taking off and land.

As I grew up, I stopped singing on airplanes. Instead, as I became more aware of the kind of surrealistic experience flying is, I became more and more stressed when I had to go on a plane. That resulted in the fact that at some point in time I did not want to fly any more, and wanted to keep my feet safely on the ground. This could be a metaphor for the fact that, while my grades had been excellent, I did not want to go to university, but decided to go to a polytechnic (HTS in Dutch). It was fear of flying, loosing touch with the ground. I contemplated studying aircraft operation and maintenance, but then a large airplane crashed less than 10 km from our house in the Bijlmermeer area, apparently due to maintenance failure. I did not want to become responsible for something like that.

So it became Civil Engineering in the end, with a main interest in infrastructure as opposed to buildings. And of course, the picture of the airplane on the highway overpass in the brochure did the trick. At least, it is the only picture I can remember, so it must have had some influence. There I was, with my feet firmly planted on the ground, learning to do a proper job, becoming an engineer! The airplanes gradually disappeared out of sight, while railways were becoming more prominent (they had always been there in the background). During my internship I spent a year at a construction site for railway infrastructure. And after I graduated I joined an engineering company and worked on the design of concrete infrastructure for railways. There are a few structures in the Netherlands I have been involved in.

During that job, a transition started to take place. I became aware of the type of work that colleagues with a university education were doing, and wanted to do the same things. But I wasn't allowed to as a result of my polytechnic background. Furthermore, I found out that the technically best design was usually not the first choice of the decision-makers. What was going on there? You will not be surprised that at the same time I had started travelling by air again. The only way to get to distant places you have always wanted to see, and to the places where Jantinus (who had become my partner) was temporarily living for his job. There was still a lot of stress involved though.

Being able to, since Jantinus was willing to support me financially, I went to university. Again Civil Engineering, the most rational choice since there was not too much bridging involved. Soon, I had to choose a specialisation, which became Traffic and Transport. Unsurprisingly for you maybe, but I needed quite some time to figure that out. I enjoyed following courses again. And of course, I contemplated a minor in aerospace engineering but that did not fit in the tight schedule I had in mind. After doing a capita selecta in Intelligent Transport Systems, I preferred doing my master's thesis with Bart van Arem as a supervisor. He warned me that in that case, the subject had to do with cars, intelligent cars. So that is where the cars came in after the airplanes and the trains.

After graduating I got in touch with Karel Brookhuis and Vincent Marchau, who could offer me a PhD position at the TU Delft, and became my promotor and co-promotor. After a year, Bart van Arem also joined my supervision as a promotor. My PhD subject turned out not to be suitable for people with 'fear of flying', since stable ground was almost nowhere to be found. Fortunately, my fear of flying was slowly deteriorating. I had to fly to go to conferences, so I did. When I was a kid I was scared of looking down to the earth's surface from the aircraft window, especially when the aircraft took a turn. But now I am glued to the window whenever the visibility allows a glance on the surface. The surrealism of flying does not scare me off anymore, instead I love to experience the surrealism, and allow myself to experience it fully. Just like I allowed myself to experience doing research, and not being scared any more about losing touch with the safe ground.

Thank you!

I would like to thank everyone who contributed in any possible way to this research project, and this resulting thesis. Special thanks to my promotors, Karel Brookhuis, Bart van Arem and Vincent Marchau for their valuable input and great support throughout the research project, you have all brought in different knowledge and a different way of looking at the subject, from which I think the complete story has benefited substantially. Furthermore, I would like to thank Bert van Wee and Risto Kulmala for their constructive comments on earlier versions of this dissertation; TNO for offering me the opportunity to hold a workshop at their symposium on Co-operative Vehicle-Infrastructure Systems; Eric Molin, Caspar Chorus, and Erel Avineri for their helpful instructions and comments on the actor and user models; Marion Wiethoff, Linda Steg, Jan-Willem van der Pas, Sven Vlassenroot, Jan-Willem Bolderdijk and Nina Schaap for their comments on the actor questionnaire and/or completing a pilot version of it; Jan Maarten Kroon and Joeri Ponten for supporting me in setting up the user questionnaire and collecting the data; Geoff Dudley for proofreading the thesis; Hester Meijer for coming up with the idea for the cover illustration; Yvonne Servaas for taking my picture on a sunny day; Conchita van der Stelt for her support in the printing of the thesis; and all my colleagues at the Transport and Logistics section of TU Delft, and the Centre for Transport and Society of the University of the West of England for their contributions to my development as a researcher. Last but not least, I would like to thank my family and friends for their ongoing support, especially Jantinus who made me feel more confident in following paths I had never followed before.

All I personally want to say about ADAS deployment is: Get On With It!

Leonie Walta
Amersfoort, March 2011

Contents

1 Introduction

It is believed widely that new technologies in transport will be instrumental in constructing systems of sustainable mobility. Consequently, given that a number of these technologies are available already, why should there be any obstacles to their introduction? For example, new technologies, like Advanced Driver Assistance Systems (ADAS), offer promising, positive effects on traffic safety and traffic flow efficiency. However, the number of vehicles equipped with ADAS is still low. Important actors in the field, such as the automotive industry, public authorities, insurance companies, and users possess the means to increase the deployment rate. The key question is, will they take actions to do so? In turn, this raises the further question of who is the most likely to take action first?

1.1 New technologies for transport problems

Mobility is of vital importance in order to maintain the current levels of welfare and social interaction, and to offer potential for economic growth. However, this general desire for mobility induces serious problems regarding traffic flow efficiency, traffic safety and the environment. This is especially the case in densely populated urban areas, many of which can be found in Europe, such as Île-de-France, Greater London, the German Ruhrgebiet and the Dutch Randstad. With regard to road transport, the vehicle-mileage in Europe has more than doubled over the last four decades (OECD, 2008). In the Netherlands, the time lost in congestion, peak hour travel times, and travel time reliability is at a worse level than that desirable to reach the respective 2020 policy goals (Rijkswaterstaat, 2008a). In addition, while the number of traffic accidents and fatalities is generally decreasing, the European traffic safety goals for 2010 (European Commission, 2001) are not expected to be met before 2012 for the EU-15, and 2016 for the EU-27 (ETSC, 2009a). Furthermore, the current discussion about climate change has increased attention on the environmental impacts of transport. In response to these challenges, new technologies, such as dynamic traffic management, vehicle safety systems and fuel efficient vehicles, have been developed to reduce the major negative impacts of mobility, thus improving the sustainability of the road transport system.

The technical performance of vehicles and infrastructure in road transport has benefited greatly from the technological advances over the past decades, having positive effects on traffic flow, traffic safety, and the environment. Next to vehicles and infrastructure, vehicle drivers are an integral part of the transport system. This means that vehicle drivers make many decisions that ultimately influence the performance of road traffic as a whole, such as choice of departure time, route choice, and choices regarding, for example, speed, acceleration, deceleration, and distance keeping. These decisions are not all equally as efficient from either an individual or a social perspective. For example, the existence of severe congestion in peak-hours, and spare capacity in the off-peak period, reveal inefficient departure time behavior. Similarly, driver impairment (e.g. fatigue, inattention, drowsiness) increases the risk of traffic accidents (e.g. Brookhuis et al., 2001). On the other hand, more efficient driver behavior in congestion, with smaller headways and reaction times, may result in a reduced amount of congestion (e.g. van Driel and van Arem, 2008).

Consequently, influencing driver behavior seems an effective way to decrease the negative consequences of transport substantially. Driver behavior can be influenced by increasing awareness of its adverse effects (e.g. by information campaigns), introducing incentives to stimulate drivers to use the transport system more efficiently (e.g. by road pricing), informing drivers of traffic conditions and optimal behavior in these conditions (e.g. by dynamic traffic management), and supporting the driver in performing the driving task (e.g. by intelligent vehicles). The development of information and communication technologies (ICT) has greatly increased the possibilities to influence driver behavior. Driver support through intelligent vehicles could be the most promising of these possibilities, since driver behavior can be directly influenced, and potentially mandated, by such systems.

In the 1980s and 1990s, the main research effort in the USA and Japan was focused on complete automation of driving in Automated Highway Systems (AHS) (e.g. Tsugawa, 2008; Bishop, 2001). Later on, research efforts in these geographical areas were directed towards support of single driving tasks, as something that could be achieved on a shorter-term basis and against substantially lower costs (Intelligent Vehicle Initiative in the USA, Advanced

Cruise-Assist Highway Systems in Japan). In Europe, the research efforts were already more focused on the support of single driving tasks. These research efforts were coordinated by projects in which research institutes and industry cooperated, starting off with PROMETHEUS, and followed up with multiple research projects in the EU Framework Programs. Systems supporting the driving task are labeled Advanced Driver Assistance Systems (ADAS; Europe), Advanced Vehicle Control Safety Systems (AVCSS; USA), or Advanced Cruise-Assist Highway Systems (AHSRA; Japan), which each has a single, or sometimes multiple, integrated functionalities to support car drivers in their driving task. They include systems that are autonomous, or co-operate with other vehicles and/or infrastructure by exchanging information. Eventually, the complete automation of driving is still considered to be an ultimate goal (AHSRA, 2010; Ehmanns and Spannheimer, 2003; Shladover et al., 2001).

In this dissertation the focus is on ADAS, since driver behavior has a large impact on traffic safety and traffic flow efficiency, and ADAS can have a substantial positive influence on driver behavior. For instance, ADAS are expected to be more effective in the area of traffic safety than other measures (eSafety Support, 2007). Furthermore, they can be implemented on a short-term basis.

Various ADAS have been developed and/or are becoming available for use in real traffic. They can be classified by the part of the driving task they support, and by the level of support they provide to this driving task. Generally, three levels of driving tasks can be distinguished: a strategic level, a tactical level and an operational level (Michon, 1989). The *strategic* level includes the actions of the driver regarding departure time and route. The *tactical* level includes actions of the driver necessary to reach his destination, for example, merging or changing lanes. The *operational* level includes the basic driving tasks, such as speed keeping, lane keeping, and distance keeping. For each of these driving tasks, three levels of support can be specified (e.g. AHSRA, 2010): (1) informing and/or warning, (2) assisting, and (3) complete automation. To illustrate these levels, Intelligent Speed Adaptation (ISA) is used as an as an example. *Informing and/or warning* ISA gives information to the driver on the speed limit and/or a warning to the driver in the case of speeding. *Assisting* ISA actively assists the driver in complying with the speed limit, e.g. by initiating a counterforce on the throttle in the case of speeding that can be overruled by the driver. A *completely automated* or limiting ISA limits the vehicle speed to the current speed limit.

Automation of the driving tasks is least complex for the operational level, and increasingly more complex for the tactical and strategic levels. Currently, only driving tasks at the operational level are most eligible for assistance by ADAS, such as Intelligent Speed Adaptation (ISA), Lane Departure Warning (LDW), and the distance control function of Adaptive Cruise Control (ACC). At the tactical and strategic levels, the driver can currently be supported only by informing and/or warning systems. For example, a Lane Change Assistant, that assists in safe overtaking on highways, and navigation systems (for a comprehensive overview of current ADAS functionalities, see Van Driel, 2007).

Given the different parts of the driving task that are supported, and the different levels of support in that task, the effects of individual ADAS on traffic are also different. Some ADAS are aimed more at increasing traffic safety (e.g. ISA), while others are aimed more at increasing driving comfort (e.g. ACC). In addition to these main effects aimed at by the ADAS, side effects can be expected on traffic safety, traffic efficiency, the environment, and driving comfort.

The effects of several ADAS on traffic safety, traffic flow efficiency, and the environment are being studied in driving simulators, traffic simulations and field operational tests. To illustrate the potential contribution of ADAS to improve traffic performance, the results of some of these studies are presented here[1]. Regarding traffic safety, ISA could reduce the number of accidents by 10 to 36%, depending on the system characteristics, such as level of support (Carsten and Tate, 2005). A combination of ACC and LDW could reduce the number of accidents, with a maximum of 8%, for which the ACC would be predominantly responsible (Alkim et al., 2007a). Regarding traffic flow efficiency, ACC could increase traffic flow efficiency, but this depends on the rate of market penetration of the system, the tuning of the following distance, and type of bottleneck on the road (e.g. VanderWerf et al., 2002; Hoogendoorn and Minderhoud, 2001). A next generation of ACC, Cooperative ACC, which coordinates following distances by wireless vehicle-to-vehicle communication, could increase traffic flow efficiency under all conditions of market penetration (VanderWerf et al., 2002). With regard to the environment, ISA could reduce fuel usage by an estimated 1-8%, depending on the road type, and ACC could reduce fuel usage by 3% (Carsten and Tate, 2005; Alkim et al., 2007a). The effectiveness of intervening systems on traffic safety and traffic flow efficiency is generally higher than informing or warning systems. However, the effectiveness of informing and warning systems can be increased by incentives that reward the driver for safe driver behavior (e.g. Mazureck and van Hattem, 2006). Driver acceptance of such reward policies may be higher than on intervening systems, such as limiting ISA (e.g. van Loon and Duynstee, 2001; Brookhuis et al., 1999).

While these results prove ADAS to be a promising means to decrease transport problems, a few remarks can be made regarding the assumptions made in these effects studies. First of all, ADAS are not yet deployed on a large scale (except for navigation systems) and only some large-scale field trials have been performed (e.g. Rijkswaterstaat, 2008b; Biding and Lind, 2002). As a result, it is necessary to make assumptions in order to generalize results from small-scale field operational tests, driving simulation or traffic simulations. For example, since no real-world accident data from ADAS-equipped vehicles are available, so-called surrogate safety measures (e.g. speed, time to collision) and their relation to accidents are used to approximate potential accident reductions (e.g. Carsten and Tate, 2005). Second, with respect to safety effects, there are many mechanisms that influence safety, which are not always all taken into account in safety effects studies (Kulmala, 2010). Potential effects of ADAS on traffic safety can, for example, be limited due to behavioral adaptation (Brookhuis et al., 2001). The extent to which these effects are limited is still uncertain. Third, it is not likely that probabilities of system failure have been considered, and as such the potential effects may be overestimated. Finally, in many studies, it has been assumed that all vehicles are equipped with ADAS in order to estimate its potential effects. Before such a 100% deployment rate is realized, however, it is highly likely that there will be a mix of equipped and non-equipped vehicles. Since most field studies include a limited amount of cars, it is uncertain how drivers of non-equipped vehicles will react to the driver behavior of ADAS–equipped vehicles, and vice versa. This could influence the effects of intermediate deployment rates.

Consequently, the promising results of studies into ADAS effects justify the attention given to these systems as a means of solving transport problems. Nevertheless, it must be taken into account that there are uncertainties involved in actually achieving these effects.

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[1] Note that these studies have been performed in different countries, which may have influenced the results in case of field operational tests. See e.g. Várhelyi and Mäkinen (2001).

In summary, increasing mobility leads to serious problems with respect to traffic flow efficiency, traffic safety, and the environment. Traditional measures, such as expansion of road infrastructure, and increasing vehicle crashworthiness, are not expected to be efficient enough to substantially reduce these problems. Since driver behavior has an important impact on traffic flow efficiency and traffic safety, influencing driver behavior directly is a promising solution. New in-vehicle technologies, known as Advanced Driver Assistance Systems (ADAS) provide an effective means to directly influence driver behavior. ADAS are expected to have positive effects on traffic safety and traffic flow efficiency. Therefore, they can contribute to reducing the major negative outcomes of increased mobility. However, it is still uncertain whether these effects will actually occur, and how large they will then be.

This dissertation will focus on ADAS as a possible solution towards transport problems.

1.2 ADAS deployment

While different types of ADAS are in different states of development, a number are already available on the market. This mainly involves convenience and safety systems, such as Lane Departure Warning, Adaptive Cruise Control and Blind Spot Warning (Bishop, 2005).
Currently, the diffusion of those ADAS that are on the market is still small, and limited to high-end vehicles. A benchmarking study on deployment of safety ADAS in the European Union (EU) considered four product lifecycle phases: market introduction, growth, maturity, and decline (De Kievit et al., 2008). It focused on the market introduction phase, since all EU countries are still in this phase with respect to this type of ADAS. The results of this study showed that the conditions for ADAS deployment in Sweden, The Netherlands, United Kingdom, Finland, Spain and France – in terms of level of awareness, research program budgets, and duration and level of cooperation among stakeholders, are more favorable than in other countries. However, none of these countries has yet succeeded in a large-scale deployment of ADAS that has significant effects on safety.

The deployment of an innovative technology, such as ADAS, is a stage in innovation development, defined by Rogers (2003) as diffusion and adoption. The process of innovation development generally includes six main stages, needs/problems, basic and applied research, development, commercialization, diffusion and adoption, and consequences (see Figure 1.1).
Figure 1.1 suggests this is a sequential process, which is true with respect to the dependency between the stages, but not necessarily in terms of time. For example, while diffusion of an innovation has already taken off, new research results can lead to the release of a new generation of this innovation.

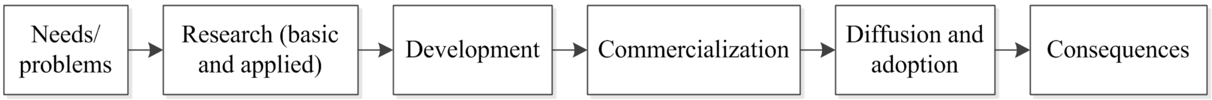

Figure 1.1: Six main stages in innovation development
Source: Rogers (2003)

The deployment of ADAS can be influenced by developments in any of the stages of its development. For instance, *needs* and *problems* can change over time, influencing the extent to which ADAS contribute to fulfill needs and solve problems. Ongoing *research* can lead to more certainty about the performance of ADAS, or to more advanced technology. First, choices during *development* can influence the performance of the ADAS. Second, choices during *commercialization* can influence the user type that will adopt the ADAS. Third, the development of *diffusion and adoption* of ADAS can influence itself by means of the awareness of the existence of ADAS. Finally, the revealed *consequences* of ADAS can positively or negatively influence diffusion and adoption.

1.2.1 The role of actors in ADAS deployment

Influenced by the (technical) performance of ADAS, deployment – or diffusion and adoption – is established through actions of individuals or organizations that have an interest in ADAS. The general term for these individuals and organizations is *actors*, which can be subdivided into *decision-makers* and *stakeholders*. Decision-makers are considered here as the actors that can directly influence deployment; stakeholders as the actors who can only indirectly influence deployment by influencing the decision-makers. In this dissertation, the term actors refers to decision-makers only. Stakeholders are not explicitly considered.

Possible actions of actors that can influence ADAS deployment are funding and coordination of research projects, stimulation of development, facilitation of commercialization, and influencing diffusion and adoption. Funding and coordination of ADAS research has been taking place in Europe through the European framework projects (e.g. ADVISORS, 2010; PREVENT, 2011; SAFESPOT, 2011) and multiple national research initiatives (e.g. the Assisted Driver in the Netherlands, ISA trials in various countries). An example of the stimulation of development is the Grand Challenge, organized by the Defense Advanced Research Projects Agency (DARPA) in the United States, in order to encourage the development of autonomous vehicles. The Grand Challenge involved three contests for autonomous vehicles, two in a desert environment (2004 and 2005), and one in an urban environment (2007). Research institutes and industry were challenged to show their best efforts in vehicle automation. While in the first contest none of the cars actually made it to the finish, the subsequent contests showed that it could be done. However, the huge amount of equipment necessary means that completely automated driving is not yet fit for commercial application (DARPA, 2010). In the Netherlands, a similar event encouraging development of cooperative driving, the Grand Cooperative Driving Challenge will be organized in 2011 (GCDC, 2011). With respect to commercialization of ADAS, a positive business case is a first requirement. Facilitation of commercialization can take place by resolving institutional and technological issues, such as legislation, standardization of technology, and acceptance by stakeholder groups (cf. Hall and Tsao, 1994). The last category of actions here are those that directly influence the deployment of commercially available ADAS in terms of diffusion (i.e. the number of cars equipped with an ADAS), and adoption (i.e. users actually and correctly using the ADAS). These ‘deployment actions’ are the main subject of research in this dissertation.

1.2.2 ADAS deployment as a system of actors’ interactions

In this dissertation, ADAS deployment is defined as the introduction of commercially available ADAS to the market, and increasing the number of vehicles equipped with an ADAS (i.e. the deployment rate). Various actors, that have a certain interest in ADAS deployment, can take actions such as adopting ADAS, stimulating adoption of ADAS, and/or making ADAS available. These actions determine the development of ADAS deployment, with the result that investigating potential actions gives insights into the possible future of ADAS deployment. However, the deployment actions are potentially related to each other. This means that, for a full picture, the interactions between the actors should be included in the investigation. Therefore, this dissertation adopts a view on ADAS deployment as a system of actors’ interactions.

Knowledge about this system of actors' interactions is available at different levels of abstraction. First, knowledge is available on the underlying factors that influence deployment actions, driving forces and barriers, or success and failure factors (e.g. Walta et al., 2005; Feitelson and Salomon, 2004). These factors include, for instance, technical feasibility, expected benefits and costs, and acceptance by stakeholders. Consequently, they give a main indication of the potential success of ADAS deployment. Second, knowledge is available on the positions of actors with respect to ADAS deployment, based on the values taken by the underlying factors. These positions are investigated by assessing preferences or opinions of actors (currently mainly studied for potential users of ISA: Vlassenroot et al., 2007; Molin and Brookhuis, 2007). They give an indication about the potential direction of actors' decisions regarding ADAS deployment.

The next step is to investigate the potential actions of the actors, based on the available knowledge of the underlying factors that influence deployment actions, and the current positions of the actors. In this way, an accurate picture of the system of actors' interactions regarding ADAS deployment can be composed, which provides a general outlook into the future of ADAS deployment, and which can support decision-making actors by showing the consequences of their actions, in terms of the actions of others.

1.2.3 Important actors involved in ADAS deployment

The actor who can make the decision to adopt ADAS is the vehicle owner. Vehicles can be owned by individuals and by companies. In the Netherlands, which is used as a case study in this dissertation, about 70% of the vehicles are privately owned passenger cars. The other 30% consist of company owned passenger cars (10%), and company owned other vehicles (20%; source: Centraal Bureau voor de Statistiek, 2010). In this dissertation, the focus is on the majority of individual private car owners as the main actors in ADAS deployment. It is acknowledged that fleet owners of company vehicles can have a substantial influence on ADAS adoption. However, since their interactions with other actors are expected to be different, they should be considered as a different case.

Which actors have an interest in, and can directly influence, deployment of ADAS? Table 1.1 shows an overview of important actors and stakeholders that are involved in ADAS deployment, as defined in the ADVISORS project (ADVISORS, 2001). These actors were selected based on their wide knowledge of the traffic system, and/or their great influence on ADAS deployment.

Table 1.1: Important actors and stakeholders involved in ADAS deployment
Source: ADVISORS (2001)

Group	**Actors**
Users	Consumer organizations, private driver organizations, public transport organizations, trucking associations, taxi associations
Industry	System manufacturers, vehicle manufacturers
Authorities/administrations	EU, governments, policy makers, transport ministries, road authorities
Traffic/transport operators	Fleet managers, road operators
Other	Insurance companies, car rental companies, researchers and consultants

These actors can all, directly or indirectly, influence the deployment of ADAS. Possible actions they can take are installing ADAS in vehicle fleets, increasing awareness among potential users, influencing user and public opinion, stimulating deployment by financial incentives, and/or even make ADAS obligatory equipment by legislation. Actors each have a specific set of options to influence deployment at their disposal, as a result of which their influence can be different. Actors with a direct influence on ADAS deployment are considered to be able to make decisions that directly result in deployment, such as making ADAS standard equipment in vehicles (automotive manufacturers). Actors with an indirect influence on ADAS deployment (i.e. stakeholders) are only able to take actions that could indirectly lead to deployment, such as increasing awareness and influencing opinions (consumer organizations). These actions influence the deployment actions of actors that have a direct influence on ADAS deployment. Despite the importance of increased awareness and changed opinions, in this dissertation the focus is on the actors that directly influence ADAS deployment.

Applying the above definition of direct and indirect influence to the actors mentioned in Table 1.1, the actors with direct influence are vehicle manufacturers, EU, governments, fleet managers, insurance companies, and car rental companies. Since the focus is on individual private vehicle owners, fleet managers and car rental companies will not be included. Henceforth, the remaining actor groups that directly influence ADAS deployment are labeled public authorities, the automotive industry, and insurance companies.

In summary, while some ADAS have been introduced to the market, there is, as yet, no large scale deployment. Consequently, it is the potential deployment of ADAS that will be studied here. In this dissertation, ADAS deployment is considered as a system of actors' interactions. Current knowledge about this system includes factors underlying the actions of actors, and current actor positions. Based on this knowledge, the subjects studied are the potential actions of public authorities, the automotive industry, insurance companies, and the adoption by individual private car users. These actors are all expected to directly influence ADAS deployment.

1.3 Current knowledge on actors' decisions regarding ADAS deployment

The importance of different actors' actions in ADAS deployment was previously underlined in the period that Automated Highway Systems were considered (e.g. Hall and Tsao, 1994). Accordingly, research took place to determine the main interests of these actors. These interests, however, do not make it clear whether the actors can be expected to take actions to influence ADAS deployment. In addition, since there is uncertainty about the real-world benefits of ADAS for every one of the actors involved, it is not yet obvious who is going to take action with respect to ADAS deployment (e.g. van Arem et al., 2004).

With respect to current empirical knowledge on actors' actions regarding ADAS deployment, the following questions are most relevant:

1. Which actors were investigated?
2. Which options for taking action were considered?
3. Which actions are the actors expected to take?
4. How do these actions depend on actions of other actors?
5. What is the importance of decision criteria?

These questions are answered in this section, based on the literature review.

1.3.1 Which actors were investigated?

The actors that are at the center of this dissertation (public authorities, the automotive industry, insurance companies, and users) each have their own decision framework in terms of the options they can choose from, in order to meet their own objectives or needs. For instance, the automotive industry is usually profit driven. Consequently, they will consider equipping a car with an ADAS, or with other equipment such as air-conditioning, that makes a car attractive for potential buyers. Public authorities, on the contrary, are driven by public policy objectives, and will compare ADAS against other road safety measures (e.g. enforcement, infrastructure measures).

Previous research on decision frameworks for ADAS has been limited to users and public authorities. Specific *user studies* regarding ADAS deployment include user-related options, described by the characteristics of an ADAS with respect to user functionalities (e.g. Ng et al., 1996; Marchau et al., 2001). *Multiple actor studies* include public authorities and some other actors, predominantly automotive industry and users (insurance companies are rarely considered). The purpose of these studies was to assess the positions of these actors on public authority actions. This becomes explicit in studies in which sets of alternatives are included, that are mainly available to public authorities. When alternative technologies are studied, ADAS are regularly compared to infrastructure measures that can only be applied by public authorities (e.g. Wiethoff et al., 2006). Similarly, when alternative deployment options for ADAS are studied, often only sets of options are considered that are exclusively available to public authorities, such as policy options for ISA deployment (PROSPER, 2004). In essence, this means that the other actors are mainly considered as stakeholders, whose opinion needs to be taken into account in ADAS decision-making (e.g. Macharis et al., 2004). The focus on public authorities' actions is probably due to the fact that for most traditional and modern solutions for transport problems (e.g. new road infrastructure, dynamic traffic management, road pricing) public authorities, on a local, national or supranational level, are the major decision-makers. Complementing this focus on the traditional role of public authorities, it is also possible that public authorities are seen as the necessary actor to accelerate ADAS deployment.

In summary, previous single actors studies focused on users' or public authorities' actions. In multi-actor studies the emphasis is on public authority's actions, including the opinion of other actors as if they were stakeholders.

1.3.2 Which options for taking action were taken into account?

Two types of options for taking action with respect to ADAS deployment were considered: alternative technology options, and alternative deployment options.

Studies including alternative technology options focus on determining a suitable technological solution for transport problems, such as different types of ADAS (e.g. ISA, ACC) and different levels of support (e.g. informing, assisting, automation) (e.g. Macharis et al., 2004; Marchau et al., 2001; Lathrop and Chen, 1997). They give insights into the preferences of actors regarding characteristics of the alternative technology options, such as costs, impact on safety, and impact on congestion. For users, the characteristics of alternative ADAS options refer to individual benefits and costs of having the ADAS. For other actors, the characteristics of alternative ADAS options often refer to the benefits and costs of the full ADAS potential, while in fact the benefits and costs depend on the deployment rates that will be reached, and the type of deployment actions used. As such, the impact of ADAS options, for actors other than users, cannot be truly compared to other technology options without reference to the expected deployment rate.

Studies including alternative deployment options focus on determining the most appropriate deployment option for a single ADAS, considering deployment options of public authorities only, such as tax reductions and mandating (e.g. PROSPER, 2004); or deployment options of different actors, such as discounts by the automotive industry, premium reductions by insurance companies, and awareness campaigns by public authorities (e.g. Alkim et al., 2007b). In doing so, they give insights into the preferences of actors regarding certain deployment actions.

In summary, the focus of current research has been on the evaluation of alternative technology options (including ADAS). In contrast, alternative deployment options for a single ADAS have been evaluated less often. Consequently, integrating ADAS technology options and deployment options makes ADAS options more comparable to other technology options.

1.3.3 What actions are the actors expected to take?

With regard to ADAS deployment, knowledge on actors' interactions is currently limited to the attitudes of actors and their perspectives on ADAS as a promising technology to increase comfort, safety, and traffic flow efficiency. Many studies focus on Intelligent Speed Adaptation (ISA). In this context, the impacts of ISA can be interpreted as positive, as well as negative, by different actors. *Users* generally prefer to receive only speed limit warnings (e.g. Piao et al., 2004; Marchau et al., 2001), depending on the type of roads. For rural roads and motorways, users prefer warning ISA, while for residential areas, they prefer physical limitation of vehicle speed (e.g. Cuypers, 2004; Várhelyi and Mäkinen, 2001). The acceptability of assisting ISA by users is relatively high (e.g. Vlassenroot et al., 2007; Várhelyi and Mäkinen, 2001). *Public authorities* generally have a preference for assisting or limiting systems (e.g. ADVISORS, 2002), which is related to their perceived positive effects on traffic safety. In contrast the European *Automotive Manufacturers' Association* (ACEA), states that it prefers warning systems, while ACEA is willing to cooperate on assisting systems, but is heavily opposed to deployment of limiting ISA (Reinhardt, 2004).

While it can be expected that the actions that actors are going to take will be in line with these positions, these actions are not explicitly considered in current research. First, the actor positions concern ADAS technology, and not ADAS deployment options. Second, the prevailing methodology used is aimed at evaluating possible decisions in the case of multiple objectives, and finding the alternative that performs best with respect to these objectives (e.g. Levine and Underwood, 1996; Lathrop and Chen, 1997; Macharis et al., 2004). In current studies using this methodology, alternative technology options are compared in order to find the best performing option with respect to the objectives of the actors. Conclusions regarding the expected actions with respect to ADAS deployment cannot be drawn from its results. Another methodology that is applied in ADAS deployment research involves the estimation of preference or choice models, based on empirical data regarding the rating or choice of ADAS options. These models give insights into the most likely actions of the respondents, given certain characteristics of the ADAS options. As far as is known, this has only been applied to potential users of ADAS technology, and not to public authorities, the automotive industry, and insurance companies (e.g. Ng et al., 1996; Marchau et al., 2001).

In summary, while we have knowledge about the positions of actors regarding ADAS deployment, it is not yet clear how they are expected to act. The methodologies applied in previous multi-actor studies do not seem suitable to answer that question.

1.3.4 How do these actions depend on actions of other actors?

Given the fact that there is little knowledge about expected actor deployment actions regarding ADAS, it is not surprising that the knowledge about the interactions between these actors is also limited. As we have seen from the different positions of the actors on Intelligent Speed Adaptation, these interactions are relevant to the study of future deployment. For example, if public authorities aim at deployment of assisting ISA, they will have to influence the automotive industry, which might otherwise only offer a warning system to the market. What type of influence is to be applied, and how will the automotive industry react? In the case of coordinated deployment, in which an agreement between the actors is made, decision analysis methods that come up with an overall preferred alternative can be applied (e.g. Marchau et al., 2002; Macharis et al., 2004). Other efforts for coordinated deployment of ADAS, or other transport technologies, include gaming simulations, aimed at deriving deployment plans (e.g. Van Noort, et al., 2007; Reed et al., 1997). However, the type of interactions included in gaming simulations is different from the type focused on here, given the coordinating nature of the game. In addition, the interactions are not explicitly studied.

In summary, a system of actors’ interactions in ADAS deployment, as defined in this dissertation, has not yet been studied for ADAS deployment. Current research efforts are focused on actor coordination.

1.3.5 What is the importance of decision criteria?

Decision criteria are specifications of actor objectives. The extent to which these criteria are satisfied by performing a certain action is presumed to influence the probability that this action is actually taken. Table 1.2 shows the top 5 ranking of decision criteria included in four different studies, that all considered deployment of a new technology in transport. They each used different criteria, related to the particular objectives that could be reached with the specific technology.

Table 1.2: Importance of decision criteria (top 5)

Source	Systems	Authorities	User	Industry
Lathrop and Chen (1997)	AHS	Safety Capital cost Incrementability Infrastructure Institutional attractiveness	Safety Travel time savings Flexibility System integrity Travel time predictability	Liability Customer objectives Marketability Image Incrementability
ADVISORS (2002)	ADAS	Third party safety Environment Network efficiency Acceptance Public expenditures	Driver safety Travel time Full user cost Driver comfort	Technical feasibility Acceptance
Levine and Underwood (1996)	FAST-TRAC*	Collision reduction Energy savings Emission reduction Reduction in driving difficulty Individual travel time reduction		
Marchau et al. (2002)	ISA	Reduction of accidents Less penalties for speeding Increased driving convenience General desirability Less fuel consumption/environmental load		

* Integration of adaptive traffic controls and real time route guidance

In the four studies highlighted in table 1.2, safety or accident reduction was ranked as most important in all cases, except for the industry. Especially for the user, safety outweighed other outcomes by far. However, safety is not present in the top 5 criteria of the industry, and it was not even included as a criterion in the ADVISORS study.

With regard to safety, some interesting differences between studies occurred, that might be due to the methodology or the choice of decision criteria. Taking ISA as an example, methods to support decision-making based on decision criteria came up with the most safety-enhancing ISA type as the most preferable, i.e. assisting or limiting. When asked directly, users and other actors preferred less intervening options, informing ISA and voluntary use of the system (e.g. Marchau, 2001; PROSPER, 2004). These findings may suggest that ‘driving freedom’ – in this case freedom of choice regarding driving speed – plays a more important role in preferences for ISA types than safety. On the other hand, actors may also expect the effects of ISA to be different than research results or experts indicate. For example, user perception of the level of safety was found to be higher for warning ISA than for intervening ISA (Molin and Marchau, 2004).

In summary, for public authorities and users safety is reported to be the most important decision criterion for ADAS deployment, but differences in the results of studies raise questions about the relation between commonly used decision criteria and actual deployment actions.

1.3.6 Conclusions

From this literature review a number of knowledge gaps were identified with respect to actors, alternative courses of action, expected actions, interactions and decision criteria:

Actors
Since the focus of current research is on users’ and public authorities’ decisions, little is known about the decisions of the automotive industry and insurance companies;

Alternative courses of action
The impacts of ADAS technology options (e.g. ISA, ACC) depend on the deployment rate, which in turn depends on the deployment actions taken (e.g. tax reduction, awareness campaigns). In comparison with other technology options, such as infrastructure adaptations, ADAS deployment rates of 100% are usually considered, which may give a too optimistic account of the (short term) impacts of ADAS. Moreover, even when the deployment rate is 100%, it is unlikely that there is 100% user compliance;

Expected actions
While we have knowledge about the positions of actors, it is not yet clear what the outcomes will be in terms of taking actual deployment actions;

Interactions
The interactions between actor decisions, as in the system of interactive decisions assumed in this dissertation, has not yet been studied for ADAS deployment;

Decision criteria
Differences in the results of ADAS studies raise questions on whether the decision criteria considered in multi-criteria analyses represent the criteria based on which actual decisions are taken.

1.4 Current methodology to study multiple actor decision-making

Current knowledge on actors' actions regarding ADAS deployment is not yet sufficient to analyze actors' interactions in ADAS deployment. This is mainly due to the type of methodology that is currently used. As a result, the next question is which type of methodology is suitable for investigating actors' interactions in ADAS deployment?

This dissertation aims to study the system of interactive actor decisions regarding ADAS deployment, in order to derive the influence of potential actor decisions on the decisions of the other actors, and the resulting effect on the number of vehicles equipped with an ADAS. To that end, multiple decision scenarios (i.e. combinations of decisions) need to be explored.

Drawing upon a common base of decision-making theories, several models of multiple actor decision situations have been developed, often in connection with a specific methodology to perform investigations on the model. Most methodologies use *autonomous actor decision* models, or *group decision* models. These models are introduced below, in a simplified form, showing the relations of the actors to each other, and to the system outcomes they can influence (in this case, the deployment rate). For each of the models, examples are referred to of methodologies that perform investigations on them. These methodologies can be divided into methodologies that aim to *derive the most optimal course of action*, and methodologies that aim to *derive the most expected course of action*.

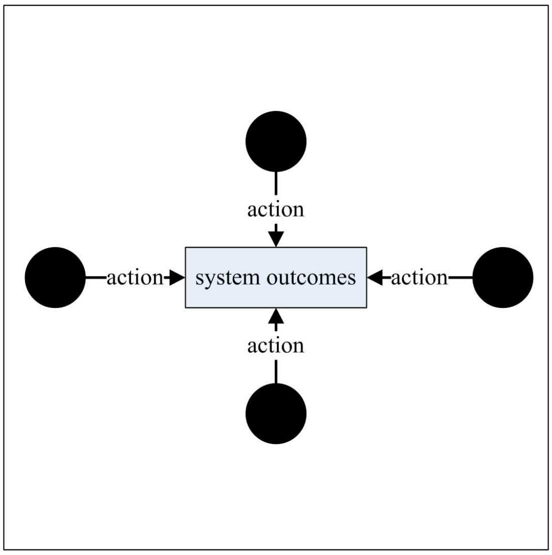

Figure 1.2: Autonomous actor decisions

The model in Figure 1.2 illustrates actors as autonomous decision-makers, who can each influence the system outcomes with their actions. They make their decisions to take action based on the current system outcomes, and the outcomes they expect to result from their actions. Each of the actors has certain interests in the system outcomes. A possible methodology to derive the most expected course of action is Agent Based Modeling, in which agents (actors) each have their own sets of goals and alternative decision options, and are programmed to apply these options to reach their goals, based on a rational goal-seeking behavior (e.g. Jennings, 2000).

The use of this model gives insights into the potential behavior of the system as a whole. Possible methodologies to derive the most optimal course of action are applications of game theory (Von Neumann and Morgenstern, 1944), such as conflict analysis (e.g. Fraser and Hipel, 1984). In this way, the system outcomes as a result of all possible combinations of actor actions are assessed. The optimal combination of actor actions can be determined, based on a certain rule that depends on the type of game.

The model in Figure 1.3 illustrates actors as group decision-makers, who have to jointly come up with an action to influence the system outcomes, each being possibly interested in different types of outcomes. An example of such a situation is when multiple actors in ADAS development have to agree upon a certain standard. Possible methodologies to derive the most optimal course of action can be found in the field of Multi Criteria Analysis, which is basically aimed at identifying preferred actions, given the objectives of the decision-maker. Some methods are available that take into account the criteria and trade-offs of multiple actors, for example, Multi Actor Multi Criteria Analysis (Macharis, 2005) and Multi Issue Actor Analysis (Bendahan et al., 2003). The main advantage of these methods is that they can present the positions and views of actors in a clear and understandable way, and as such they are reliable tools for decision-makers. In order to identify the preferred alternative group action, the preferences of multiple actors are usually averaged. Other possible methodologies can be found in the field of Actor Network Analysis (see Hermans, 2005 for an overview), which includes methodologies based on voting. The methods on the network level are based on the notion that actors depend on other actors to reach their objectives, and as such most interaction between the actors takes place before actual decision-making.

A possible methodology to derive the most expected course of action is to assess the preferences of actors for a certain action, given the preferences for this action of other actors involved in decision-making. This can be done using Stated Preference modeling, and was applied by Molin (1999) to assess the preferences of household members for housing alternatives including the opinions of the other household members.

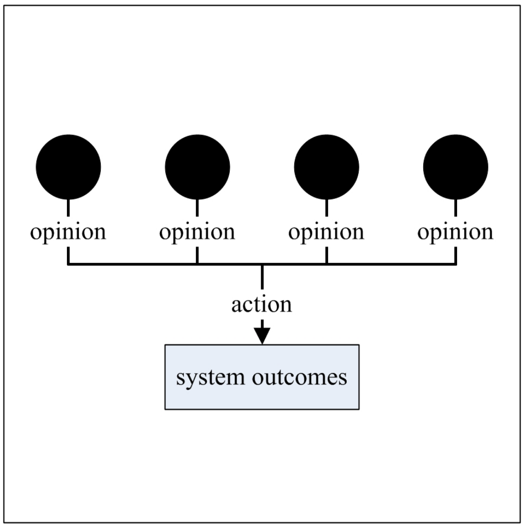

Figure 1.3: Group decisions

To what extent are the models of autonomous actor decisions and group decisions, and their connected methodologies, applicable to the system of actors' interactions regarding ADAS deployment? To answer this question, a simple model of the considered system is presented in Figure 1.4. In this model, there is one main actor through which the system outcomes (the deployment rate) can be directly influenced, which are the users/car buyers. The other actors are able to influence the users by applying deployment options. The main difference with respect to the other models is that user actions are explicitly included as an entity in the model. The result is that most of the actors cannot directly influence the system outcomes, only through the decisions of the user. An exception to this rule is when actors force users to adopt an ADAS.

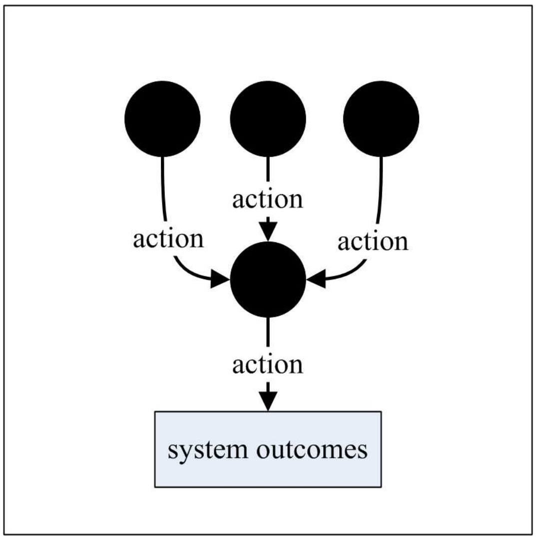

Figure 1.4: Interactive decisions

This type of system is rarely studied, which means the first step is to develop a conceptual model based on existing theories about actors' interactions and decision-making.

Furthermore, since a methodology is usually connected with the model type, a suitable methodology needs to be identified. In order to explore and compare multiple possible scenarios, in which actors take different actions, a mathematical representation of this conceptual model is needed. Empirical data are also required to estimate the mathematical model for relevant ADAS deployment scenarios, and to validate the model structure. To collect these data, the above-mentioned Stated Preference approach for group decision-making, applied by Molin (1999), has potential. Instead of preferences of other actors, the actions of other actors could be included in the alternative decision options, and instead of preferences, choice probabilities could be measured. Furthermore, there are no revealed preference data available as yet, and empirical data are necessary to verify the model structure assumed in this dissertation.

In conclusion, there is a need to develop a conceptual model of the system of actors' interactions in ADAS deployment, to develop a mathematical representation of this model, and to determine a methodology to analyze actor decision interactions.

1.5 Objective and research questions

1.5.1 Objective

To develop a mathematical model of actors' interactions in ADAS deployment, and apply this model in order to explore the effects of expected actor actions on the probability that users will buy an ADAS on their next new car.

The actors included are public authorities, the automotive industry, insurance companies, and users (car buyers). In this dissertation, users are regularly referred to separately. On these occasions, the term 'actors' refers to public authorities, the automotive industry, and insurance companies only.

Ideally, the objective would be to explore the effects of expected actor actions on the deployment rate of ADAS. Since the effects on the deployment rate are not directly measurable, the probability that users will buy and ADAS is used as a proxy.

ADAS can be deployed by equipment of new cars and/or existing cars (i.e. retrofitting). Systems like ACC and LDW are currently introduced in new cars only, since they need to be integrated with other systems in the car. Consequently, this dissertation focuses on the equipment of new cars with ADAS.

1.5.2 Research approach

This dissertation adopts a view on ADAS deployment as a system of actors' interactions. In order to explore potential ADAS deployment, a model of this system is required. Before defining a *conceptual model* of this system, first some *preliminary explorations* are made in order to increase the knowledge on actor positions, their deployment options, and their decision criteria. This conceptual model is then translated into a *mathematical model*, in order to be able to perform explorations with it. This is a stochastic model, defined by the probabilities that each of the actors takes a certain action, given the actions of the others. A *methodology* is developed to estimate the parameters of this mathematical model for the *deployment scenarios* (e.g. combinations of actors' actions) to be explored. The outcomes of two *empirical studies* – one collecting data on the interactions between public authorities, automotive industry, and insurance companies, and one collecting data on the reactions of users on these actors' deployment actions – are used to estimate the model parameters. Finally, the estimated mathematical model can be used to *explore deployment scenarios*, their probability of occurrence, and the probability that users will buy an ADAS on their next new car as a result of the deployment scenario. This approach is summarized in Figure 1.5.

This leads to the following research questions to be answered in this dissertation.

1.5.3 Research questions

1. *What mathematical model can describe the system of actors' interactions in ADAS deployment?*
   This research question addresses the need for a model of the system of interactive actor decisions in ADAS deployment. The following two sub-questions involve building a conceptual model, and translating it into a mathematical model.

   a. *What conceptual model can describe the system of actors' interactions in ADAS deployment?*
      A conceptual model is defined, based on existing theories and frameworks on decision-making with respect to innovations. This conceptual model defines the relations between the actors in ADAS deployment, and how they make decisions as individual actors. The theoretical framework leading to the model is presented in Chapter 3.

      Two preliminary actor studies on ADAS deployment were performed at the beginning of this research project, in order to increase knowledge on actor positions, their deployment options, and their decision criteria. The results of these studies, and particularly the reflection on these results, have led to valuable insights that have influenced the theoretical framework and methodology used in this research project. The outcomes of these studies are discussed in Chapter 2.

   b. *How can this conceptual model be described in mathematical expressions?*
      A stochastic model is used to describe deployment scenarios (combinations of multiple actor actions), and their probability of occurrence. To describe the individual actor decisions, utility models are used, in which a distinction was made between the decisions of users and those of the other actors. The mathematical models are discussed in Chapter 4.

2. *How can the mathematical model of actors' interactions in ADAS deployment be estimated?*
   This research question addresses the need to identify a methodology designed to estimate the mathematical model of actors' interactions in ADAS deployment. The methodology chosen to estimate the model is based on stated preference modeling of the individual actor decisions, integrating the decisions of other actors as attributes in alternative deployment scenarios. This enables the analysis of the actors' interactions. Chapter 4 explains the methodological choices, and gives a detailed outline of the research approach.

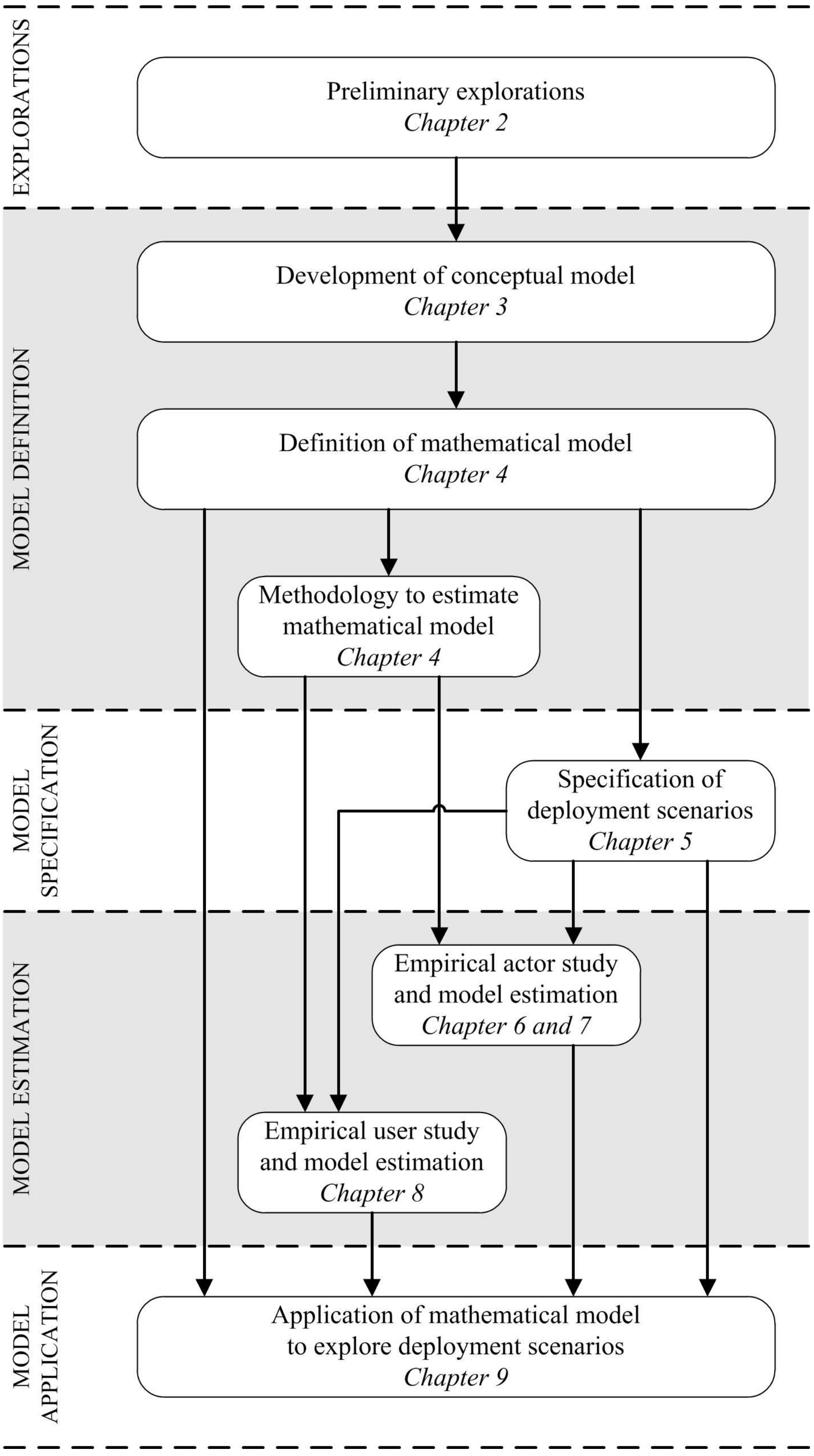

Figure 1.5: Research approach

3. *What is the probability that users will buy an ADAS on their next new car, based on the application of this model?*
   This question involves applying the model to potential cases of near-future ADAS deployment. The three sub-questions involve the specification of relevant decision scenarios for near-future ADAS deployment, the estimation of the probability of potential actor decisions, and decision scenario simulations to analyze the probability that a new car will be equipped with an ADAS.

   a. *Which potential actor deployment actions, and which ADAS, are relevant, given the current state of ADAS deployment?*
      A number of ADAS that are eligible to deployment in the near future were defined to be included in this research project: a Speed Assistant, a Congestion Assistant and a Safe Driving Assistant. Furthermore, a number of potential actions are included that each of the actors can take to influence ADAS deployment (i.e. deployment options). These include a ‘do nothing’ option, an option stimulating user adoption (ADAS as optional equipment, tax reduction, and optional ADAS with premium reduction), and an option forcing user adoption (ADAS standard equipment, mandatory ADAS, and standard ADAS with premium reduction). This “stage setting” is discussed in Chapter 5.

   b. *What is the probability that an actor takes a certain ADAS deployment action, given the deployment actions of other actors?*
      For each of the actors included in this research project, models were estimated that describe the probability that they will take a certain deployment action, given a type of ADAS, and the deployment actions of other actors with respect to that ADAS. The data to estimate these models were collected by means of two surveys, one directed to respondents from public authorities, the automotive industry, and insurance companies, and one directed to car users only. This distinction was made since the types of actions that can be taken by the user differ from the types of actions that can be taken by the other actors. Users can choose to buy or not buy an ADAS, while the other actors have multiple options that can influence the user to buy or not buy an ADAS, or even to force user adoption of ADAS. The setup and results of the actor survey are discussed in Chapters 6 and 7, and those of the user survey in Chapter 8.

      In addition to using the individual actor and user decision models in order to provide data for simulations with the overall model, they were also used to validate the structure of the conceptual model with respect to the relations between the actors. This validation is discussed in the conclusions sections of Chapters 6 and 8.

   c. *What is the probability that users will buy an ADAS on their next new car, given the deployment actions of the actors?*
      The stochastic model of deployment scenarios (question 1.b) was applied to simulate different combinations of actions by public authorities, the automotive industry, and insurance companies (i.e. deployment scenarios), as a reaction to several starting conditions. These starting conditions included scenarios in which all actors do nothing, and also in which one actor is taking action. For each of these starting conditions, the probabilities that certain deployment scenarios will occur were determined, using the actor models. The reactions of the users to these

deployment scenarios, in terms of the probability that they will buy an ADAS on their next new car, can be determined based on the user model. In summary, this leads to knowledge about the effects of expected actor actions on the probability that users will buy an ADAS on their next new car. Using the different starting conditions, the effects of single actor decisions on ADAS deployment are explored. The results of the simulations are discussed in Chapter 9.

The overall conclusions of this research project are discussed in Chapter 10.

1.5.4 Scientific relevance

This dissertation focuses on the development of a mathematical model of actors' interactions in ADAS deployment, based on a conceptual model of a system of actor interaction in ADAS deployment. In addition, a methodology is developed to estimate the model and to apply the model to explore different deployment scenarios (i.e. combinations of actors' deployment actions), based on existing methodology. The approach to study ADAS deployment, as a system of interactive actor decisions, is an extension of current deployment studies, which predominantly make an in-depth analysis of the actors' positions.

ADAS deployment can be viewed as a system of actors' interactions, since it is the result of (interdependent) deployment actions of multiple actors with respect to ADAS. To study the potential behavior of this system, and its outcomes regarding ADAS deployment, a model of this system is needed. Currently, there is no suitable model available that describes the mutual relations between the deployment actions of important actors – public authorities, automotive industry, and insurance companies – and the relation of their deployment actions with the adoption decision of the user/car buyer, influencing the deployment rate of the ADAS. Furthermore, current methodologies to investigate multiple actor decisions are based on models of different types of systems than the one considered here. The main difference is in the types of relations between the actors and the user.

1.5.5 Social relevance

This dissertation investigates the responses of actors to each others' deployment actions regarding ADAS, and the reaction of the user to these deployment actions in terms of adoption (i.e. buying an ADAS on their next new car). A model of actors' interactions in ADAS deployment is provided with which the outcomes of various deployment scenarios (i.e. combination of actors' deployment options), in terms of the user reaction, can be explored. This knowledge supports decision-making regarding ADAS deployment actions. Consequently, it contributes to ADAS deployment in general, and eventually to solutions for the problems arising from a high level of mobility.

Improvements in traffic safety and traffic flow efficiency are highly desirable, as a result of the high level of mobility in countries like the Netherlands. The impact of ADAS on traffic safety and traffic flow efficiency are promising, but they are not yet deployed on a sufficient scale to take effect. The deployment of ADAS requires actions to be taken by actors – public authorities, automotive industry and insurance companies. Generally, these actors will take a deployment action based on the impact they expect to result from this action, and as such, knowledge about these impacts is essential to decide which actions to take. In ADAS deployment, the impacts depend on user adoption of the ADAS. User adoption can be influenced by the deployment actions of multiple actors. This means that, in order to decide which action to take, actors need to be informed of the influence of their action on user adoption. Furthermore, they need to be informed about the deployment actions of other actors as a reaction to their deployment action, and the influence of these deployment actions on user adoption. Current knowledge regarding user adoption of ADAS is limited to the preferences of users for different types of ADAS. Knowledge on deployment actions of actors is currently limited to the positions of actors with respect to ADAS technology.

1.6 Case study: The Netherlands

In order to minimize complexity in the empirical studies, it was decided to focus on a single country as a case study. This means that it is not necessary to include national actors of multiple countries, whose organization and opinions may differ substantially. Since this research project was funded by the Transumo research program, which focused on sustainable solutions for transport in the Netherlands, the choice of the Netherlands as a case study is obvious. Moreover, the Netherlands is, among other European countries, an interesting case with respect to the urgency of the transport problems. This means that, because much attention has already been paid to ADAS deployment in the Netherlands, actors are well informed about ADAS.

The Randstad area, a densely populated urban area in the West of the Netherlands, has a very high rate of traffic demand versus the provided road capacity, when compared to similar areas in North Western Europe like the Ruhrgebiet (KiM, 2008). The societal costs of transport problems in the Netherlands are 18-23 billion euros per year, of which approximately 60% are due to traffic accidents, 25% to environmental damage, and 15% to congestion (Van Mourik, 2008). Emissions of road traffic contribute to 45% of national CO emissions, 27% of national NO_x emissions, 19% of national noxious dust emissions, and 17% of national CO_2 emissions (source: Centraal Bureau voor de Statistiek, 2010). The time lost in congestion per vehicle has been continuously increasing over the last decade, and almost doubled since 1995 (Van Mourik, 2008). Finally, the number of fatal traffic accidents has been decreasing – around 2% per year since 1972 – as well as the fatal accident risk per vehicle kilometer (V&W, 2007), but traffic accidents are still a major drawback of mobility.

The Netherlands is among the seven countries that currently perform best in initiating deployment of ADAS (De Kievit et al., 2008). However, deployment actions, performed by public authorities, have up to now been limited to the organization of demonstrations and pilot projects. In 1998, a demonstration of Automated Highway Systems was held in Rijnwoude, at the opening of a new stretch of road. It featured vehicles equipped with lateral and longitudinal guidance, and the platooning of these vehicles. In 2005, as part of the Dutch national road authority’s innovation project “Roads to the Future”, a demonstration was held in Lelystad. A large number of ADAS were demonstrated, including systems still in R&D and systems that were already introduced to the market. Furthermore, several ADAS were tested in pilot projects, including Intelligent Speed Adaptation in a residential area in Tilburg (AVV, 2001), Lane Departure Warning Assistance for trucks (AVV, 2003) and the combination of Adaptive Cruise Control and Lane Departure Warning for private vehicles (Rijkswaterstaat, 2007). More recently, five types of crash avoidance systems were tested in the Netherlands in a pilot with 2,400 trucks (Hogema, 2009).

A focus on the Netherlands as a case study does not mean a focus only on Dutch national actors. Cars sold in the Netherlands are almost exclusively produced by the automotive industry outside the Netherlands, so it is a necessity to include the foreign automotive industry. Furthermore, next to national authorities, EU authorities can also influence the deployment of ADAS. Since the empirical studies are concentrated on one country, the mathematical model estimated based on the outcomes of these studies is not expected to be applicable to other countries. However, that does not necessarily hold for the underlying theoretical framework. The conditions under which the theoretical framework can be applied to other countries are discussed in Chapter 10.

1.7 Conclusions

The current level of traffic demand is exceeding the infrastructure supply in densely populated areas, such as the Randstad area in the Netherlands. This leads to problems in terms of traffic safety, traffic flow, and the environment. New technologies, such as Advanced Driver Assistance Systems (ADAS), are promising means to help overcome these problems. To be effective, ADAS need to be installed in a substantial number of vehicles. The development of the deployment rate of ADAS depends on the deployment actions of relevant actors – public authorities, the automotive industry, insurance companies, and users. Current knowledge about the actors with respect to ADAS is focused on public authorities and users. They have been asked to evaluate alternative technologies, but rarely to evaluate alternative deployment options for a single technology. Their positions regarding ADAS are fairly well known, but it is uncertain what the relation is between these positions and the deployment actions these actors can be expected to take. As a consequence, the potential interactions between the actors’ deployment actions have also yet to be studied. Finally, the influence on actual decisions of expected impacts on decision criteria is not yet clear. This dissertation addresses these knowledge gaps. ADAS deployment is viewed as a system of actors’ interactions, of which a mathematical model is developed in order to explore different decision scenarios. Empirical data on the relation between deployment actions of public authorities, the automotive industry, insurance companies and users is used to estimate the model. The model is applied to provide insights into the potential success of ADAS.

2 Preliminary explorations of actor preferences regarding ADAS deployment

How do actors evaluate ADAS and ADAS deployment options? How do these evaluations depend on criteria with respect to safety, cost, environment, etc? Two workshops, aiming to derive actor preferences regarding safety measures in road transport, served as preliminary explorations for specifying the investigations covered by this dissertation. The first workshop was held in Amsterdam, April 6, 2006, during the Intertraffic conference, as part of the EU 6th framework project IN-SAFETY. The second workshop was held in Eindhoven, March 28, 2007, during the TNO symposium on Co-operative Vehicle-Infrastructure Systems, and was part of the Transumo project Intelligent Vehicles. An evaluation of these workshops has led to the insight that instead of an approach that focuses on public authorities' deployment actions, an approach that studies multiple actors' actions better fits the case of ADAS deployment.

2.1 General approach in the workshops

The main assumption in both the Amsterdam and the Eindhoven workshops was that public authorities have the chief responsibility with respect to problems of traffic safety, traffic flow efficiency, and the environment. The workshops focused on the use of Advanced Driver Assistance Systems (ADAS) already available on the market to address these problems. Table 2.1 shows an overview of ADAS, their main application areas, and if, and how, they are cooperative, together with what their deployment stage was in 2006 (the relevant date for the workshops). It can be concluded from this table that the systems that are already on the market are merely effective on individual driver safety and/or driving convenience. Since the current potential of ADAS to solve transport problems focuses on increasing traffic safety, this was the area of interest in the workshops. Substantial effects on traffic flow are only expected from the deployment of a next generation of ADAS, using vehicle-to-vehicle, or vehicle-to-infrastructure, communication (Bishop, 2005). Apart from the necessary establishment of a communication standard, systems that enhance traffic flow need a large deployment rate to become effective (e.g. VanderWerf et al., 2002).

In the first workshop, in-vehicle (ADAS) alternatives were compared to infrastructure, together with co-operative vehicle-infrastructure alternatives designed to increase traffic safety, while the second workshop focused on a number of safety-enhancing ADAS only.

It was decided to organize workshops instead of surveys since a secondary goal, next to collecting data for research, was to increase awareness and interaction among key actors in traffic safety and ADAS, in order to stimulate problem solving. A disadvantage of using a workshop to collect data is that all participants have to be gathered at the same place at the same time. Furthermore, single participants could dominate the discussion, and it requires a lot of effort to accurately record all workshop data. With respect to the organization issue, both workshops could be organized as part of a larger conference, where many participants from target groups were already present. Furthermore, some of the disadvantages could be taken away by using a mobile *Group Decision Room* (GDR) facility. A GDR facilitates the process of decision-making by groups, and includes a variety of tools like brainstorming, surveys, polls, and categorization. The advantage of using a GDR over a regular meeting is that people can participate anonymously, and the advantage of using a GDR over an individual survey is that people can react on each other's input. In both workshops, the GDR facility was primarily applied in order to collect data efficiently, and to be able to present the results during the workshop.

2.2 The Amsterdam workshop[2]

This workshop was part of the IN-SAFETY project (EU 6th framework program), which aimed to "use intelligent, intuitive and cost-efficient combinations of new technologies and traditional infrastructure best practice applications, in order to enhance the forgiving and self explanatory nature of roads" (Wiethoff et al., 2006, p. 6).

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[2] This work was performed in co-operation with partners within the IN-SAFETY consortium. For the complete description of this part of the project I would like to refer to:
Wiethoff, M., Marchau, V. A. W. J., Waard, D. d., Walta, L., Brookhuis, K. A., Macharis, C., Brucker, K. d., Lotz, C., Wenzel, G., Ferrari, E., Lu, M., and Damiani, S. (2006). "Implementation scenarios and concepts towards forgiving roads." Deliverable 1.1, In-Safety Consortium.

Table 2.1: Overview of ADAS characteristics grouped by functionality

			Application area			Cooperation			Deployment stage (in 2006)		
		Source	Convenience	Safety	Traffic flow	Autonomous	Vehicle to vehicle	Vehicle to infrastr.	R&D	Introduced	On the market
Lane keeping	Lane departure warning	A/B		X		X		X			X
	Lane keeping assistance	A/B	X			X		X		X	
	Lane/road departure avoidance	B		X		X			X		
Distance keeping	Headway advisory	B		X		X					X
	Adaptive cruise control	B	X			X					X
	Low speed ACC	B	X			X				X	
	Full speed range ACC	B/C	X			X			X		
	ACC+Stop&Go	A/B	X			X			X		
	Cooperative ACC	B			X		X	X	X		
Speed keeping	Intelligent speed assistance (warning)	A/B		X		X		X	X		
	Intelligent speed assistant (intervening)	B		X		X		X	X		
Crash avoidance	Forward collision warning	A/B/C		X		X		X			X
	Forward collision mitigation	B		X		X		X		X	
	Forward collision avoidance	A/B/C		X		X	X	X	X		
	Blind spot warning	A/B/C		X		X					X
	Lane change support	A/B/C		X		X	X	X	X		
	Parking assist	B	X			X					X
	Backup/parking assist	B		X		X					X
Crash mitigation	Precrash brake assist	B		X		X					X
	Precrash systems	B/C		X		X			N/A		
Vulnerable road users	Pedestrian detection and warning	B/C		X		X		X		X	
	Pedestrian protection	C		X		X			N/A		
Emergency notification	E-call	C		X				X	N/A		
Vision enhancement	Adaptive front lighting	B		X		X					X
	Night Vision	A/B		X		X				X	
Conditions monitoring (driver/vehicle/ environment)	Driver impairment monitoring	B/C		X		X				X	
	Driver alcohol measurement	C		X		X			N/A		
	Road surface condition monitoring	B/C		X		X		X	X		
	Local hazard warning	A/C		X			X	X	X		
	Local risk information	C		X		X		X	N/A		
	Emergency braking	C		X		X	X		N/A		
	Electronic stability control	C		X		X					X
Traffic flow enhancement	Speed advisories	B			X			X	X		
	Traffic responsive ACC	B			X			X	X		
	Traffic jam dissipation	B			X		X	X	X		
	Start-up assist (traffic lights)	B			X			X	X		
Automated driving	Automated vehicle control	A/B	X			X	X	X	X	*	
	Platooning	A/B			X		X		X		

*	people movers were introduced, but autonomous driving in normal passenger cars is not
A	Ehmanns and Spannheimer (2004)
B	Bishop (2005)
C	Vollmer et al. (2006)
N/A	No information available

The workshop was part of the first stages of the project, and aimed to assess the feasibility of *traffic safety* measures, in terms of their compliance to the objectives of important road transport actors: users, public authorities, and industry (automotive as well as traffic system manufacturers). Since actors usually have more than one single objective, there is a need for ex-ante evaluation methodology to derive a prioritization of traffic safety measures for each of the actors. Possible methods of ex-ante evaluation include Cost-Benefit Analysis (CBA), Cost-Effectiveness Analysis (CEA), and Multi Criteria Analysis (MCA). Since the aim is on feasibility of traffic safety alternatives in terms of compliance to actor objectives, and not in terms of costs, an MCA was performed to derive prioritizations of these alternatives for users, public authorities and industry.

2.2.1 Methodology

In an MCA a set of predefined alternatives n is analyzed in terms of the scores of these alternatives $[e_{nm}]$ on a number of important decision criteria m. Furthermore, the importance of the criteria is determined in terms of the weights $[w_m]$ of these criteria. The overall scores $[S_n]$ of the alternatives are a function of the scores and criteria – the decision rule - and indicate the prioritization of the alternatives. Usually this function is the weighted sum of the scores (2.1).

$$S_n = \sum_m w_m e_{nm} \tag{2.1}$$

In order to obtain comparable scores, and to derive overall scores from them, different methodologies have been developed to assign numbers to the score and the weights. In this case, the methodology of the Analytic Hierarchy Process (AHP; Saaty, 1980) was applied. This methodology involves pairwise comparisons of alternatives on criteria to determine the scores, and pairwise comparisons of criteria to determine the weights. Both are measured on a nine-point scale, as shown below. If alternative or criterion A completely dominates alternative or criterion B, the value 1/9 is returned. If it is the other way around, the value 9 is returned. And, if both are equally important, the value 1 is returned.

	A>>B		*A>B*		*A =B*		*B>A*		*B>>A*	
A	1/9	1/7	1/5	1/3	1	3	5	7	9	**B**

This reciprocal instead of linear scale was used as a result of the matrix-style calculations of the weights and scores. The weights vector $[w_m]$ and the m scores vectors $[e_n]$ are the eigenvectors of the matrices of pairwise comparisons of the criteria and alternatives respectively. The overall score of the alternatives is produced by the weighted sum of the scores on criteria.

Alternatives

In the workshop, 18 alternatives towards forgiving and self-explaining roads were considered. These alternatives were generated by addressing the five types of driver behavior that most frequently are the causes of traffic accidents, according to European and German national accident statistics. One additional type of driving behavior was included by the experts within the consortium. To mitigate the traffic safety consequences of these six types of driving behavior, three groups of alternatives were considered: in-vehicle alternatives, infrastructure alternatives, and co-operative alternatives (i.e. vehicle-vehicle or vehicle-infrastructure). Table 2.2 gives an overview of the alternative traffic safety measures.

Table 2.2: Alternatives considered in the first workshop

Driver behavior related to traffic accidents	**In-vehicle alternatives**	**Infrastructure alternatives**	**Co-operative alternatives**
Speeding	Speed sign recognition	Speed warning (Variable Message Sign)	Speed alert (digital map)
Wrong use of lane	Lane Departure Warning Assistant (LDWA)	Audible delineation	Adaptive LDWA
Violation of priority rules	Priority sign recognition	Priority signs	Traffic light status emission to vehicle
Failure when overtaking	Blind Spot Detection	Rumble strips	Overtaking warning (vehicle-vehicle)
Insufficient safety distance	Forward Collision Warning	Distance warning (Variable Message Sign)	Dynamic Forward Collision Warning
Too fast in unexpected sharp bend	Bend warning (digital map)	Bend warning (Variable Message Sign)	Bend warning (local beacons)

Criteria

For each of the three actor groups, a number of criteria were pre-defined by the IN-SAFETY consortium members, based on earlier experience. The user criteria included were driver comfort, driver safety, full user cost, and travel time duration. The public authorities' criteria included were environmental effects, network efficiency, overall safety, public expenditure, and socio-political acceptance. Automotive industry's criteria included were investment risk, liability risk, and technical feasibility.

The scores of the alternatives on these criteria were determined prior to the workshop by experts within the IN-SAFETY consortium, and translated into the nine-point scale explained above (see Wiethoff et al., 2006).

2.2.2 Workshop outline

In the workshop, 27 people participated: 11 representing public authorities, 9 representing users, and 7 representing the automotive and traffic industries. The participants originated from different European countries.

After an explanation of the alternatives, the criteria, and the GDR system, the following tasks had to be performed by the participants:

1. A pair-wise comparison of criteria per actor group;
2. Specification of additional criteria to the pre-defined lists;
3. Provision of comments on all criteria, followed by a group discussion.

During tasks 2 and 3, the data collected within task 1 was processed, resulting in the overall scores per alternative per actor.

2.2.3 Results

Here, the focus is on the overall scores of the alternatives, and the discussion on criteria. The details of how the overall scores on the alternatives were derived can be found in Wiethoff et al. (2006).

Overall scores of alternatives

The overall scores of the alternatives are presented in Figures 2.1 – 2.3. Each of these figures presents the overall scores of each actor for one of the groups of six alternatives introduced in Table 2.2: in-vehicle alternatives, infrastructure alternatives, and co-operative alternatives. For each actor, the sum of the overall scores over all 18 alternatives is equal to 1. The overall scores are based on an average over all respondents representing an actor. The alternatives are presented in order of increasing average overall scores over all actors.

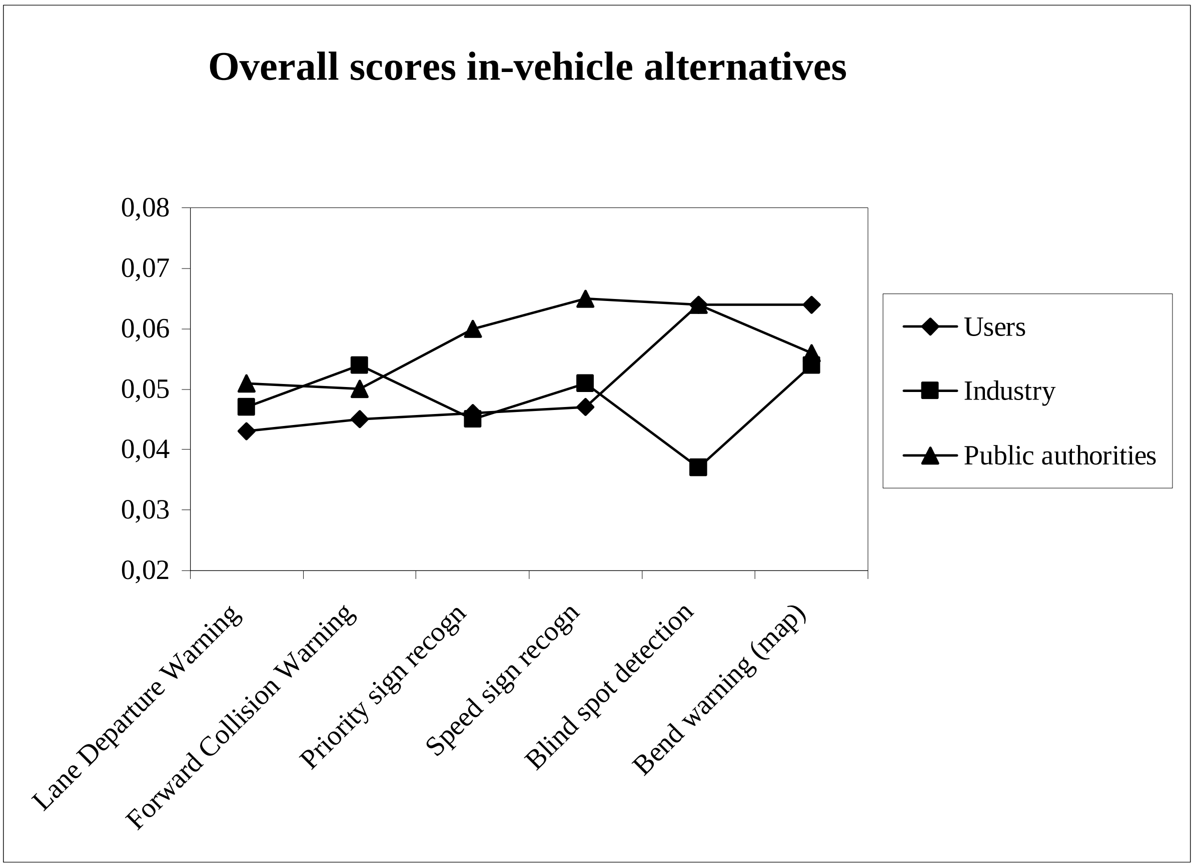


Figure 2.1: Overall scores of in-vehicle alternatives

With regard to in-vehicle alternatives, the warning for unexpected bends scores has the highest average score. For industry, this alternative is about equal to forward collision warning, and for the users bend warning is about equal to blind spot detection. For public authorities, the score of speed sign recognition is highest. Overall, the scores of most in-vehicle alternatives are higher for public authorities than for the other actors.

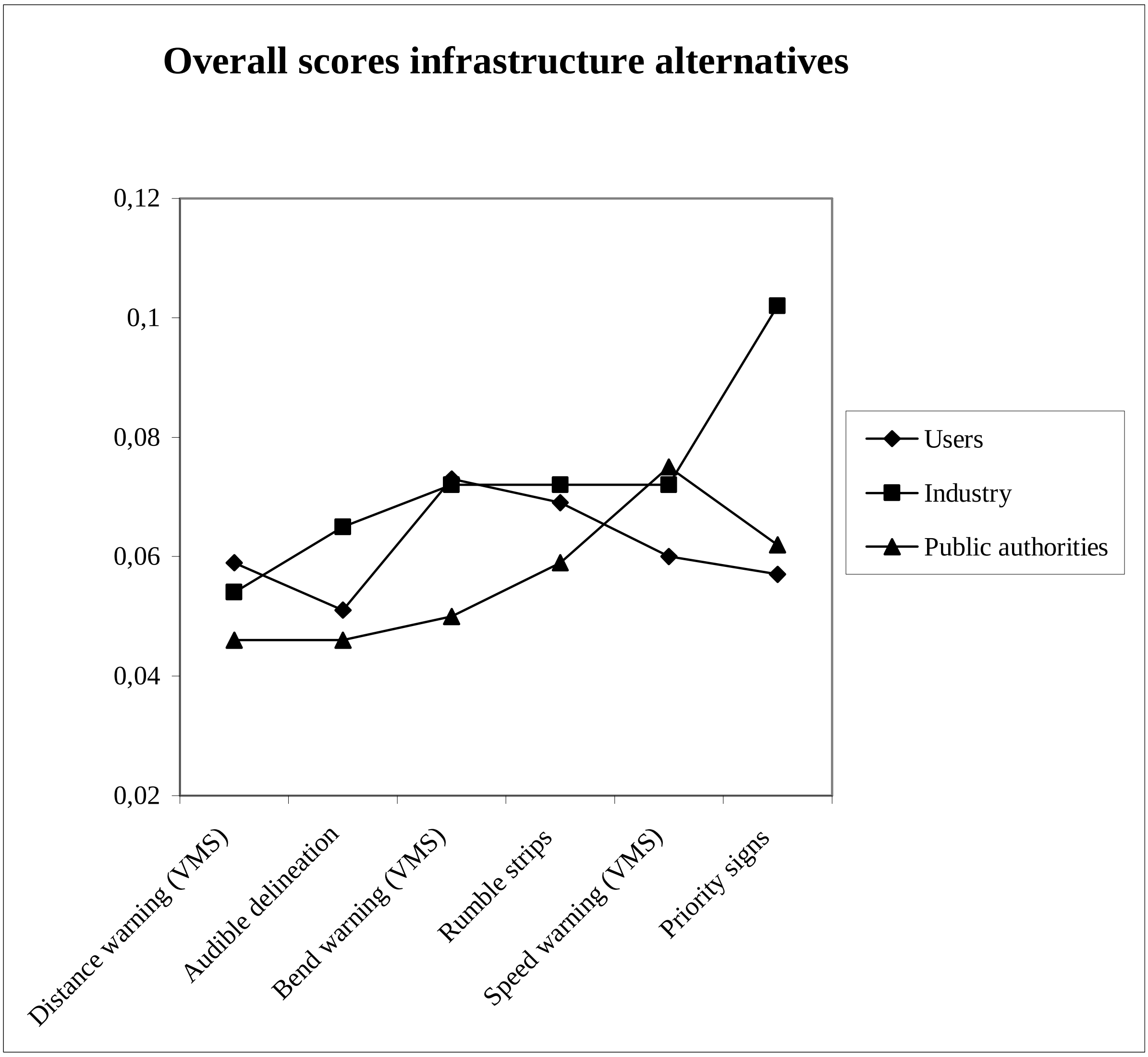


Figure 2.2: Overall scores of infrastructure alternatives

With regard to the infrastructure alternatives, it can be concluded that they generally score highest for industry. The priority signs alternative receives the highest average score over all actors, mainly because of the relatively high score for industry. For users, the score on bend warnings via variable message signs is highest. For public authorities, the score on speed warnings via variable message signs is highest.

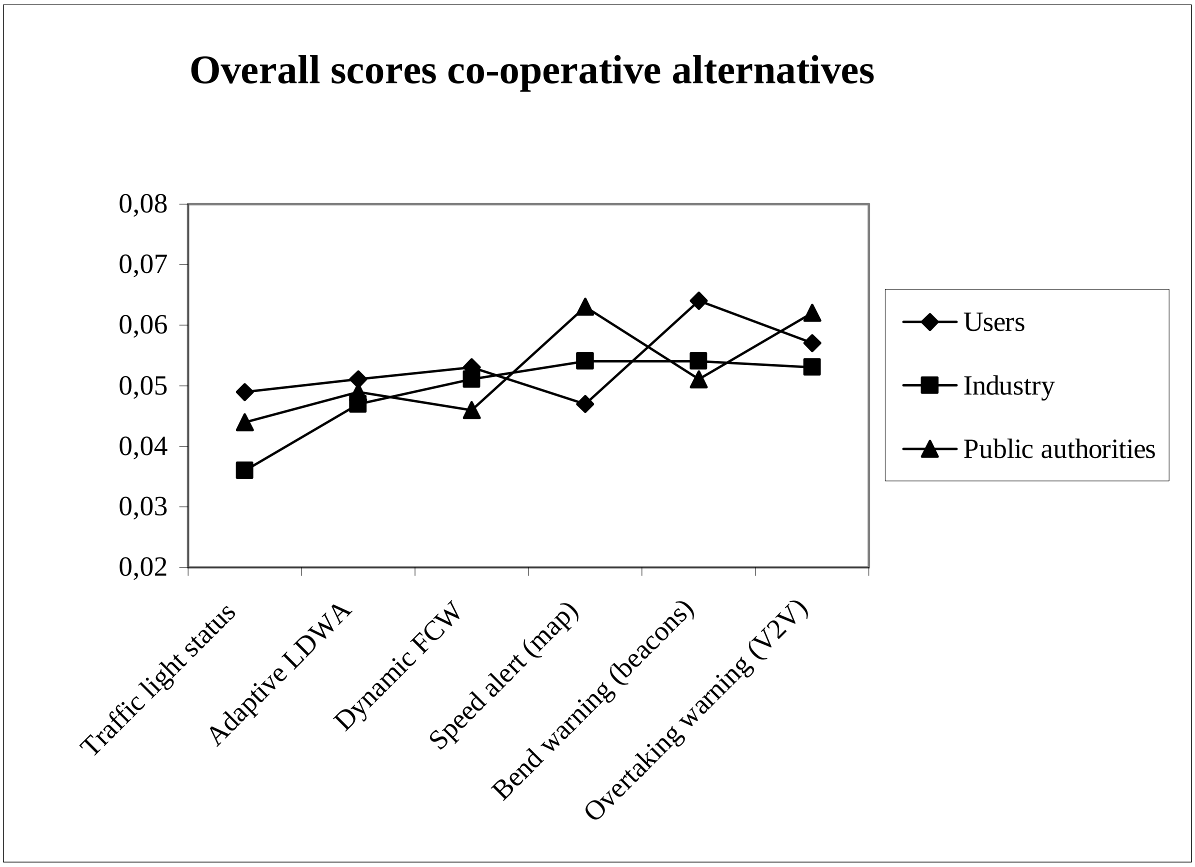


Figure 2.3: Overall scores of co-operative alternatives

With regard to the co-operative alternatives, vehicle-to-vehicle overtaking warning has the highest average score, but not for any of the individual actors. For public authorities, the score of speed alert by digital map is highest. For users, bend warning by local beacons scores highest. For industry, there is a tie between speed alert and unexpected bend warnings. With respect to the other groups of alternatives, the differences between the scores of co-operative alternatives and between the actors are relatively small.

In general, it can be observed that infrastructure alternatives score highest for industry, alternatives that address speeding score highest for public authorities, and alternatives that address unexpected bends on rural roads score highest for users. However, the differences between the alternatives and the actors are quite limited, except for the high score of industry for priority signs.

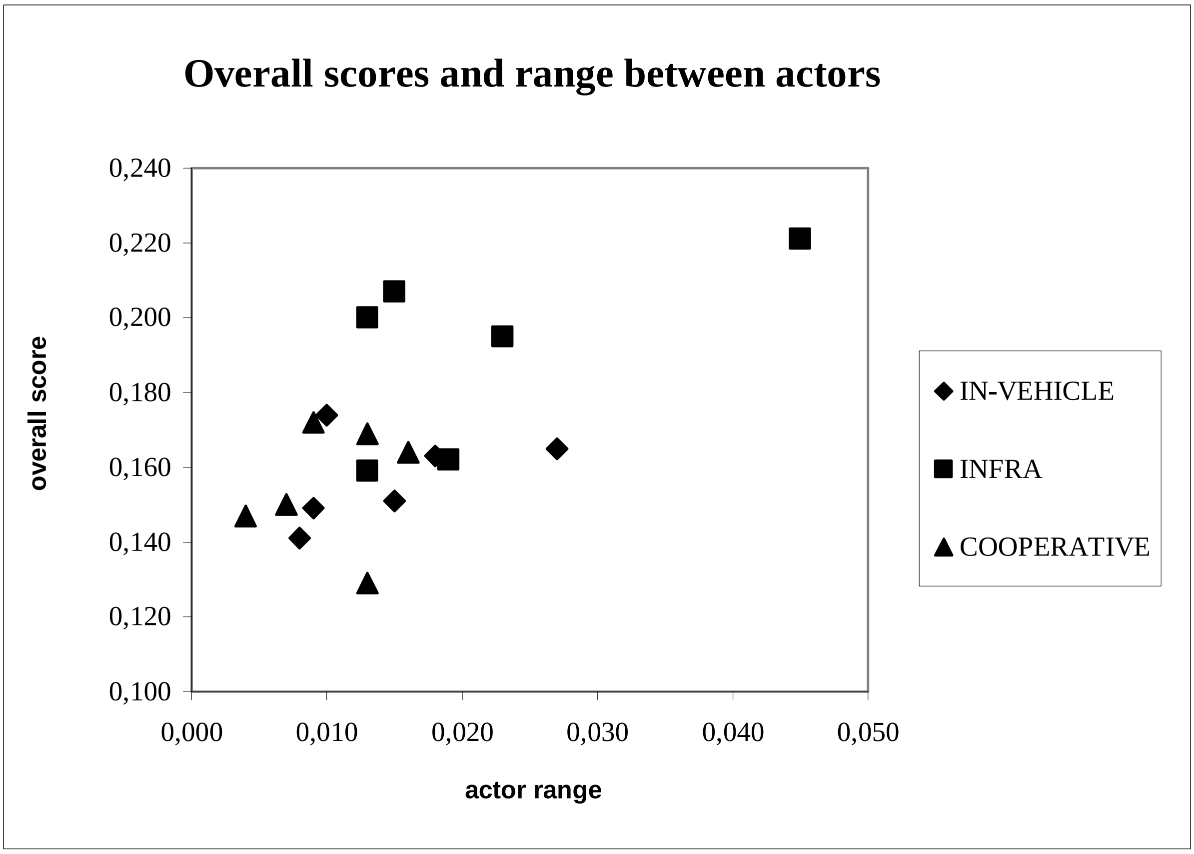


Figure 2.4: Overall scores of the alternatives and range between actors

In knowing the prioritization of the individual actors, it is interesting to see on which options (with a high score) there is most agreement among all actors. Figure 2.4 shows the sum of scores over all actors, for each alternative plotted, against the maximum difference between the scores of the different actors – the actor range. The top left alternatives, that have a high overall score with a small range across actors, could be considered as promising. The two alternatives, that can be considered as such, are both infrastructure alternatives: speed warning via variable message signs, and rumble strips to prevent overtaking failure. Most agreement among actors can be observed regarding co-operative alternatives, but these have relatively low scores.

Group discussion on criteria

In Table 2.3 the comments of the participants on the pre-defined and added criteria are summarized. It was found that most criteria added by the participants refer to prerequisites rather than to decision criteria. Prerequisites (or ‘musts’ instead of ‘wants’ that refers to criteria) need to be satisfied to a certain level before an alternative becomes feasible for deployment (e.g. harmonization, self-explanatory). The main difference with decision criteria is that there is no trade-off possible with prerequisites. They particularly play a role in the early stages of a project, when feasible alternatives need to be determined. Decision criteria are then used to determine which feasible alternative suits the (multiple) goals best. The fact that prerequisites are often mentioned, illustrates the current preliminary standing of ADAS deployment in Europe. Furthermore, the outcomes of this discussion show that there is a need to take deployment issues into account (e.g. importance of human factors, international harmonization etc.).

Table 2.3: Additional criteria and comments

Public authorities	**Summary of comments**
Environmental effects	Expected positive relation between safety and environment, but not in all cases.
Network efficiency	Safety and efficiency are related. Positive effects on one part of the network can have negative on another.
Overall safety	Attention needed for vulnerable road users.
Public expenditure	Cost-benefit analysis is necessary, but difficult since measures have multiple (intended) effects. Return on investment should be considered from other sectors (health, economy, etc)
Socio-political acceptance	Difficult barrier. Measures to increase acceptance needed.
Human factors*	Authorities should take human factors into account better
Public consultation*	(unclear)
Socio-economic impact*	(no comments)
Network interrelations*	International cooperation necessary
Communicative context*	Amount of information presented has to be tuned to what the driver can handle
Harmonization*	Not only international but also multi-modal cooperation
Accessibility of transport system*	Overall accessibility of the transport system by all modes
Self-explainability and clarity in design*	Too many traffic signs do not help users
Liability of public authorities*	Issue in case of provision of safety-relevant information
Public health*	Costs of safety-measures are high, but very effective taking into account the costs of fatalities
Implementation questions*	Difficulties when implementing same measures over all EU-countries
Users	
Driver comfort	Comfort for drivers and passengers
Full user cost	Only applicable to in-vehicle measures Public authorities should avoid competition on safety features by introducing legal obligations
Driver safety	Also safety for passengers and people outside the vehicle
Travel time duration	Very important criterion, but might be hidden
Maintenance cost*	Should be low
Integration of functions onboard*	Important for safety/comfort/costs
Harmonization*	Avoid confusion and reduce costs
Industry	
Investment risk	Fundamental issue for manufacturers
Liability risk	Should be regulated first
Technical feasibility	If it is not feasible, why take it into account as an alternative?

*criteria added by the participants

2.2.4 Discussion

The MCA performed in this study gives insights into the expected support of actors for deployment of traffic safety alternatives. However, it has to be taken into account that the prioritizations were made for full deployment of the alternatives, and not for the intermediate deployment steps to be taken to achieve this. These deployment steps tend to be very different when either infrastructure or in-vehicle alternatives are concerned. This relates to the fact that infrastructure measures can be deployed at one location at a time, and already be effective for many passing vehicles. While in-vehicles measures can be directly effective on an individual basis for a large area, they need to be deployed on a large scale to become effective overall. Since co-operative measures are a combination of both, deployment of these measures is increasingly difficult.

With regard to the overall scores, the dominance is eye-catching of the infrastructure alternatives for industry, over the in-vehicle and co-operative alternatives. Focusing on the criteria that were included for industry, it was found that all of these criteria intuitively had a lower score for in-vehicle alternatives compared with the infrastructure alternatives. It could, however, be expected that there are also more positive sides to vehicle measures for the automotive industry, such as generating competitive advantage. As a consequence,, we should reconsider the criteria included in future investigations.

The number of people participating in the workshop was rather small. This is generally the case when adopting actors such as public authorities and industry as the target groups of research. The users were represented by participants from user organizations, or general participants at the meeting. The latter are usually better informed than the average road user. There is uncertainty, therefore, on the extent to which these results can be generalized for all actors.

For comparable investigations in the future, it is recommended to include deployment options as a means to differentiate between deployment steps. Furthermore, it is recommended to reconsider the criteria to be included for the different actors in the investigation. In the subsequent workshop, these recommendations have been taken into account.

2.3 The Eindhoven workshop

The focus of the second workshop in Eindhoven was on safety-related ADAS only, and the possible options policymakers can apply to influence deployment of these ADAS. Furthermore, relevant decision criteria, with respect to ADAS deployment, were assessed.

2.3.1 Methodology

In reviewing the results of the first workshop in Amsterdam, it was learned that more attention should be paid to deployment aspects, and that criteria should be further explored. Consequently, it was decided to organize the second workshop on the basis of performing a survey on these issues. The input for the survey consisted of a set of safety ADAS that were already on the market, a set of policy options for public authorities to influence ADAS deployment, and a set of important criteria for decision-making.

ADAS

The workshop included a selection of ADAS that already have been introduced onto the vehicle market, and of which deployment is expected to be mainly public policy driven. Currently, systems have been introduced that mainly support driving convenience and/or safety (see Table 2.1). Since public authorities are more interested in improving traffic safety then in improving driving convenience, their focus should be on ADAS that enhance traffic safety. Most safety effects are currently expected from support of simple driving tasks, such as lane keeping and distance keeping, and from monitoring the condition of the driver.

Consequently, a set of ADAS with four different support functions was selected, i.e. (1) lane keeping, (2) distance keeping, (3) speed keeping, and (4) driver drowsiness/impairment monitoring. For each of these functionalities, warning and active assistance variants were included (see Table 2.4), except for driver monitoring, for which only a warning variant is available.

Table 2.4: Relevant ADAS for public authorities

Functionality	**Warning variant**	**Active assistance variant**
Lane keeping	Lane Departure Warning	Lane Keeping
Distance keeping/ head-tail crash avoidance	Forward Collision Warning	Forward Collision Avoidance
Speed keeping	Speed Limit Warning	Speed Limit Keeping
Driver monitoring	Driver Impairment Monitoring	-

Public authorities' deployment options

Public authorities can play different roles in the deployment of new technologies in transport, such as ADAS. Possible roles are that of a monitor, a framework body, an implementer, an R&D agent, an innovation agent, or a developer (Jansen, 1995). Depending on the role they want to play, they can use policy measures – ADAS deployment options – to influence the development and/or deployment of ADAS. In general, public authorities' deployment options regarding in-vehicle systems can vary from doing nothing (and let the market decide what happens) up to legally mandating the use of a system (e.g. as applied to speed limiters for trucks in the Netherlands). In between, there is a wide range of stimulation measures available to influence deployment of ADAS. Without being comprehensive, these other options include actively supporting standardization activities, and stimulating purchase and use by, for example, awareness campaigns and financial incentives (e.g. eSafety Support, 2007). Figure 2.5 indicates that both the supply side (automotive industry) and the demand side (users) of the ADAS market can be influenced by public authorities' deployment options. Evidently, different deployment options can be combined or focused on specific types of vehicles, users, roads, etc. The workshop included doing nothing, standardization, stimulation, obligation for target groups, obligation for all users, and prohibition of the ADAS. Combinations of these deployment options were not considered.

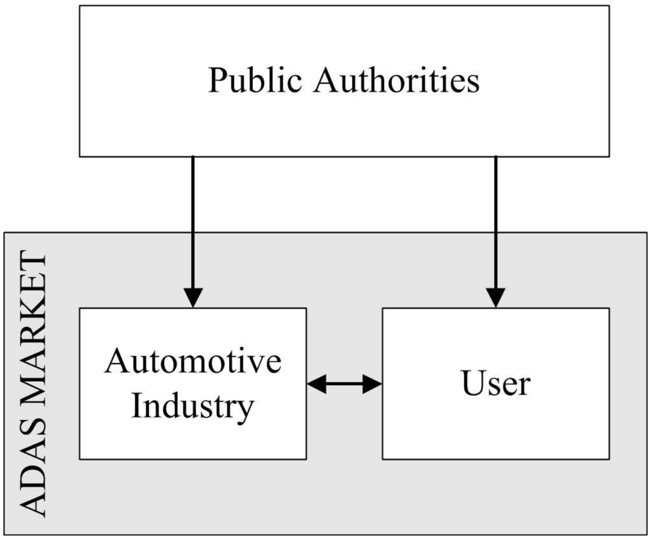


Figure 2.5: Public authorities' influence on ADAS deployment

Decision criteria

A preliminary list of decision criteria was developed, based on an overview of criteria for the three main actor groups that are usually studied (see e.g. ADVISORS, 2002; Lathrop and Chen,1997): users, public authorities, and the (automotive) industry. This list was to be assessed on comprehensiveness and importance by the workshop participants. To create this overview, five studies that define actor decision criteria – or objectives from which criteria are derived – were selected. These studies were all in the field of intelligent transport systems. From these studies, a number of categories of criteria were identified (see Table 2.5). The criteria for interest groups were included in those of the user, since these reflect the interests of general users as well as specific target groups. As a basis for these overviews, the extensive list of criteria created by Lathrop and Chen (1997) on Automated Highway Systems was used. For public authorities, a number of criteria were added that were mentioned in a recent policy document for the Netherlands (Nota Mobiliteit, V&W, 2004).

Table 2.5: Overview on categories of criteria

Actor group	Category		Examples of criteria
User	Safety		Driver safety[a;b;d;e]
	Cost[d;e]		Vehicle capital cost[a;b] Vehicle operating cost[a] Maintenance cost[a]
	Travel time		Travel time predictability[a;c]
	Societal, environmental impacts[a]		Accessibility[c] Environmental impacts[c]
	Operating convenience		System incrementalism[a] Border crossing functionality[e]
	Privacy[b]		Development of databases including personal information[a]
	Driving convenience		Comfort[b;d;e] Required skills[a]
	Other		Clarity of benefits[b] Efficiency[b] System image[b]
Public authorities	Costs[b;d;e]		Maintenance costs[a] Infrastructure costs[a]
	Safety		Traffic safety[b;c;d;e] Fatalities[f] Injuries[f]
	Environment		Environmental impacts[c;d;e] CO_2 emissions[f] Land use[a]
	Traffic (flow) efficiency[b]		System throughput[c;d;e] Accessibility of locations[e] (Reliability of) Travel times[f] Time lost in congestion[f]
	Institutional attractiveness[a]		Information provision[a] Socio-political acceptance[d;e]
	Accessibility		Accessibility of transport[e]
Industry	Profitability[b]		Market demand[e] Investment risk[e]
	Liability[a;e]		Liability[a;e]
	Competitive advantage[b]	Cost advantage (Porter, 1985)	Manufacturing efficiency[a;c] Maintenance service costs[a]
		Differentiation advantage (Porter, 1985) or Unique selling points[b]	Customer objectives[a;c] (Comfort[b], Safety[b], Image[a]) Marketability[a] Technical feasibility[d;e] Incrementability[a]

[a] Lathrop and Chen (1997); [b] Walta et al. (2005); [c] Reed et al. (1996); [d] ADVISORS (2002); [e] Wiethoff et al. (2006); [f] Rijkswaterstaat (2008)

For public authorities and users, the categories are similar, but the related criteria show that public authorities have a social perspective, whereas the users have an individualistic perspective. For example, while system throughput is a criterion for authorities, users are interested in travel time predictability. The criteria for industry include many that are similar to those of authorities and users, but these seem to be subordinate to their main goal of sustainability of the company.

It was decided to create one list of criteria for all the actors in the workshop. Since the level of detail in the individual criteria in Table 2.6 is large, a shortlist of criteria was created. This shortlist included the categories listed in Table 2.6, without privacy and accessibility. These were thought not to be main issues with respect to the ADAS included in the workshops. Furthermore, for greater clarity some category names were replaced by one of the underlying criteria.

Shortlist of criteria included in the workshop:
- Safety;
- Costs;
- Travel time/network efficiency;
- Environmental pollution (incl. noise);
- Product incrementability;
- Driver comfort;
- Driver freedom;
- Product image;
- Profitability;
- Liability.

2.3.2 Workshop outline

The participants for the workshop were dependent on the symposium participants. Since there were few participants from user organizations, and many more from research institutes, it was decided to include the latter as an actor group instead of users. General participants to the symposium were considered to be too well informed to represent general users. Consequently, the actor groups included in the workshop were public authorities, industry, and research institutes.

In the workshop, 29 people participated: 11 representing public authorities, 9 representing industry and 9 representing research institutes. The participants were from the Netherlands, Belgium, Germany, Italy, Sweden, Finland, Greece and the United Kingdom. There were two workshop sessions, one with 18 participants, of which the majority represented public authorities and industry, the other with 11 participants, of which the majority represented research institutes.

After a short explanation of the ADAS to be considered in the workshop, the following tasks had to be performed by the participants:
1. Indicate which of the given public authorities' deployment options is most suitable for different ADAS;
2. Comment on the relevance of the given criteria (participants could read each others' reactions);
3. Add one criterion per participant, and then vote which 5 criteria should be added to the list;
4. Rate the criteria of the updated list on a scale 1-10.

2.3.3 Results

Public authorities' deployment options

Figure 2.6 summarizes the results of the evaluation of alternative deployment options. Each of the diagrams in this Figure shows the percentage of the respondents that chose a particular deployment option for one of the ADAS, and which actor they represented. The total percentage for each diagram is 100%, which is evenly distributed among the actors (33⅓% per actor).

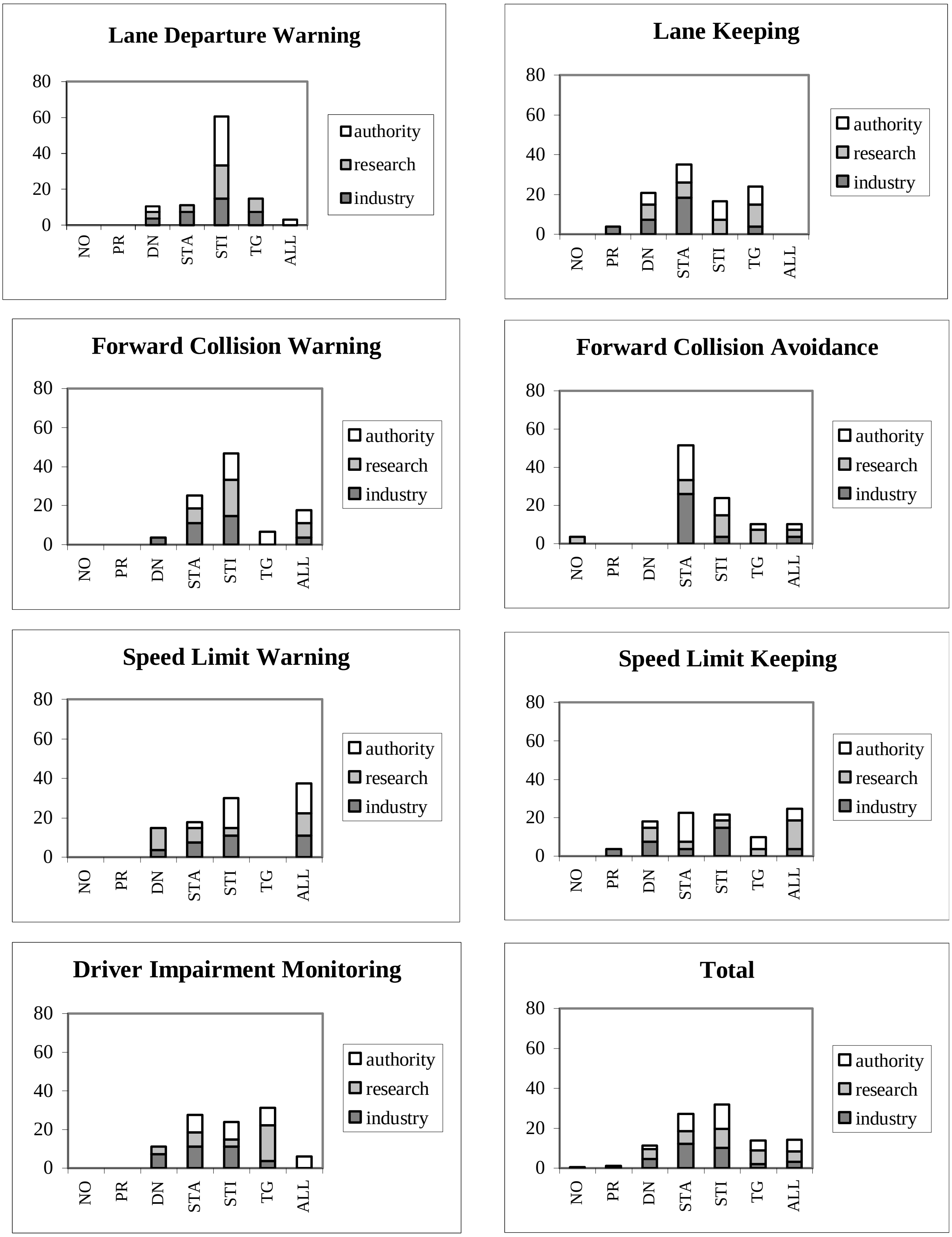
Generally, industry prefers a less active role by the public authorities than do researchers and the public authorities themselves. This might be due to industry generally not being very fond of regulations, since, for example, they decrease the opportunity for competitive advantage. In contrast, public authorities and researchers are more focused on unleashing the potential of ADAS to contribute to the solution of transport problems.

For Lane Departure Warning and Forward Collision Warning there is (almost) a majority that states stimulation to be the most suitable measure, with no large difference between actors. With regard to Lane Keeping and Forward Collision Avoidance, standardization is the most preferred option, showing that the technology is not considered to be ready for large-scale deployment.

A major role for the public authorities, by means of stimulation or obligation, seems to be generally found most appropriate for Speed Limit Warning, Speed Limit Keeping, and Driver Impairment Monitoring. However, there is also a large difference of opinion, regarding these systems, *between* the actor groups, as well as *within* the actor groups. These differences are specifically large for Speed Limit Keeping. Surprisingly, the majority of public authorities saw a more limited role for themselves than the other actors did.

The participants were also asked to specify which type of incentive they found most suitable (in the cases where they chose an incentive) and which target groups (in the cases where they chose obligation). With regard to the incentive options, most actors agree on financial incentives (by tax reduction or insurance premium reduction) being the most appropriate incentives. If an ADAS should become mandatory for a target group, most participants agreed that this should be truck drivers, and to a lesser extent bus drivers.

The results show a wide range of differences in opinion between, and within, the actor group with respect to the ADAS considered. These differences may be caused by differences in perceived effectiveness of the systems, and general differences in opinion about policy intervention in ADAS deployment. General differences in opinion between the ADAS may be caused by differences in development stage of the systems. Apart from a number of systems that are still being developed, none of the ADAS was assigned a minor role for the public authorities, which confirms the pre-selection of – likely – policy driven ADAS.



NO = No opinion
PR = Prohibit further deployment
DN = Do Nothing

STA = Standardization
STI = Stimulate use
TG = Mandate for target groups
ALL = Mandate for all road users

Figure 2.6: Prioritization of policy options in %

Group discussion on criteria
The participants were asked to comment on the pre-defined criteria. The most important comments – on safety, travel time/network efficiency, environment, driver freedom, and liability – are summarized below.

Safety – The participants have different perceptions regarding safety. For instance, some value safety by loss of life, and others value safety by societal costs of accidents. Alternatively, safety may have been interpreted by some of the participants as inherent system safety, which could be considered as a prerequisite for ADAS deployment, instead of a contribution to traffic safety.

Travel time/network efficiency – Participants from different actor groups value this criterion differently. As expected, participants from public authorities are more interested in network efficiency, while participants from industry are more interested in travel time, reflecting their customers' interest. The participants from research institutes address both perspectives, but state that ADAS are mainly effective regarding network efficiency.

Environment – Environmental issues are considered an enormous driving force by some of the participants, but very sensitive to trends. The discussion is complicated, since there are different opinions about the expected effects of ADAS on the environment. If the general attitude will be 'to apply everything that helps in protecting the environment, even if the effects are small', environment may become a driving force of ADAS deployment. Other (technological) solutions, however, are probably more effective.

Driver freedom – Some of the participants see the limitation of driver freedom as obvious and necessary to achieve policy goals, but some also state it to be a politically sensitive issue, which is confirmed by some very strong statements against limitation.

Liability – The resolution of liability issues mainly seems to be a prerequisite for ADAS deployment. It is not clear whether liability issues would be included in trade-offs that actors make, in order to decide which option to implement.

Addition of criteria
Since the pre-defined list of criteria was based on literature only, participants were asked to add criteria to the list before the importance rating took place. By a voting procedure, eleven criteria were added in the workshop sessions, of which some were comparable. In the first workshop, session driver acceptance/user friendliness, standardization/international application, certification/validation, technical performance, level of adaptation needed, and driver distraction, were added. In the second workshop session, public acceptance, deployment aspects, legislation/laws, privacy, and standardization were added. These criteria were included in the importance rating assignment, but only for the participants in the session that added the criteria, which means that the predefined criteria were rated by a larger group of participants than the added criteria.

Importance of criteria
The participants were asked to rate the importance of the criteria on an 11-point scale.. This scale is detailed enough to make a distinction between the criteria included, and is still capable of being understood, since it is a commonly applied system for grading. Table 2.6 shows that safety and driver acceptance were rated as the most important criteria. They also have a relatively low standard deviation, showing a large amount of consensus about the

importance. Almost all criteria have a higher score than 5 out of 10, which means that all criteria included are relatively important to the participants. However, the standard deviation of many of the criteria is relatively large, indicating that there is a lower amount of consensus about the importance of these criteria, than there is for safety and driver acceptance. Unfortunately, due to the level of anonymity of the data resulting from the GDR, the importance scores could not be evaluated per actor.

Since participants in both workshop sessions could add criteria, which were then evaluated only in their own workshop session, the number of respondents for each of the criteria in Table 2.6 varies. Furthermore, some participants did not provide answers for all criteria.

Table 2.6: Importance rating of criteria

Criterion	Mean	N	Std. Deviation
Safety	9.45	29	1.121
Driver acceptance	8.41	17	0.939
Technical performance	7.61	18	1.944
Liability	7.41	27	2.308
Driver distraction	7.35	17	1.998
Costs	7.11	28	1.892
Level of adaptation needed	7.00	18	1.879
Certification/validation	7.00	18	2.058
Standardization	7.00	29	2.220
Environment	6.62	29	2.211
Public acceptance	6.40	10	1.578
Deployment aspects	6.30	10	2.312
Profitability	5.88	26	2.957
Driver comfort	5.75	28	2.222
Travel time/network efficiency	5.72	29	2.999
Legislation/laws	5.45	11	2.296
Privacy	5.45	11	3.045
Driver freedom	5.18	28	2.894
Incrementability	4.96	26	2.088
Image	4.58	26	2.873

When using the resulting list of criteria for further research, one should be aware that some of the criteria added by the participants have hierarchical relations with other criteria, or merely represent prerequisites for the decision criteria. An example of a possible hierarchical relationship is the one between driver distraction and safety. It is important to identify these hierarchical relations, in order to avoid including criteria in research that are highly correlated. Prerequisites are, unlike criteria, not included in trade-offs, but have to be satisfied at a certain level in order to include a certain option in decision-making (see also 2.2.4). Criteria such as certification and standardization, for example, probably represent prerequisites. The fact that these criteria were referred to primarily by the actors themselves, might illustrate the current premature status of ADAS deployment in Europe.

2.3.4 Discussion

From the results of the second workshop, it can be concluded that the participants expect public authorities to play an important role in ADAS deployment, but that this role depends on the type of ADAS considered. Previously, it has been assumed that public authorities have the main responsibilities with regard to transport problems, such as traffic safety. While this is not queried here, the deployment of ADAS to increase traffic safety involves more decision-makers than public authorities alone, such as industry and possibly insurance companies. This is different from the application of infrastructure solutions, in which industry is also involved, but does not make deployment decisions. As a result, the rate of deployment of ADAS is not under the complete control of the public authorities (unless they mandate the ADAS for all vehicles, which is highly unlikely). However, the rate of deployment is very important for the effectiveness of ADAS.

Consequently, it is important to focus more on the decisions of other decision-making actors, regarding ADAS deployment in further investigation. This would lead to a very complicated situation if the problem-oriented approach, which is common in current research, were to be applied. All decision-making actors that influence ADAS deployment have their own problems for which ADAS are a potential solution, and have their own alternative solutions to these problems. For example, public authorities may be interested in safety, and prefer infrastructure alternatives next to ADAS, while industry is interested in competitive advantage, and prefers (other) driver comfort options next to ADAS.

Since there is not a clearly common problem among decision-making actors that can be the basis of further, problem-oriented, analysis, it is recommended here to shift the focus in this research project from solving transport problems, to deployment of a technology that could contribute to solving transport problems, i.e. ADAS. This implies adopting a technology-oriented approach, in which potential deployment actions of different actors, with respect to a certain technology, are considered as the alternatives, instead of different technologies to solve a common problem.

2.4 Conclusions and reflections

This chapter described the results of two workshops with road transport actors, which can be considered as preliminary explorations of the preferences of actors with respect to ADAS deployment.

Main results of the Amsterdam workshop
A multi-criteria analysis was performed on infrastructure, in-vehicle, and co-operative traffic safety alternatives. The analysis showed that infrastructure alternatives, in general, best match the criteria of the automotive industry; alternatives on speeding best match the criteria of public authorities; and alternatives on unexpected bends on rural roads best match the criteria of users. Taking into account the height and the range of the overall scores for all alternatives, and all actors, it can be concluded that most actor support could be expected for implementing variable message signs to prevent speeding, and rumble strips to prevent overtaking.

Main results of the Eindhoven workshop
In the second workshop, actor preferences for policy options for different ADAS, and the importance of decision criteria, were assessed. The analysis of the workshop results shows that industry generally prefers a less active role of public authorities in ADAS deployment when compared with public authorities and researchers. For Lane Departure Warning and Forward Collision Warning, stimulation by public authorities is generally preferred. For the more intervening alternatives of these systems, Lane Keeping and Forward Collision Avoidance, standardization activities are preferred. Public authorities are generally expected to play a major role in Speed Limit Warning and Speed Limit Keeping, but, especially with respect to Speed Limit Keeping, the opinions are divided among actors. Surprisingly, the majority of public authorities saw a more limited role for themselves than did the other actors.

Reflection on methodology used in the workshops

From the results of the Amsterdam workshop, it was concluded that they indicate the general support of actors for a specific solution, but, since the deployment of infrastructure, in-vehicle, and co-operative systems needs different types of actions from different actors, no conclusions can be drawn with respect to which decisions are likely to be taken, and by whom. Furthermore, the results for manufacturers seemed to be substantially influenced by the choice of criteria, investment risk, liability risk and technical feasibility. These mainly refer to the ‘costs’ and not to the ‘benefits’ of the alternatives, and since these manufacturer ‘costs’ are lowest for infrastructure alternatives, this explains the high scores for these. It is therefore recommended to reconsider criteria included in future studies, to better reflect trade-offs made by actors.

Reflection on application of Group Decision Room (GDR)

The advantages of using the GDR were that large amounts of data could efficiently be collected during the workshops, and that all participants could be equally involved in the different evaluations. However, there are also some disadvantages with respect to the way data are recorded in a GDR. For example, unlike usual surveys, all answers are recorded as single cases, and not as an overall case per participant. The latter would have made the data richer, and at the same time would not have compromised anonymity. Hence, not all data collected returned the detailed insights that we would have liked, but they were sufficient to obtain interesting results.

In conclusion

The results of the workshops have led to the insight that, instead of an approach that focuses on public authorities’ deployment actions, an approach that studies multiple actors’ actions better fits the case of ADAS deployment. This insight was an important ingredient in the definition of the theoretical framework that will be introduced in the next chapter. Furthermore, the data collected in the workshops on deployment options and criteria were used in the remainder of this research project.

3 Conceptual model of actors’ interactions in ADAS deployment

How are the actions of actors in ADAS deployment influenced by the actions of other actors? In addition, how do they decide to take these actions? In this chapter, a conceptual model of the system of actors’ interactions in ADAS is introduced. First, the relations between the ADAS deployment actions of public authorities, the automotive industry, insurance companies, and users are specified. Second, underlying models are introduced, that explain how the actors decide to take actions. These models distinguish between decision-making of public authorities, the automotive industry, and insurance companies on the one hand, and on the other hand, decision-making of users. They are based on theories concerning human decision-making.

3.1 Introduction

In this dissertation, ADAS deployment is defined as a system of actors' interactions in ADAS deployment. A conceptual model of this system is described in this chapter. This model is, wherever possible, based on existing theories, and otherwise on assumptions. It consists of an overall model of the system of actors' interactions in ADAS deployment, and underlying models of actor and user decision-making regarding ADAS deployment. The conceptual model forms the basis of the development of a mathematical model, which is required to study multiple scenarios for the system, and to quantify the outputs of such studies.

3.2 Conceptual model of actors' interactions in ADAS deployment

The system of actors' interactions in ADAS deployment, studied in this dissertation, consists of the ADAS deployment rate on new vehicles, and the four actors presumed to directly influence this deployment rate by their actions (i.e. users, public authorities, the automotive industry, and insurance companies). The conceptual model of this system defines the interactions between the actors, and the interactions between the actors and the deployment rate. Figure 3.1 presents these interactions.

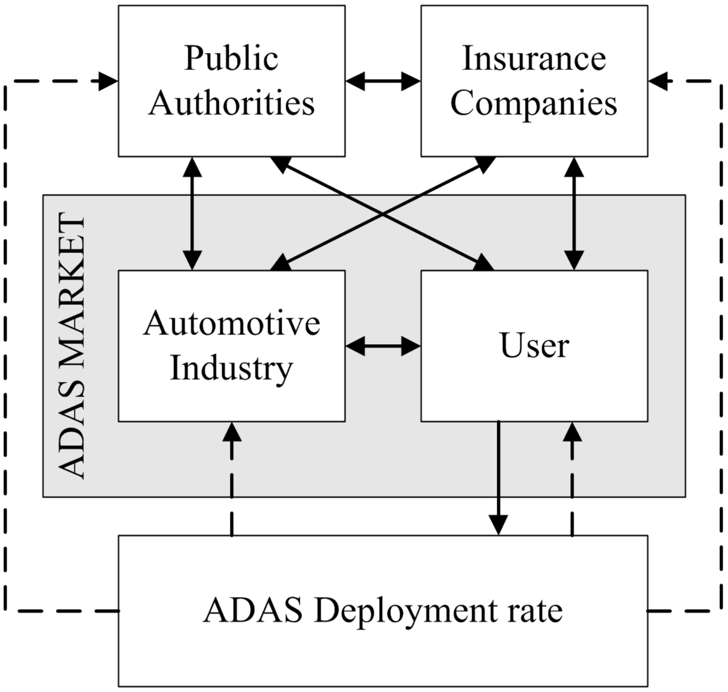


Figure 3.1: Conceptual model of actors' interactions in ADAS deployment

In the following sub-section, the roles of the actors in ADAS deployment, their interaction with the deployment rate, and how their actions can be influenced by the other actors, are discussed in more detail.

Roles of the actors

Smit and van Oost (1999) distinguish four roles of actors in technological innovation in general: technology users, technology developers, technology regulators, and other actors (those influenced by technology, but not directly using it). In ADAS deployment, the *users* can be considered as the technology users, the *automotive industry* as the technology developers, and *public authorities* and *insurance companies* as the technology regulators. The technology users use, or will use, technology provided by the technology developers. In ADAS deployment, the interactions between these two actors can be considered as an ADAS market. Technology regulators are defined as those actors that can influence technology development by laws, standardization, financial incentives, etc.

In this interactive network of actors, many possible actions of the actors can be considered, such as standardization of ADAS technology, or lobbying against speed limiters. In this dissertation, the focus is on those actions that are directed to influence the ADAS deployment rate, i.e. adoption of ADAS by users, and ADAS deployment actions by the other actors. Other actions are only implicitly taken into account. For example, the reluctance of actors to take deployment actions could be influenced by their conviction that standardization should take place first.

Interaction with the deployment rate

The deployment rate of ADAS is directly influenced by user adoption behavior, i.e. to buy or not to buy an ADAS on their new car. It is assumed here that if the users buy an ADAS, they also use it. Although they can theoretically be forced to buy an ADAS by the other actors, they are considered here as the main ‘entity’ through which the deployment rate is influenced.

The current ADAS deployment rate can, in turn, influence the actions of all actors. User adoption of ADAS can be influenced by the number of other users that have already bought it, and other actors may want to reconsider prior actions, since the deployment rate influences the extent to which their objectives are met.

Influencing users’ actions

According to Rogers (2003), there are five main aspects that influence users decisions to adopt innovations, and as such the speed with which the deployment rate increases. These include (1) the *relative advantage* of adopting the innovation over not adopting it, (2) the *compatibility* of the innovation with current practice, (3) the *complexity* to understand or use the innovation, (4) the *trialability* of the innovation before adopting it, and (5) the *observability* of the innovation in the user’s daily life. Several of these aspects can be influenced by other actors. The relative advantage of an ADAS, which is usually determined by factors such as comfort, safety, costs, image and privacy, can be influenced by (financial) incentives of other actors. The compatibility of an ADAS involves the way it fits in current driving. For example, can the ADAS be used on all roads and in all types of vehicles? This can be mainly influenced by technology design. The complexity of an ADAS involves whether the user can easily understand how an ADAS works. This is also mainly a design issue. The trialability of an ADAS involves whether you can easily experience driving with ADAS before adopting it. Demonstrations and free trial periods could increase the trialability. Finally, the observability of an ADAS involves whether people will easily come across ADAS in daily life. ADAS are currently less observable than, for example, navigation systems that are almost ubiquitous. Media campaigns could increase the observability.

Users can also influence each other’s decisions. If the deployment rate of ADAS increases, this means that the observability and trialability also increase, since the probability of meeting other people with a car equipped with an ADAS becomes higher. It becomes easier then to be aware of ADAS, and experience the impacts of ADAS.

Influencing the automotive industry's actions

With respect to ADAS deployment, the automotive industry can, for instance, decide to offer the ADAS as optional or standard equipment on specific ranges of vehicles, offer discounts to early adopters, or include the ADAS in safety or comfort packages. Retrofitting and integration of nomadic devices is, of course, also possible, but not specifically considered in the present investigation.

Important driving forces for the automotive industry to engage in ADAS deployment are potential profit, competitive advantage, and unique selling points (e.g. Walta et al., 2005). Currently, these driving forces mainly seem to apply to several in-car safety and comfort systems, and user needs and acceptance play a major role in determining the unique selling points of a product. A highly institutionalized example in this respect is the EuroNCAP program, among others backed by consumer organizations, which gives a safety rating to new car models. Furthermore, regulations can guarantee sales of particular systems, and as such influence profit. On the negative side, liability issues play a role in the automotive industry's deployment decisions, which could possibly be resolved by agreements on liability distribution. Currently, this mainly limits the deployment of ADAS that completely automate a part of the driving task, and causes safety systems to be sold as comfort systems.

Influencing public authorities' actions

As a technology regulator, their decisions are mainly aimed at influencing the ADAS market. They can influence user decisions, for instance, by increasing the observability of an ADAS through launching an awareness campaign, or by increasing the relative advantage of an ADAS through providing tax reductions to vehicles equipped with an ADAS. This indirectly influences automotive industry decisions. At the same time, they can influence the automotive industry directly, for instance, by mandating the equipment of new vehicles with ADAS by law.

Walta et al. (2005) showed that the most important driving forces of public authorities to regulate ADAS are traffic efficiency (or throughput), safety, and cost savings. Environmental issues were not reported as a driving force in this study, which is probably due to the relatively small expected contribution of ADAS to reduction of fuel usage, and emissions of CO_2 and NO_x (e.g. Alkim et al., 2007; Carsten and Tate, 2005). However, dedicated in-car systems for reduction of fuel usage and emissions potentially result in considerable emission reductions (Klunder et al., 2009).

Public authorities' decisions can be influenced by the decisions of other actors, because the decisions of these actors potentially influence the objectives of public authorities. For example, if an ADAS has a positive effect on traffic throughput at a certain deployment rate, and this deployment rate is achieved by market deployment (i.e. the automotive industry and users as the only decision-makers), the objectives of public authorities are met without any interference in deployment. Furthermore, it is anticipated that the decisions by public authorities will be influenced in the same way as the decisions they expect the other actors to make, as a reaction to their decision.

Influencing insurance companies' actions

Insurance companies offer vehicle indemnity insurance against a premium that is based on accident statistics. In order to be able to cover risks effectively, and offer a competitive product, premiums are usually differentiated by characteristics that particularly influence accident statistics, such as age, type of car, and city of residence. Their main driving forces are likely to be the same as for the automotive industry, those of profit, competitive advantage and unique selling points. As such, insurance companies could be interested in stimulating deployment of ADAS with proven safety impacts, by lowering premiums for cars with that ADAS. In the first stages of ADAS deployment, insurance companies could financially benefit from the increased road safety, while no statistics are yet available on which to base premium differentiations. In the later stages, when accident statistics are available that include the impact of ADAS, this effect will be leveled out by competition. When accident statistics are not yet available, and the impacts of ADAS on accidents are still uncertain, insurance companies can offer insurance against flexible premiums, based on monitoring of the main aspects of driving behavior that are of influence on accident risk. This type of insurance policy is relatively new, and related to flexible insurance premiums by mileage (i.e. pay-as-you-drive; Litman, 2005).

Remarks

The conceptual model does not explicitly address the influence of external developments on the actions taken by users, public authorities, the automotive industry, and insurance companies. The influence of external developments is acknowledged, but was considered subordinate to the focus on the interactions between the actors.

3.3 Actor and user decision-making in ADAS deployment

The conceptual model of actors' interactions in ADAS deployment presented in Figure 3.2 is the basic starting point for the investigation described in this dissertation. In this conceptual model, the actors are represented as 'black boxes', with the deployment rate and other actors' deployment actions as input, and the actor's own deployment actions as output. In these boxes, we assume some form of decision-making takes place.

In order to explore possible combinations of deployment actions with the conceptual model, it is necessary to establish mathematical models of actor decision-making in ADAS deployment, as building blocks of an overall mathematical model of actors' interactions in ADAS deployment. To that end, it is first necessary to define conceptual models of actor decision-making in ADAS deployment. These conceptual models are based on theories of human decision-making. Different models are defined with regard to decision-making by two groups of actors that can be classified as business organizations (public authorities, the automotive industry, and insurance companies), and users. This distinction is made since they have different types of potential deployment actions, and are influenced in a different way by the deployment rate, and the actions of other actors.

3.3.1 Theories of human decision-making

Generally speaking, human decision-making can be analyzed as a mental process that takes place between a situation in which taking action is desired, and the actual action taken as the outcome of the process. Many disciplines in science, such as economics, mathematics, management science, and behavioral sciences, have studied human decision-making for different purposes. These purposes can generally be characterized as 'how should people make decisions' (*normative*), 'how people actually make decisions' (*descriptive*) and 'how can we help people make better decisions' (*prescriptive*) (Bell et al., 1988). Theories have been developed that assume a conscious decision process (i.e. people deliberately decide on whether or not to take a certain action), as well as assuming an unconscious decision process (i.e. people act instantaneously, based on intuition or experience; e.g. Klein, 1999). These theories apply to different decision situations, and on different types of decision-makers. For example, driving a car involves many ‘automated’ decisions that involve no conscious decision process, whereas deciding to build a new infrastructure project does.

It is assumed here that ADAS deployment actions are generally based on a conscious decision process. For public authorities, the automotive industry, and insurance companies, deployment actions involve long-term decisions that influence the future of these organizations, which is assumed to induce deliberate decision-making. Users are expected to be heterogeneous with respect to buying an ADAS on their new car. It may depend on the amount of money they have available, or their personal style of decision-making, as to whether or not a conscious or unconscious decision process applies to their behavior. It is assumed, though, that a conscious decision process applies to the majority of users when buying a car.

A widely used theory employed to study decisions is that of rational decision-making. This theory is rooted in economics, and assumes perfect knowledge of alternative courses of action, consequences, and external forces, and also assumes that decision-makers choose the alternative that maximizes their utility (e.g. Von Neumann and Morgenstern, 1944). While this theory generally performs well in describing decision situations, it has been criticized. Consequently, other theories have been developed, mainly rooted in psychology, that aim to better describe actual decision-making. Examples are Prospect Theory (Kahneman and Tversky, 1979), and the Theory of Planned Behavior (Azjen, 1991). Some of these theories build upon the general framework of rational decision-making, while others have developed completely new theories.

McFadden (1999) introduces the conceptual model presented in Figure 3.2, which describes rational decision-making, integrated with elements from psychology. The bold arrows link the elements included in rational decision-making. The other arrows link the elements that influence rational decision-making from a psychological point of view.

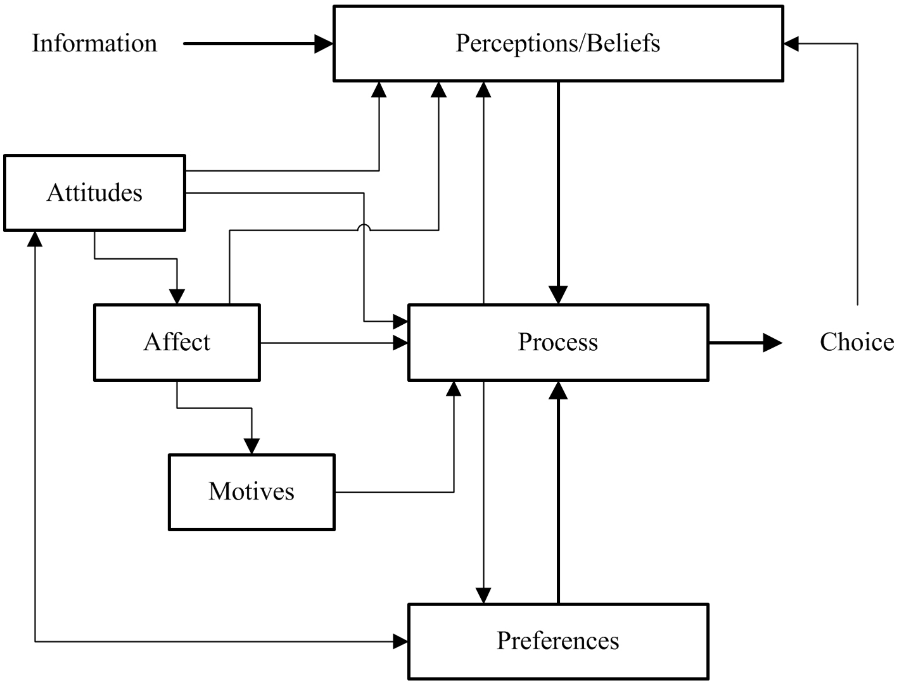


Figure 3.2: Elements in the decision process and their linkages
Source: McFadden (1999)

In rational decision-making, the decision-maker makes a *choice* as an outcome of the *decision process*. This process is influenced by the *perceptions* and *beliefs* of the decision-maker, and his *preferences*. McFadden (1999) defines perceptions as the cognition of sensation, beliefs as mental models of the world, and preferences as comparative judgments about entities. The perceptions/beliefs are influenced by *information*. The elements of psychology that can influence perceptions/beliefs, the decision process and preferences are *attitudes*, *affect* and *motives*. McFadden (1999) defines attitudes as stable psychological tendencies to evaluate particular entities with favor or disfavor, affect as the impact of the emotional state of the decision-maker, and motives as drives directed towards perceived goals. Besides the influence of these elements on rational decision-making, some feedbacks are also included, based on the psychological point of view. The arrows depicting these feedbacks refer to the reconciliation and rationalization of trial choices (McFadden, 1999).

3.3.2 Actor decision-making

Classical economic theory describes organizations as rational decision-makers, who choose between alternative courses of actions based on utility maximization, in order to achieve their objectives. In this they may need to make trade-offs between multiple objectives. Nelson and Winter (1982) emphasize that this theory does not give an explanation for economic change, possibly induced by innovations. They introduce the evolutionary theory of economic change, in which they argue that in the case of innovation, utility maximization is impossible. The behavior of business organizations according to this theory is related to the work of Simon (1979), who argues that in these business organizations there is no perfect knowledge of alternative courses of action, consequences, and/or external forces. He introduced the concept of ‘bounded rationality’ (Simon, 1955), in order to better describe actual decision-making than by the assumption of perfect rationality. Rationality is bounded if there is no perfect knowledge, which means that not all alternatives are known, consequences cannot be precisely calculated, and there is uncertainty about the occurrence and influence of external forces. Consequently, decision-makers search for alternatives that fit their objectives well enough, i.e. they show ‘satisficing’ decision behavior as opposed to utility maximizing. From the available theories on organizational decision-making, Simon (1979) also concludes that perfect rationality in decision-making could occur by organizational learning from recurrent decisions. Beach and Connolly (2005) also give the example of insurance companies who act rationally in premium calculation, usually based on risks retrieved from accident statistics. Insurance companies may be the only types of organizations who have such perfect and detailed information as input to their decision-making. However, this does not apply to decision-making with respect to ADAS deployment, since statistics are not yet available in that area.

Decision-making of actors regarding ADAS deployment is very likely to be boundedly rational. First of all, the consequences of ADAS deployment cannot yet be determined unambiguously. Many of the consequences will depend on factors such as the specific design and parameter settings of the ADAS, the ADAS deployment rate, and the behavioral adaptation of users to the system in the long term. Second, since multiple actors can influence these factors, these can prove to be non-controllable for an individual actor. Third, research on ADAS shows that the actual consequences are not yet known in sufficient detail. While ongoing research may reduce uncertainties, the actual consequences will probably remain uncertain until deployment of the ADAS takes effect. Thus, generally, actors in ADAS deployment make their decisions based on bounded rationality.

Since the decision process of actor decision-making is considered to be rational, the conceptual model of actor decision-making in Figure 3.3 is based on the main conceptual model of rational decision-making. The assumption that actor decision-making is boundedly rational, is reflected in the individual perceptions and beliefs of the actors.

General information relevant to ADAS decision-making is expected to be available to the actors, shaping their perceptions and beliefs. However, the focus in this dissertation is on specific information regarding ADAS deployment: the ADAS type, the deployment rate of this ADAS, and the deployment actions that are currently taken by the actors.

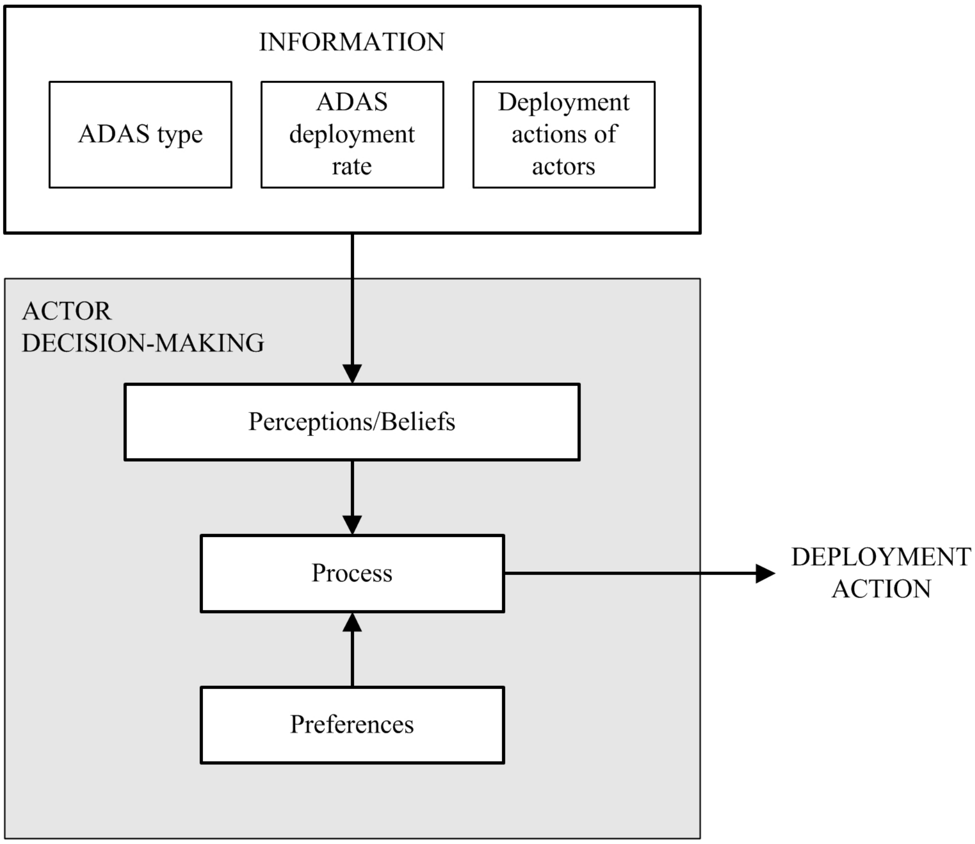


Figure 3.3: Conceptual model of actor decision-making regarding ADAS deployment

Differences with respect to decision-making are expected to exist between the actors – public authorities, the automotive industry, and insurance companies. First, the primary objectives of these actors are different. Thus industry and insurance companies have as a primary goal to sell products that generate profit, and to hold a competitive advantage which keeps the company in business, while public authorities in transport aim to keep the transport system running safely, alongside operating with costs as low as possible (e.g. Walta et al., 2005). Second, each of the actors will view the user, who in the end decides whether or not to adopt the ADAS, in a different way. The automotive industry and insurance companies mainly view the user as a customer, while public authorities view the user as an entity in the transport system, as well as a member of society. These differences imply that the actors apply different courses of actions, have different preferences, but also a different mental model, by which they relate courses of action to consequences.

A final remark concerns whom best to consider as the decision maker, the organization, or (specific) members of the organization. Here, the notion is followed, as described by Nelson and Winter (1982), that behavior of individual members of an organization is a metaphor for the behavior of an organization.

3.3.3 User decision-making

In transport science, user decision-making has been much more studied than decision-making by transport organizations. Consequently, common theories and methods regarding user decisions are more readily available. In the transport sector, random utility theory is widely used to study user decisions, such as route choice, mode choice, and the choice to buy a car (e.g. Cascetta, 2009). This theory describes users as utility maximizing, with part of their utility being unobservable (i.e. random). It is based on rational decision-making. The question is, however, to what extent user behavior is fully rational with respect to buying an ADAS on a new car. For example, since ADAS are an innovation, it can be expected that so-called early adopters mainly decide based on attitude, rather than on a fully rational decision process. On the other hand, user choice behavior can be heterogeneous with respect to their decision processes, so that different models could apply to describe their overall choice behavior.

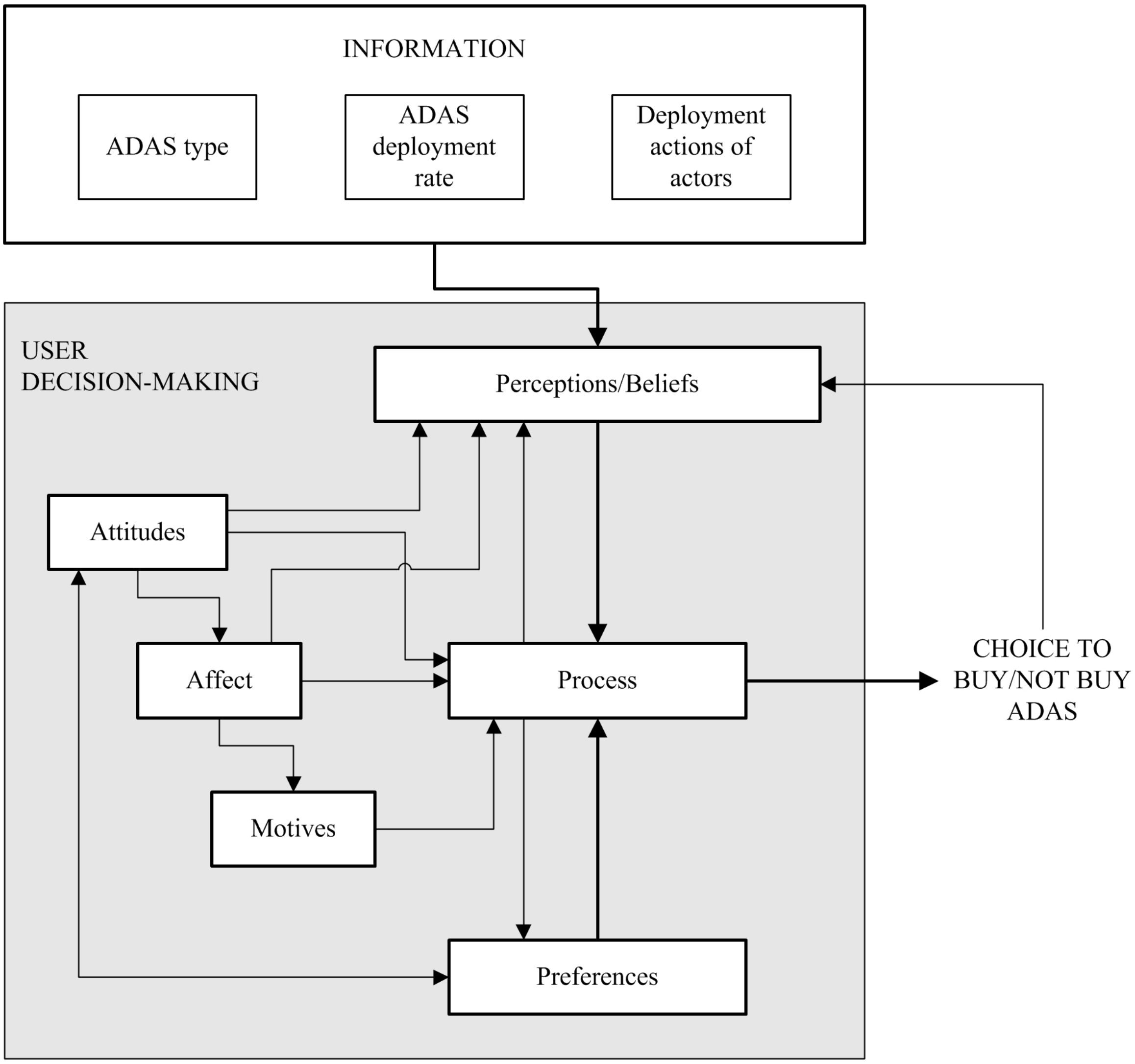


Figure 3.4: Conceptual model of user decision-making regarding ADAS deployment

McFadden’s models provide the opportunity to describe different methods of decision-making, and were therefore adopted here as the conceptual model for user decision-making in

ADAS deployment (see Figure 3.4). General information relevant to ADAS is expected to be available to the users, shaping their perceptions and beliefs. However, the focus in this dissertation is on specific information regarding ADAS deployment: the ADAS type, the deployment rate of this ADAS, and the deployment actions that are currently taken by the actors.

3.4 Conclusions

In this dissertation, ADAS deployment is viewed as a system of actors' interactions. A conceptual model of this system was developed in order to study the probability of different deployment scenarios, consisting of deployment actions of public authorities, the automotive industry, insurance companies, and the probability that users will buy an ADAS on their next new car, given these deployment scenarios. This conceptual model is based on several assumptions about the interactions between actors. Underlying models of actor and user decision-making, based on existing theories of human decision-making, serve as building blocks for this conceptual model. To define these models, an existing conceptual model was used, that combines traditional rational decision-behavior, with contemporary insights about decision-making taken from psychology (McFadden, 1999). The conceptual model of actor decision-making is based on the assumption of bounded rationality. Individual user decision-making is expected to be less rational and more heterogeneous. Both conceptual models were specifically set-up to fit in the overall system model of ADAS deployment decision interactions.

4 Methodology to investigate actors' interactions in ADAS deployment

How can the model of actors' interactions in ADAS deployment be translated into a measurable form? How can it be measured in order to explore various deployment scenarios for ADAS? This chapter introduces the methodology, in order to investigate the relations between the actors in the model of actors' interactions in ADAS deployment. A mathematical model of actors' interactions in ADAS deployment is introduced, consisting of a stochastic model of actors' interactions, and underlying models of actor and user decision-making. These underlying models can be estimated based on empirical data, and serve as input to simulations of deployment scenarios with the stochastic model. The main challenge is to model the influence of deployment actions on actor and user decision-making. To this end, an application of Stated Preference modeling is proposed, specifically designed for this purpose.

4.1 General

This chapter answers the research questions with respect to the mathematical representation of the model of actors' interactions in ADAS deployment, and the methodology to perform investigations with this model. With the resulting methodological approach, the research question can be answered, with respect to the effects of expected actor deployment actions, on the probability that users will buy an ADAS on their next new car.

4.2 Methodological approach

Since existing methodologies to investigate actors' interactions are connected with models that are different from the conceptual model of actors' interactions in ADAS deployment, it is necessary to develop a new methodology connected with this model. This methodology aims at estimating the relations in the model by means of empirical data on actors' interactions, and simulating various deployment scenarios to explore the probability that users will buy an ADAS on their next new car. This approach consists of three main steps:

Step 1: Definition of an overall mathematical model of actors' interactions in ADAS deployment, and the models of actor and user decision-making as its building blocks;
Step 2: Estimation of the models of actor and user decision-making;
Step 3: Simulation of relevant deployment scenarios to explore the probability that users will buy an ADAS on their next new car, based on expected actor deployment actions regarding ADAS.

4.2.1 Step 1: Definition of an overall mathematical model of actors' interactions in ADAS deployment

It was decided to focus specifically on the deployment actions of actors and their interactions in this dissertation. To this end, the original model of actors' interactions in ADAS deployment was reduced, by removing the feedback relation from deployment rate to the actors, and the feedback relation from the users to the actors (See Figure 4.1).

The consequences of removing these relations are that, with respect to the deployment rate feedback, only one time step can be considered in the simulations; and that user acceptance of deployment actions has to be taken into account implicitly. In a later stage, when and if the reduced model is validated, these relations may be added. Consequently, this stage will not be considered any further in this dissertation.

The resulting conceptual model, presented in Figure 4.1, is the starting point for the empirical studies in this dissertation. The relations in this conceptual model represent the deployment actions taken by the actors, and their influence on the other actors. In order to simulate different ADAS deployment scenarios, the conceptual model should be translated into a mathematical model. If all reactions of the actors to each others' deployment actions would be exactly known, this mathematical model could be deterministic. However, since future actions are explored, there are a number of uncertainties, such as the uncertainty of how actors will react. The conceptual model, therefore, was translated into a stochastic model. The output of this stochastic model includes the probability that deployment scenarios occur, and the probability that users will buy an ADAS on their next new car, given a certain deployment scenario. Mathematical models of actor and user decision-making, based on the respective conceptual models, were used as building blocks to this stochastic model.

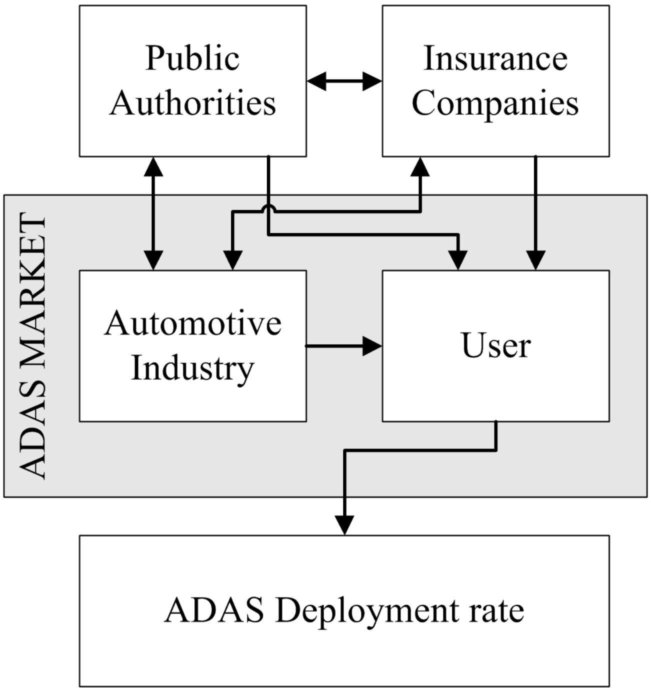


Figure 4.1: Reduced model of actors' interactions in ADAS deployment

In order to estimate the relations within the conceptual model, empirical data of these relations are required. It was decided to separately study actor and user decision-making. This is possible since the users have no two-way relation with the actors in the conceptual model, and it allows us to focus specifically on the different types of actions of actors and users.

4.2.2 Step 2: Estimation of the models of actor and user decision-making

Interactive actor deployment decision-making

A common approach to the study of decision-making is by modeling preferences or choice behavior of the group or person of interest. The available alternatives are translated into a number of common attributes (e.g. costs, functionalities, color), which have a different value across alternatives. The models resulting from the investigation then show the influence of each of the attribute values on the overall preference, or the choice of a decision-maker for a specific alternative. In the transport field, preference and choice modeling are applied to investigate route choice (e.g. Chorus et al., 2007), choice for mode of transport (e.g. Hensher and Rose, 2007), and preferences for new technologies (e.g. Marchau, 2001).

In this particular case, the main interest is to model the influence of other actors on actor deployment actions. This knowledge is also needed for the second phase, in which the interaction between actors is further analyzed. This means that deployment actions of the other actors will be included as attributes in the investigation. This is comparable to modeling household decision-making, in which the preferences of other household members are included as an attribute (Molin, 1999).

User deployment actions

The output needed from the investigation of user deployment actions is the probability that they will buy an ADAS on their next new car, given the deployment actions of the actors. This gives a first indication of the possible development of the ADAS deployment rate.

Ideally, the development of the ADAS deployment rate would be based directly on the deployment actions of the actors. The development of the deployment rate of an innovation that is on the market is often represented by an s-shaped curve. Several mathematical models are available, all based on different assumptions regarding the process of adoption (e.g. Mahajan and Peterson, 1985). These models can be estimated based on historical data of adoption of the innovation, and can as such be used to study diffusion of past innovations, or forecast adoption of current innovations. When historical data are not available, assumptions have to be made in order to make forecasts. For example, Collantes (2005) interviewed relevant actors on their forecasts of adoption of fuel cell vehicles, and used these data to estimate an adoption model.

With regard to the adoption of ADAS, there are some specific circumstances that have to be taken into account. First of all, ADAS generally are embedded in vehicles, and therefore are not an independent innovation. This means that the adoption rate is influenced by vehicle life cycles, and the exchange rate of older vehicles by new ones. There are though some exceptions, such as nomadic devices and retrofitting of ADAS. A second circumstance is that adoption of ADAS can be influenced substantially by different deployment options of actors, such as mandatory or standard equipment of all new vehicles (e.g. Abele et al., 2005).

Since the information on how users will react to ADAS deployment options is limited, empirical data is needed on users' decisions whether or not to buy an ADAS on their new car. To this end, a *Stated Preference* approach will be applied to model user decision-making. The resulting user models may be used as input to models of ADAS deployment development, but this is not further addressed in this dissertation.

4.2.3 Step 3: Simulation of deployment scenarios

The results of step 2 include the probabilities that actors take certain deployment actions, given the deployment actions of other actors, and the probabilities that users will buy an ADAS on their next new car, given the deployment actions of the actors. In step 3, these results are combined to explore different deployment scenarios, using the stochastic model of actors' interactions in ADAS deployment defined in step 1. Deployment scenarios consist of combinations of deployment actions for the three actors, public authorities, the automotive industry, and insurance companies. In departing from different starting conditions (i.e. combinations of current actor deployment actions), the probability of occurrence with regard to deployment scenarios will be calculated. This results in a probability distribution over deployment scenarios, for each starting condition. The deployment scenarios can be described in terms of the probability that users will buy an ADAS on their next new car. As such, the overall results will represent a probability distribution over probabilities that users will buy an ADAS on their next new car.

4.3 Stochastic model of actors' interactions in ADAS deployment

The conceptual model of actors' interactions in ADAS deployment was translated into a stochastic model. The purpose of this stochastic model is to study the probability of occurrence of multiple deployment scenarios for an ADAS – combinations of deployment actions of the main actors – and the probability that users will buy an ADAS on their next new car, given these deployment scenarios.

4.3.1 Stochastic model

The following definitions introduce the variables included in the mathematical model of the deployment scenarios. These are the *actors*, public authorities, the automotive industry, and insurance companies, the *deployment options* of these actors, such as doing nothing, a tax reduction by public authorities or a premium reduction by insurance companies, and the *deployment scenarios*. The deployment options become deployment actions, once they are applied by the actors. For simplicity, but without loss of generality, we assume that the interaction structure is the same for each ADAS system, and that each actor has the same number of deployment options. The following notation is used for a generic ADAS system:

n_a = number of actors;
n_d = number of deployment options of an actor.

The deployment scenario D_t describes the deployment actions of the different actors with respect to an ADAS system at discrete time instant *t*. It is represented by a n_a dimensional stochastic vector:

$$D_t = [D_{t,1},...,D_{t,n_a}] \tag{4.1}$$

Each actor takes deployment actions that are specific to the actor. $D_{t,a}$ can take the value of one of the deployment options of actor *a*, i.e. *the sample space S_a of $D_{t,a}$* is:

$$S_a = \{d_1(a),...,d_{n_d}(a)\} \tag{4.2}$$

Consequently, the *sample space S of D_t* is:

$$S = S_1 \times ... \times S_{n_a} \tag{4.3}$$

In this model one time step is considered, from a starting condition at *t=0* to an updated deployment scenario at *t=1*. This time step represents the possibility for each of the actors to reconsider their deployment action at *t=0*, given the deployment actions of the other actors at *t=0*. The resulting deployment scenario at *t=1* is input to reactions of the users.

At time *t=0*, the probabilities of deployment scenario occurrence satisfies the following condition:

$$\sum_{x \in S} P(D_0 = x) = 1 \tag{4.4}$$

in which *x* is the outcome of the stochastic variable D_0, and a vector of the deployment actions x_a of all actors at time *t*=0:

$$x = [x_1,...x_{n_a}] \tag{4.5}$$

At time *t=1*, all actors can react to the outcome *x* of the initial deployment scenario D_0. The probability of *y* as outcome of the resulting deployment scenario D_1 is:

$$P(D_1 = y) = \sum_{x \in S} P(D_1 = y \mid D_0 = x) P(D_0 = x) \tag{4.6}$$

for which the following condition is satisfied:

$$\sum_{y \in S} P(D_1 = y \mid D_0 = x) = 1 \tag{4.7}$$

in which y is a vector of the deployment actions y_a of all actors at time $t=1$:

$$y = [y_1,...y_{n_a}] \tag{4.8}$$

The conditional probability of D_1, given D_0, is the product of the probabilities of the actors' deployment actions y_a in D_1, given D_0 , while assuming that these actions are independent:

$$P(D_1 = y \mid D_0 = x) = \prod_a P(D_{1,a} = y_a \mid D_0 = x) \tag{4.9}$$

for which the following condition is satisfied:

$$\sum_{y_a \in S_a} P(D_{1,a} = y_a \mid D_0 = x) = 1 \tag{4.10}$$

in which $P(D_{1,a}=y_a|D_0=x)$ is the probability that actor a takes deployment action y_a in deployment, given deployment scenario x. This probability is calculated based on empirical data.

The choice of the users to buy an ADAS on their next new car is described by a binary stochastic variable C, where 1 indicates that the user chooses to buy an ADAS. The probability that the user chooses to buy an ADAS is assumed to depend on the decisions made by the actors at time $t=1$. Consequently, the probability that the user chooses to buy an ADAS is:

$$P(C = 1) = \sum_{y \in S} P(C = 1 \mid D_1 = y) P(D_1 = y) \tag{4.11}$$

in which $P(D_1=y)$ follows from (4.6). For a single starting condition $D_0=x$, the probability that the user chooses to buy an ADAS is:

$$P(C = 1 \mid D_0 = x) = \sum_{y \in S} P(C = 1 \mid D_1 = y) P(D_1 = y \mid D_0 = x) \tag{4.12}$$

in which $P(C=1|D_1=y)$ is the probability that the user chooses to buy an ADAS, given deployment scenario y. This probability is calculated based on empirical data.

4.3.2 Simulation of deployment scenarios based on the stochastic model

Figure 4.2 shows how deployment scenarios can be simulated with this model, and explains the outcomes in terms of the probability that users will buy an ADAS on their next new car, and the probability that decision scenarios occur that lead to this particular probability.

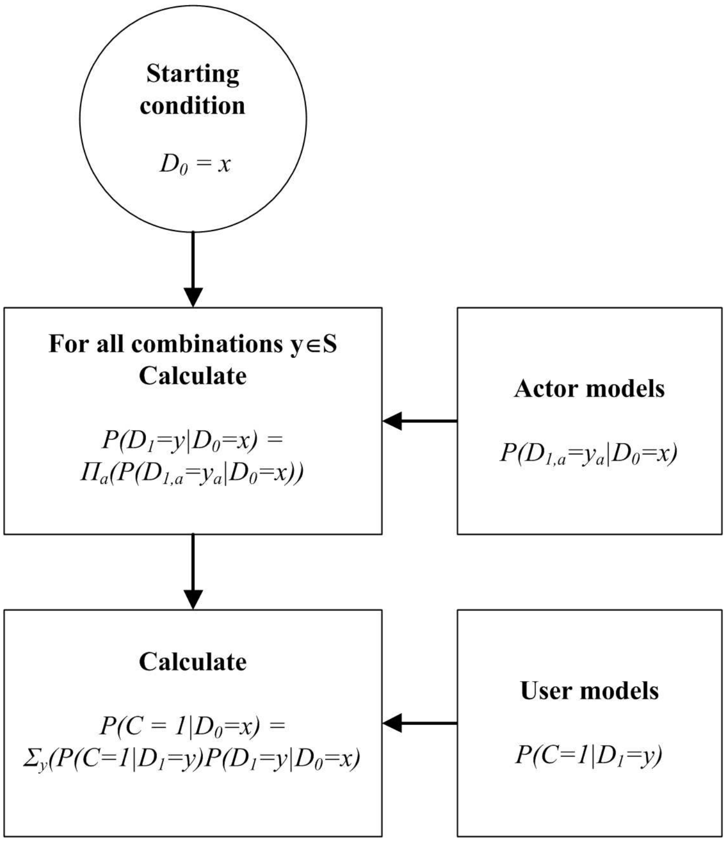


Figure 4.2: Simulation of deployment scenarios

The actor and user models are based on theoretically assumed interactions among actors, and between the actor and the user. Before simulations can be performed with this model, these interactions first need to be determined by empirical data.

These empirical data include the conditional probability $P(D_{1,a} = y_a|D_0=x)$ of the actors' deployment options applied to ADAS, and the conditional probability $P(C=1|D_1=y)$ of users' choice for an ADAS. For both probabilities, the underlying models are defined in the following sections. The necessary data to estimate these models are collected by an actor and a user survey. The different strategies that are present among actors are identified based on an analysis of the results of the actor survey.

4.4 Modeling actor decision-making to take ADAS deployment actions

The main aim of the actor study included in this dissertation is to derive the probability that actors take a certain deployment action with respect to ADAS, for different initial deployment scenarios. Stated preference modeling is applied to model the influence of different deployment scenarios on the probability that actors apply a certain deployment option. The mathematical model used in this investigation is introduced here. It is based on the conceptual model of actor decision-making regarding ADAS deployment presented by Figure 4.3 (for an explanation of this model, see Chapter 3).

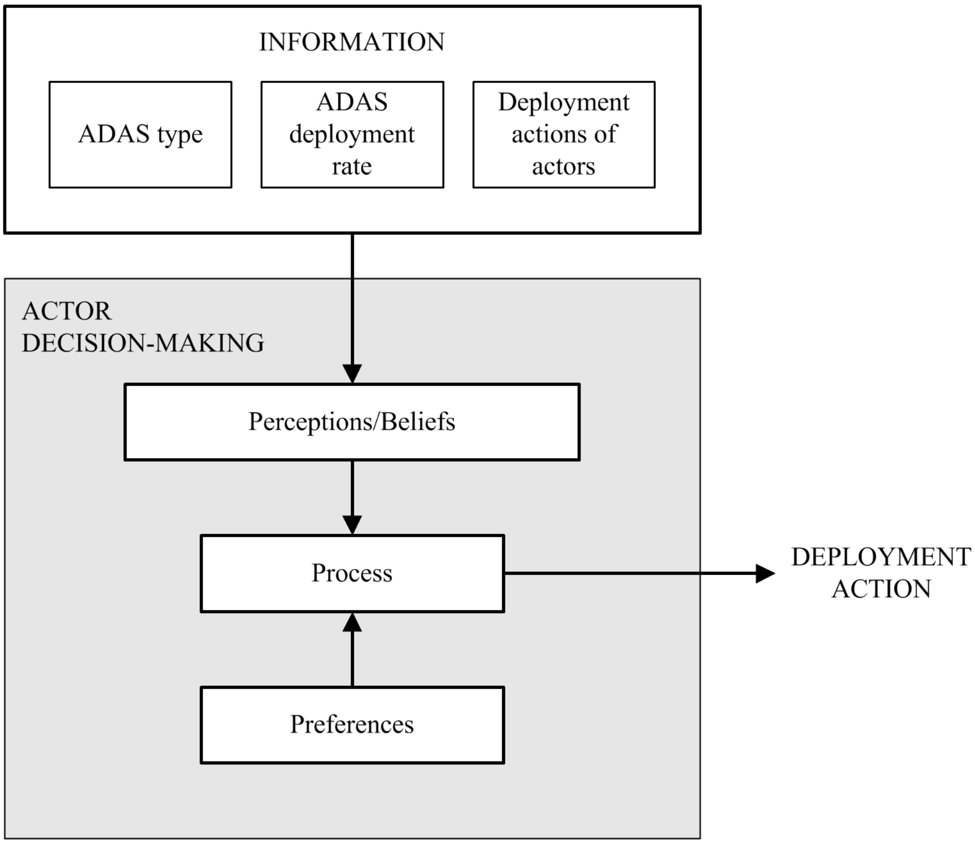


Figure 4.3: Conceptual model of actor decision-making on ADAS deployment

4.4.1 Specification of the model

The purpose of the mathematical model described in this section is to establish a mathematical relationship between the input and the output of actor decision-making in ADAS deployment. The inputs to be explicitly considered are the current deployment actions of all actors. For simplicity, the model is specified for a single ADAS type. Furthermore, the deployment rate is only implicitly taken into account, based on the actors' beliefs of the effect of the current deployment actions on the deployment rate. The outputs to be explicitly considered are the probabilities that certain deployment actions are taken by the actors.

Stated preference modeling

The mathematical relation between the defined input and output can be established by stated preference modeling. This method requires a number of deliberately chosen alternatives (input) to be evaluated by respondents (output). These alternatives are represented by a number of characteristics (i.e. attributes) that can take different values for each of the alternatives (i.e. attribute levels). The alternatives are defined here as the deployment scenarios at time $t=0$, the attributes as the deployment actions of the actors, and the attribute levels as the possible deployment actions for each of the actors (see Figure 4.4). The respondents' evaluations involve attaching a certain value to possible deployment options, out of which they can choose their deployment action. These evaluations form the data based on which the mathematical relation between the input and the output can be estimated. These data are usually collected by structured questionnaires completed by relevant respondents.

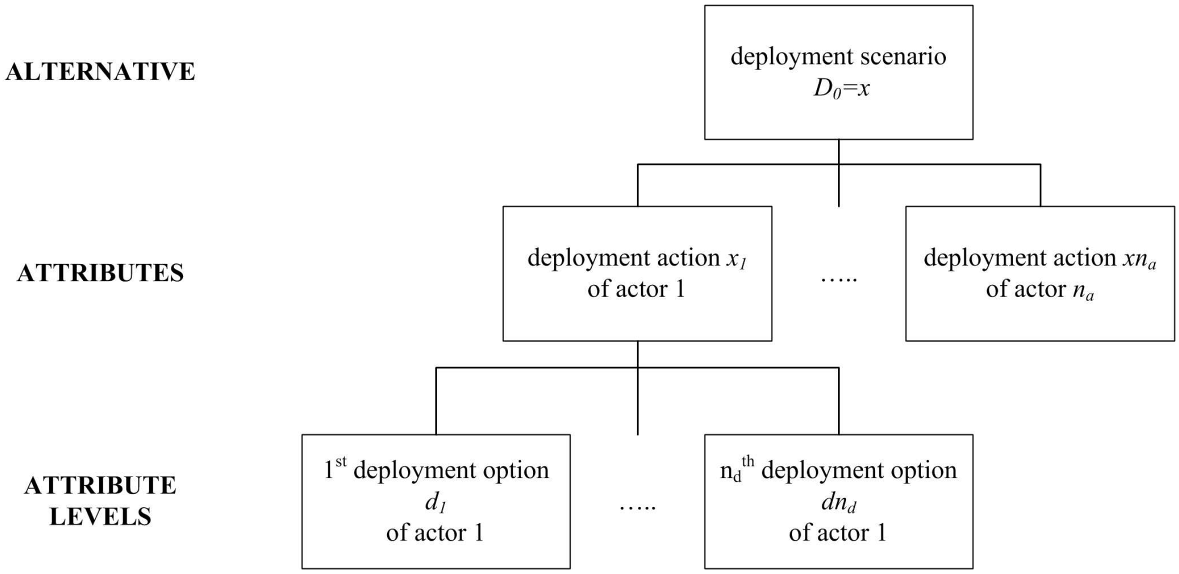


Figure 4.4: Relation between alternatives, attributes, and attribute levels for actor survey

There are different types of mathematical models that can be applied in stated preference modeling, of which *choice models* and *utility models* are most widely used. The type of mathematical model chosen depends on the required output of the model. In this case, the required output is the probability that an actor takes a certain deployment action with respect to an ADAS. This type of output can be provided by using a choice model, such as a logit model (e.g. Train, 2009). The estimation of a logit model requires discrete choice data, and is performed by logistic regression. In this case, these choice data would involve the choice for a certain deployment action out of all possible deployment options, for each of the presented deployment scenarios. Simulation of deployment scenarios with this model would then result in the probability that deployment actions will be taken. However, the number of potential respondents among ADAS actors is not expected to be large enough to generate a sufficient amount of choice data to estimate such a model.

Instead of a choice model, a utility model is considered. Due to the type of data, in the case of the rating of each deployment option for each of the presented deployment scenarios, the required amount of data to estimate such a model can be smaller than for a choice model. A utility model can be estimated for each single deployment option, based on (utility) ratings of the deployment options for each deployment scenario, using (multi)linear regression. Simulation of deployment scenarios with the utility models of the deployment options results in the utility of these deployment options. In theory, probabilities can be calculated as a function of utilities. However, the utility ratings of the deployment options for each deployment scenario are relatively independent, which could result in inaccurate probabilities calculations based upon these ratings (e.g. the sum of probabilities of deployment options for one deployment scenario could exceed 100%). The following approach, therefore, is applied to determine the probabilities of deployment options.

Based on the assumption that a positive relation exists between utility and probability (i.e. the higher the utility of an alternative, the higher the probability that this alternative is chosen), a generic utility model is applied, in which probability is used as a measurement unit instead of utility. The advantage of this approach is that the (probability) ratings could be made dependent, by the requirement that the sum of the probabilities of all deployment options for each deployment scenario should equal 1.0.

When investigating actors as decision-makers, it can be argued whether the actor should be considered an individual, an organization, or even a sector (e.g. the automotive industry can be considered as a sector, consisting of many companies, in which many individual persons operate). At the level of ADAS deployment studied in this investigation, the main interest is in the probability of deployment actions at a *sector* level. However, the expectations of individual respondents of what the sector will do may not match their personal preferences. In order to investigate this, modeling also took place at an individual level, using basic utility models.

Possible extensions of the model

The above specification results in a basic model, considering the relation between deployment scenarios and deployment actions, in which actor decision-making is not further specified. Including more elements of actor decision-making requires the estimation of more sophisticated mathematical models.

In order to explain potential heterogeneity among actors, the perceptions/beliefs of the actors were considered to be included in the model in terms of the expected impacts of the ADAS on criteria, such as traffic safety, traffic flow and the environment. An elegant way to do this, analytically, is to apply structural equation modeling, which was applied to user preference models for ADAS by Molin and Marchau (2004). In this approach, the respondents would be asked to evaluate their deployment options, for each deployment scenario, on utility/probability, as well as on their expected impacts on criteria. The relation between the expected impacts and the deployment scenario attributes can be estimated. However, this approach requires a large number of respondents to retrieve meaningful results. Given the limited number of potential respondents from the ADAS actor groups, this approach is not feasible for the present study.

Another possible way to integrate the expected impacts in the models, is to use a stepwise approach, consisting of two steps in data collection. In this case, these steps would be (1) the evaluation of the actors' deployment options for each of the deployment scenarios on their expected impacts on criteria, and (2) the evaluation of combinations of impacts decision criteria on their overall utility/probability. Two models would then be estimated from which, by means of substitution, the overall utility/probability of the deployment options can be derived. This approach was tested in a pilot study, which concluded that the respondents' task was too difficult and too abstract to expect meaningful results.

It can be concluded that, given the characteristics of this investigation, it is not feasible to explicitly integrate the expected impacts in the model. Instead, a number of expected impacts on decision criteria were separately measured, based on which differences between actor strategies could possibly be explained (see Chapter 6).

4.4.2 Mathematical model[3]

The probability $P(D_{1,a} = y_a|D_0=x)$ that an actor takes deployment action y_a, given the current deployment scenario $D_0 = x$, is defined as a function f_a of vector of deployment actions [x] currently applied by all actors.

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[3] For notation see 4.3.1.

$$P(D_{1,a} = y_a \mid D_0 = x) = f_a(x) + \varepsilon_1 \tag{4.13}$$

The error term ε in this function refers to the amount of ‘probability’ that cannot be described by the model, for example due to individual differences or attributes that were not included.

Analogously, the utility $U(y_a)$ for an actor of taking deployment option y_a is defined as a function g_a of the vector of deployment options $[x]$ currently applied by all actors:

$$U(y_a) = g_a(x) + \varepsilon_2 \tag{4.14}$$

Several functional forms of f_a and g_a are possible. The simplest functional form is additive, a linear combination of the attributes. Depending on the methodology used to estimate the models, it requires the least amount of data. However, some of the variance that cannot be explained by an additive model, could possibly be explained by adding interaction terms (i.e. products of two or more attributes) to the model. Adding interaction terms substantially increases the amount of data required to estimate the model. While an additive model usually explains most variance (Louviere, 1988), and a smaller amount of data required leads to fewer questions for respondents, and assuming more accurate answers, it is worthwhile to assess the influence of interaction terms. Since the influence of interaction terms depends on the case investigated, the choice for a model is described later in this dissertation, when the deployment scenarios have been further specified.

4.4.3 Estimation of the model

Generally, there are two different approaches to stated preference modeling, a compositional and a de-compositional approach. The compositional approach requires respondents to evaluate separate attribute levels. These data are used to “compose” the evaluation of alternatives, by combining the respondents’ attribute level evaluations using some combination rule. The advantage of this approach is that the measurement task to be performed by the respondents is relatively easy. However, the main drawback is that it does not explicitly take into account potential trade-offs decision-makers make between attributes. The de-compositional approach does take these trade-offs into account, using conjoint measurement of attribute levels. The respondents are required to evaluate (hypothetical) alternatives composed of attribute levels. These evaluations are then analytically decomposed into the evaluations of the different attribute levels. While the task for the respondents is more difficult than for the compositional approach, it is also more realistic, which may have a positive influence on the resulting model.

Applying conjoint measurement to estimate the probability and utility models introduced above means that the measurement of the probability and utility for each deployment action y_a is performed in a survey in which $[x]$ is given. From these measurements, the constants and coefficients included in functions f and g can then be estimated by means of linear regression.

4.4.4 Identification of strategies

All actors are assumed to have a probability distribution of their deployment actions, given a certain deployment scenario. The set of these probability distributions over all deployment scenarios is called the strategy of the actor. The existence of different strategies could be related to differences in background of actors, like country of residence or type of actor (e.g. EU or national public authorities). In addition, however variables that are difficult to measure could play a role, such as experience or (virtual) membership of a coalition of actors with a similar view on ADAS deployment. It was therefore decided to identify groups of respondents with similar strategies based upon similarities in their evaluations of deployment options. The strategies are identified in this dissertation by performing a cluster analysis (e.g. Hair et al., 2006), which groups cases (i.e. individuals who participated in the survey) into clusters of cases with similar values on the measured variables. Applying this procedure to the utility data, also gives additional insights into the preferred strategies of the actors.

4.5 Modeling user decision-making to adopt an ADAS

The aim of the user study included in this dissertation is to derive the probability that users will buy an ADAS on their next new car, for different decision scenarios, and for different ADAS. Similar to the actor investigation, stated preference modeling is applied to model the influence of ADAS and actor deployment actions on the user choice to buy an ADAS. The mathematical model used in this investigation is introduced here. It is based on the conceptual model of user decision-making regarding ADAS deployment presented by Figure 4.5 (for an explanation of this model, see Chapter 3).

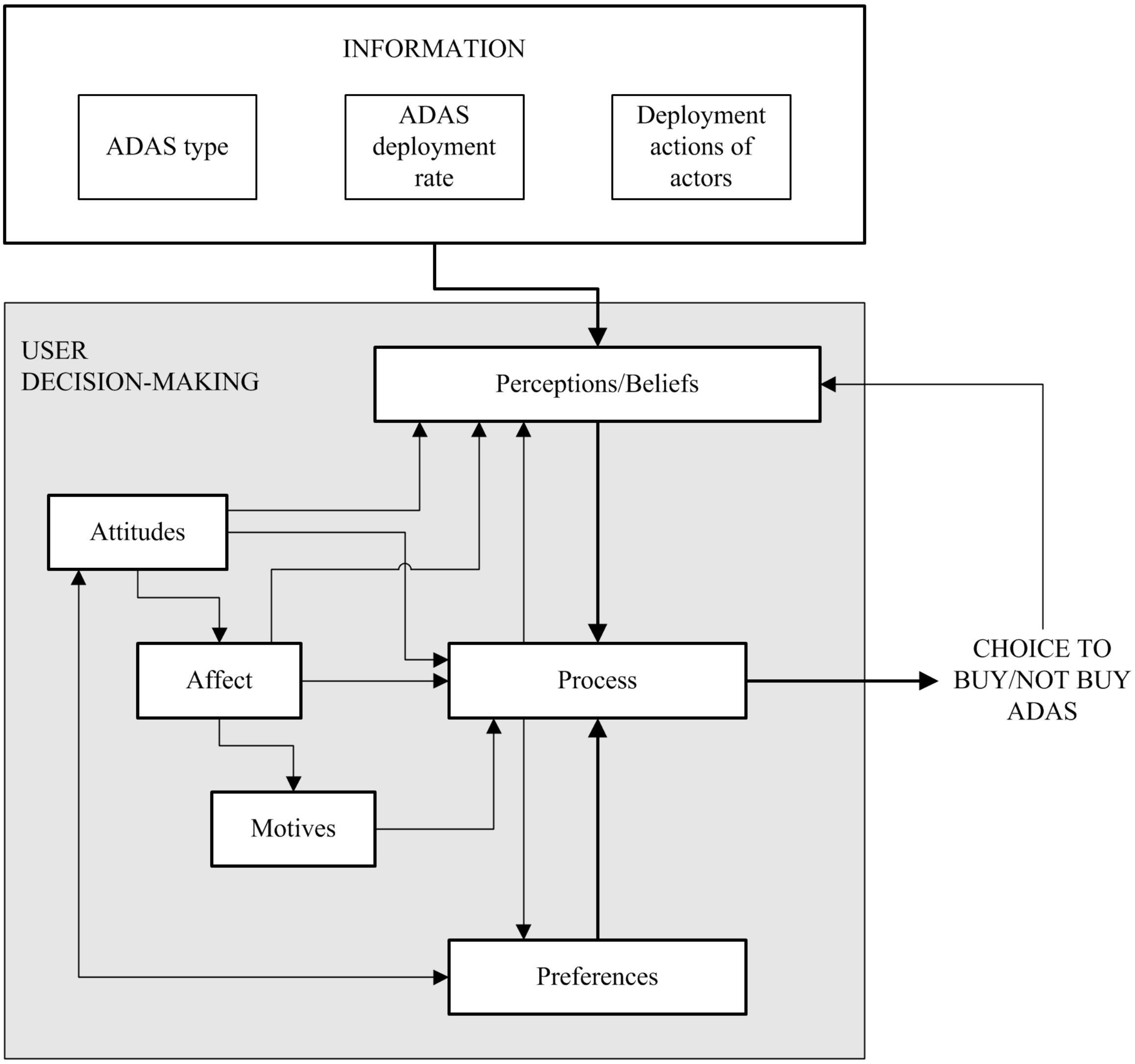

Figure 4.5: Conceptual model of user decision-making regarding ADAS deployment

4.5.1 Specification of the model

The purpose of the mathematical model described in this section is to establish a mathematical relationship between the input and the output of user decision-making in ADAS deployment. The inputs considered are the current deployment actions of all actors. For simplicity, the model is specified for a single ADAS type. Furthermore, the deployment rate is not taken into account, since this is not expected to be deliberately taken into account by users themselves. The outputs to be explicitly considered are the probabilities that users will buy an ADAS on their next new car.

Choice model

Since the main desired output is the probability that users will to buy an ADAS on their next new car, the most appropriate mathematical model is a choice model. Unlike the actor investigation, the number of respondents was expected to be large enough to estimate such a model. Since the output of user decision-making in this case is binary (buy or not buy an ADAS), a binomial logit model can be applied to model these probabilities.

The alternatives are defined here as the deployment scenarios at time $t=1$, the attributes as the deployment actions of the actors, and the attribute levels as the possible deployment actions for each of the actors (see Figure 4.6). The respondents' evaluations involve choosing between buying, or not buying, an ADAS, under the conditions described by the deployment scenarios. These evaluations form the data based on which the mathematical relation between the input and the output can be estimated.

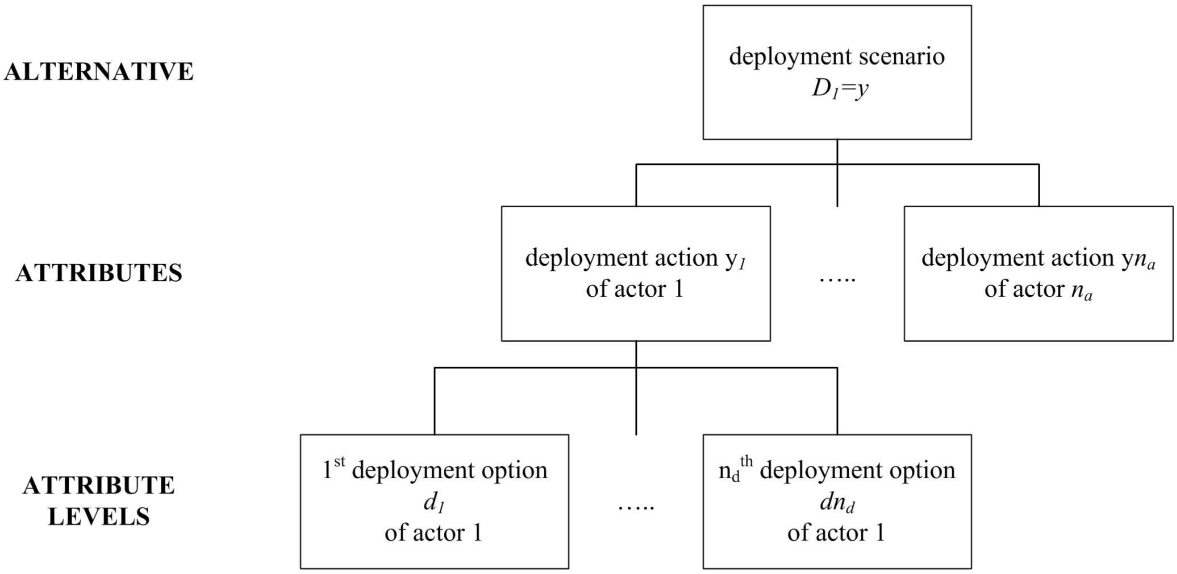

Figure 4.6: Relation between alternatives, attributes, and attribute levels for user survey

It was decided not to include further elements of the choice process within the mathematical model, in order to keep the user questionnaire limited, and to focus on the desired output as input for the stochastic model. In the questionnaire, some questions were included to explain heterogeneity among users (see Chapter 8).

4.5.2 Mathematical model[4]

The probability that users will buy an ADAS on their next new car, given the current deployment scenario *y* is modeled as a binomial logit model in which $V_{0,y}$ represents the observed utility for the user of buying a non-ADAS equipped car, and $V_{1,y}$ the observed utility for buying an ADAS equipped car.

$$P(C=1 \mid D_1 = y) = \frac{1}{1+e^{V_{0,y}-V_{1,y}}} \tag{4.15}$$

When $V_{0,y}$ is considered as the reference point, the value of $V_{0,y}$ is zero. This means the logit model can be reduced to:

$$P(C=1 \mid D_1 = y) = \frac{1}{1+e^{-V_{1,y}}} \tag{4.16}$$

The following condition applies to the binomial logit model introduced here. The actual utility $U_{1,y}$ of buying an ADAS equipped car, given deployment scenario *y*, includes the observed utility $V_{1,y}$ and an error term ε to explain the amount of utility not observed in the choice experiment:

$$U_{1,y} = V_{1,y} + \varepsilon_3 \tag{4.17}$$

When the assumption is made that the error term ε follows a Gumbel distribution (type I), the binomial logit model holds (Train, 2009).

The observed utility $V_{1,y}$ is defined as a function *h* of the vector of deployment actions [*y*] currently applied by all actors:

$$V_{1,y} = h(y) \tag{4.18}$$

In a similar manner to the actor models, different functional forms of *h* are possible. Without testing, it was assumed here that an additive model is appropriate. The background of this assumption is that the deployment actions will mainly influence the price of the ADAS for the user. Since utility is assumed to be objectively (and negatively) related to price, no significant interactions are expected.

Consequently, the model of observed utility V_1 used in this dissertation is additive, including a constant *q* and coefficients r_a:

$$V_1 = q + \sum_a r_a y_a \tag{4.19}$$

4.5.3 Estimation of the model

An analysis similar in type to the actor investigation conjoint analysis is also applied in the case of user investigation. This means that a measurement of choice for an ADAS equipped car is performed in a survey, in which the attributes [*y*] are given, and based on which *q* and r_a are estimated by means of binary logistic regression.

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[4] For notation see 4.3.1.

In order to increase the explained variance of the model, respondent characteristics collected in the survey (such as age, mileage and car price) can be included in the model.

4.6 Conclusions

In this chapter, the methodology is introduced that is designed to answer the empirical research questions of this dissertation. To that end, the model of actors' interactions in ADAS deployment is translated into a stochastic model, with which simulations can be made of different deployment scenarios (i.e. combinations of all actors' deployment actions), resulting in the probability that deployment scenarios occur, as well as the probability that users will buy an ADAS on their next new car, given this deployment scenario. Before these simulations can be made, it is necessary to estimate the relations in this model. To that end, mathematical models were defined of the probability that actors take a certain deployment action with respect to an ADAS, and the probability that users will buy an ADAS on their next new car. These models were based on the conceptual models of actor and user decision-making. They are to be estimated using data from an actor and a user survey.

5 Setting the stage: scenarios for ADAS deployment

Which ADAS are expected to be of interest to public authorities, the automotive industry or insurance companies? In addition, what deployment options are expected to substantially influence user adoption of ADAS? In this chapter, the decision scenarios to be included in the empirical part of the dissertation are specified, consisting of an ADAS, and deployment options applied to it by actors. They are translated into attributes and attribute levels, to be applied in the conjoint measurement tasks to be performed by the respondents in the actor and user surveys.

5.1 Specification of deployment scenarios

As a first step in the empirical part of this dissertation, the deployment scenarios to be addressed are specified. The methodology proposed to perform the actor and user surveys, based on conjoint measurement, puts constraints on the number of deployment decision scenarios that can be addressed. In the following sub-sections, the steps to be taken in conjoint measurement are briefly explained, focusing on the steps that are directly related to the deployment decision scenarios.

5.1.1 Basic steps in conjoint measurement

In both of the surveys, conjoint measurement will be applied to collect data to estimate the actor and user decision models. In general, the following steps need to be taken to set up a conjoint measurement (Molin, 1999):

- Selection of salient attributes;
- Determination of relevant attribute levels;
- Selection of a method to combine attribute levels into profiles;
- Choice of a measurement task for the respondents;
- Choice of a method for estimating utility or preference function;
- Simulation of preferences and choices.

The first two steps are addressed in this Chapter: selection of salient attributes and determination of relevant attribute levels. These specify the deployment decision scenarios addressed by the actor and user surveys. The further steps are addressed in Chapter 6 for the actor survey, and Chapter 8 for the user survey.

5.1.2 Selection of salient attributes

Salient attributes represent important characteristics of the alternatives to be evaluated. The number of attributes included should be sufficient to capture the most important characteristics on the one hand, but should limit the task burden for the respondents on the other, since any additional attribute will exponentially increase the number of questions to be answered in the survey. A rule of thumb regarding the maximum number of attributes is that respondents can generally oversee not more than nine attributes, depending on the case studied (e.g. Hair et al., 2006).

In this case, the alternatives are represented by the initial deployment scenarios, i.e. the combination of current deployment actions taken by public authorities, the automotive industry, and insurance companies (see also Chapter 4). Respondents from public authorities, the automotive industry, and insurance companies are to evaluate their own ADAS deployment options for each of the current deployment scenarios. Respondents from user groups are to choose if they buy an ADAS on their next new car for each of the current deployment scenarios. For them, the deployment scenarios are not specified by the current deployment actions, but by the effects of these deployment actions on the product characteristics that do not reflect ADAS functionality, such as purchase costs.

It is expected that the type of ADAS will influence the actors' and users' evaluations. Consequently, ADAS are included as an attribute, next to the deployment actions. A broad range of ADAS may be investigated by specifying the ADAS into a number of attributes, such as functionality (e.g. distance keeping), level of support (e.g. assisting), and operation (e.g. overrulability). However, since the focus of the investigation is on the interactions between actor decisions, it was decided to confine the selection to one attribute characterizing the ADAS, and to choose carefully the types of ADAS to be included.

In summary, a total of four attributes are included in the investigation: (1) the deployment actions of public authorities, (2) the deployment actions of the automotive industry, (3) the deployment actions of insurance companies, and (4) the ADAS. This is considered a fair number of attributes, with respect to the task burden for the respondents.

5.1.3 Determination of relevant attribute levels

For each of the attributes, a number of *relevant attribute levels* are to be determined, in order to measure the influence of the attributes on the evaluations of deployment options of actors and users. Similar to the number of attributes, there is a trade-off in the number of attribute levels to be included. The higher the number of attribute levels included, the more information is obtained on the functional form of the utility function of the particular attribute. However, more attribute levels also lead to more profiles to be evaluated. In the case of attribute levels that are measured on an interval (or ratio) scale (e.g. price), and if two attribute levels are included, the utility function of the corresponding attribute is necessarily linear. When three or more attribute levels are included, other functional forms can also be captured. This is particularly important if the utility of intermediate levels is required. In the case of discrete attribute levels, intermediate levels cannot be derived, and the attribute levels to be included need to be carefully chosen, in order to capture all situations to be described by the model.

For each of the attributes, it is preferable that all attribute levels are present in the profiles equally often (i.e. a balanced design). If this is not the case, it will result in more observations for one attribute level than for another, which means they have a different probability to become statistically significant. In addition, the value of the model constant may be influenced. The most efficient way to equalize the number of observations per attribute level, is to use the same number of attribute levels for each attribute. To limit the number of profiles to be evaluated, in both the actor and user survey three attribute levels for each attribute were included.

5.2 Selection of deployment options

For each of the actors, public authorities, the automotive industry, and insurance companies, three deployment options are selected. Deployment options are potential courses of action, which can be turned into deployment actions.[5] An ordinal scale of deployment options is applied, based on differences in expected effectiveness. Generally, the deployment options included in the investigation should cover a broad, but realistic, range. For the lower end point of the ordinal scale, the deployment option “do nothing” was included for all of the actors. Herewith, it is implicitly assumed that the actors will not negatively affect user adoption, which may be considered a pro-innovation bias. However, doing nothing is expected to have a sufficiently negative effect on deployment. For the higher end point of the scale, deployment options are chosen that are expected to be most effective to increase user adoption of ADAS, and are still realistic from the point of view of the actor. These are usually deployment options that involve forced adoption, depending on the resources of the actor. The intermediate level then involves some measure to stimulate users to adopt ADAS, without forcing them to do so. In the following sub-sections, the selected deployment options for each actor are described.

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[5] In the remainder of this dissertation, the term deployment options is used when referring to the available options, to which no value has been attached yet. When value is attached to a deployment option, or when it is chosen, this is referred to as the value of, or the choice for, a deployment action.

5.2.1 Public authorities' deployment options

The set of deployment options that is available to public authorities includes doing nothing (and, by doing so, leave deployment to the market), influencing user opinions and awareness by public campaigns, stimulating user adoption by financial incentives (e.g. direct subsidies, tax reductions), and forcing adoption by legislation (e.g. Alkim et al., 2007; Walta et al., 2007). These deployment options can be applied to all motor vehicles, but also to specific target groups such as speed offenders, elderly drivers, young drivers, professional drivers, or truck drivers. Combinations of deployment options are possible as well. The feasibility of the deployment options depends on the resources available to the public authorities. While combinations of deployment options and/or application of deployment options to different target groups are feasible, this investigation is confined to single deployment options for all motor vehicles. This is due to the focus of this investigation on actors' interactions, rather than on the appraisal of feasible deployment options.

The deployment options for public authorities included in the investigation are 'do nothing' as the least intervening option, and 'legislative mandatory equipment of all vehicles' as the most intervening option. For the intermediate option, the main choice is between influencing user opinions and awareness, and providing financial incentives. These options were perceived as being of equal effectiveness by stakeholders interviewed in the eIMPACT project (Alkim et al., 2007). However, when respondents from different actors were asked which option respondents would apply to stimulate ADAS deployment, financial incentives were more often mentioned as a stimulation measure than awareness campaigns (Walta et al., 2007). Financial incentives are a more tangible deployment option, of which effectiveness is more comprehensible than that of awareness campaigns. Consequently, financial incentives are used as the intermediate option for public authorities.

There are several types of financial incentives, such as direct subsidies and tax incentives. Since the ADAS in this investigation are considered to be systems to be available only on new vehicles, a tax reduction on vehicle purchase tax (i.e. "Belasting op personenauto's en motorrijwielen (BPM)" in the Netherlands) is selected here, as a feasible and effective option. In order for the respondents to evaluate "tax reduction" in the same way, it should be made more specific by giving the amount of tax reduction. Similar tax reductions are currently awarded, or have in the past been awarded, for equipment of diesel cars with specific dust filters (600 euros) and on hybrid vehicles (2,500-5,000 euros depending on the energy efficiency of the vehicle; Belastingdienst, 2010). Taking into account this information, and the general costs of ADAS systems and their effectiveness for transport problems, it may be realistic to think of a tax incentive in an order of magnitude of 1,000-2,000 euros. Here, 1,500 euros will be applied.

This leads to the following attribute levels as public authorities' deployment options:
- Do nothing;
- 1,500 euros tax reduction for vehicles with ADAS;
- Mandate ADAS for all vehicles by legislation.

5.2.2 Industry's deployment options

The deployment options available to the industry include doing nothing – which is a very strong deployment option as it represents the blocking power of industry – offering an ADAS as optional equipment, offering retrofitting of an ADAS, advertising campaigns, discounts (for example in packages), awards, dealer training, and eventually offering an ADAS as standard equipment. These deployment options can be applied to part of the vehicle range offered by industry, like some systems are already available as an option on high-end vehicles only, or to the complete range of vehicles of a specific brand. Again, the deployment options are considered for all new vehicles.

The deployment options for the automotive industry included in the investigation are ‘do nothing’ as the least intervening option, and ‘ADAS as standard equipment on all vehicles’ as the most intervening option. Intermediate deployment options of industry are related to the usual marketing strategy, in which a new product is first introduced in high end vehicles in order to recover the development costs, which is referred to as a cascade of innovation in the SEiSS report (Abele et al., 2005). These strategies are valid for both optional and standard equipment of vehicles. Other deployment options include the promotion of optional available equipment. Since we cannot go into much detail, and other choices would be arbitrary, the general option to offer ADAS as optional equipment is chosen as the intermediate level here.

This leads to the following attribute levels as industry’s deployment options:
- Do nothing;
- ADAS is optional equipment for all new vehicles;
- ADAS is standard equipment for all new vehicles.

5.2.3 Insurance companies’ deployment options

Insurance companies have, next to doing nothing, a single type of deployment option available to influence user adoption of ADAS, which is insurance premium reduction. Currently, the calculation of the premium for an insurant is still mainly based on statistics of insurance claims as a result of traffic accidents, and differentiation is based on vehicle type and driver type. This is what we would call static premium calculation. There is a rising trend of more dynamic “pay-as-you-drive” based insurance policies, with premiums based on important and measurable variables regarding accident statistics (e.g. Litman, 2005). In several countries, vehicle insurance based on the number of kilometers driven is already available on a limited scale.

Static premium reduction is not yet a desirable option for insurance companies to stimulate user adoption of ADAS. Reliable accident statistics related to ADAS are not yet available, as a result of which essential risk calculations cannot be made. Dynamic premium calculation, however, is a feasible option, since it is possible to monitor certain aspects of driving behavior that are related to accident risk, such as speed and following distance. It has been shown, for example in the Dutch Belonitor trial, that rewarding drivers for safe driving behavior has a positive effect on driving behavior (Mazureck and Van Hattem, 2006). A trial with a dynamic insurance premium bonus for using Intelligent Speed Adaptation is running in Denmark. Some preliminary results show that the combination of speeding information, and a prospective incentive of 30% premium reduction, has a very positive effect on speeding (Agerholm et al., 2007).

The deployment options for insurance companies included in the present study are ‘do nothing’ as the least intervening option, ‘variable premium reduction in combination with ADAS as optional insurance policy’ as the intermediate option and ‘variable premium reduction in combination with ADAS as standard insurance policy’. There are few clues about a realistic level of insurance premium reduction, apart from the 30% discount of the Danish trial, which refers to young drivers (Agerholm et al., 2007). Since different ADAS are considered, with possible various levels of effectiveness regarding safety, it is decided to include a lower reduction, of maximum 25%.

Selected attribute levels as insurance companies' deployment options:
- Do nothing;
- Optional up to 25% premium reduction for safe driving using ADAS;
- Standard up to 25% premium reduction for safe driving using ADAS.

5.3 Selection of user attributes based on deployment options

For users, only those deployment options are considered that leave a choice to the user. This means that all of the options forcing deployment of ADAS are not considered, as well as the option that the automotive industry is doing nothing. The remaining deployment options to be considered are then 'do nothing' and '1,500 euros tax reduction' by public authorities, 'ADAS as optional equipment' by the automotive industry, and 'do nothing' and 'optional 25% premium reduction' by insurance companies. The industry deployment option (ADAS as optional equipment), is taken as a starting condition in the survey, and the extent to which public authorities and insurance companies can influence the probability that users purchase an ADAS is investigated, given that it is provided as an option.

The deployment options of public authorities can be interpreted as 'no tax reduction' and '1,500 euros tax reduction'. Since users will not only decide based on the amount of the tax reduction, but also on the (remaining) purchase costs of the ADAS, it was decided to include an attribute *cost* in which the total cost can be varied, representing different levels of tax reductions. The maximum costs were set to 1,500 euros, representing the ADAS without a tax reduction, and the minimum to 100 euros. The latter level was chosen instead of 0 euros to include a small cost barrier for purchasing ADAS. The intermediate costs were set to 750 euros. Table 5.1 presents the combinations of the purchase price of the ADAS and tax reductions that can be considered by these attribute levels.

Table 5.1: Combinations of price and tax reduction represented by the cost attribute

Total	**Combination 1**		**Combination 2**		**Combination 3**	
Costs	Price	Tax reduction	Price	Tax reduction	Price	Tax reduction
100 euros	100	0	750	750*	1,500	1,500*
750 euros	750	0	1,500	750	-	-
1,500 euros	1,500	0	-	-	-	-

*While these reductions would lead to a total cost of 0 euros, it was decided to apply a minimum total cost of 100 euros

In summary, the attribute levels for the attribute ADAS costs are:
- 100 euros;
- 750 euros;
- 1,500 euros.

The deployment options of insurance companies can be interpreted as no premium reduction and 25% premium reduction. It was decided to include an attribute *premium reduction,* representing reductions on recurrent (monthly) insurance payments by users. Next to no premium reduction, and 25% premium reduction, the third level included in this investigation is 50% premium reduction, which is expected to be around the upper limit of feasible premium reductions. One might argue that a percentage is a different amount of money for each of the respondents, and as such is not specific enough. However, insurance premiums are very different for each type of driver, and as such using a percentage is a better measure than

monetary units. Besides, this type of measure is also used in other experiments (e.g. Agerholm et al., 2007).
In summary, the attribute levels for premium reduction in combination with ADAS are:

- 0% premium reduction;
- 25% premium reduction;
- 50% premium reduction.

5.4 Selection of ADAS

Given the wide range of ADAS available, it is expected that the impacts of different ADAS correspond to the interests of different actors. For example, ADAS that mainly increase driving comfort are more interesting for users or the automotive industry than for public authorities or insurance companies. Accordingly, it is expected that actors' decisions to apply a deployment option are influenced by the type of ADAS concerned. Thus the ADAS included in the actor and user investigation were selected to predominantly match the interests of public authorities, the automotive industry, or insurance companies. Public authorities are generally most interested in traffic safety from a societal point of view (e.g. ADVISORS, 2002; Lathrop and Chen, 1997). In contrast, the automotive industry is most interested in accomplishing competitive advantage and, as a result, in user benefits such as individual driver safety, comfort and convenience (Walta et al., 2005). Insurance companies are also interested in competitive advantage, and are therefore expected to be interested in possibilities for product differentiation, including insurance products that are more tailored to individual accident risk. For each of the actors, one ADAS is selected that particularly matches their interests. This ADAS should be technologically feasible, and some evidence on positive effects on traffic should be available.

5.4.1 ADAS of interest for public authorities

Since public authorities are mainly interested in traffic safety, the choice of Intelligent Speed Adaptation (ISA) as an ADAS to be (presumably) public policy driven is quite straightforward. The more intervening types of ISA are expected especially to have substantial effects on traffic safety (e.g. Carsten and Tate, 2005; Várhelyi and Mäkinen, 2001). Moreover, the automotive industry proves still to be reluctant to move towards ISA implementation, as illustrated by the fact that, while safety systems take an important place in it, ISA has not been included in the roadmap for the automotive industry (CARS21, 2005). However, agreement among actors has been established with regard to warning ISA in the SpeedAlert project, of which the general objective was: "to support the implementation of in-vehicle speed alert applications that can contribute to improve road safety" (SpeedAlert, 2005, p.5).

Speed Assistant

The different functional options for ISA can be categorized by the level of intervention in the driving task, and the type of speed limits supported (e.g. Carsten and Tate, 2005). Here, we chose to focus only on the intervention level, since most differences in actor opinions can be attributed to it (Morsink et al., 2007).
Generally, the following levels of intervention are considered:

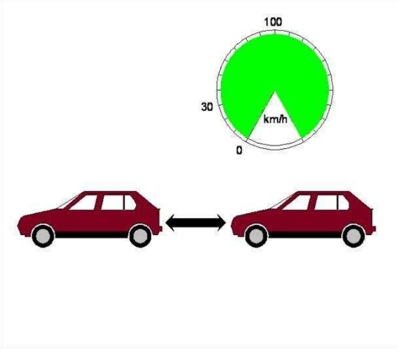
- Warning: warns the driver by an acoustic and/or visual signal that he is over the current speed limit;

- Assisting: supports the driver in keeping the speed limit by an active accelerator pedal that can still be overruled by the driver;
- Limiting: makes it physically impossible to drive faster than the speed limit.

Limiting ISA is generally expected to have the highest impacts on traffic safety, with a potential reduction in fatal accidents of 37-59%, against 19-32% for assisting ISA, and 18-24% for warning ISA (Carsten and Tate, 2005). However, limiting ISA receives a lot of opposition from, for example, car manufacturers. Furthermore, in the Netherlands it is mentioned mainly as a potential means to enforce speed offenders to comply with the speed limits. For these reasons, limiting ISA is currently unlikely to be eligible for large-scale deployment. Assisting ISA is still expected to have substantial effects on traffic safety, while its acceptance among users is relatively high (e.g. Vlassenroot et al., 2007). Since warning ISA is already being implemented (for example in navigation systems), assisting ISA is chosen as the system most eligible for government intervention. In the present study, this ADAS is further referred to as the *Speed Assistant*.

5.4.2 ADAS of interest for the automotive industry

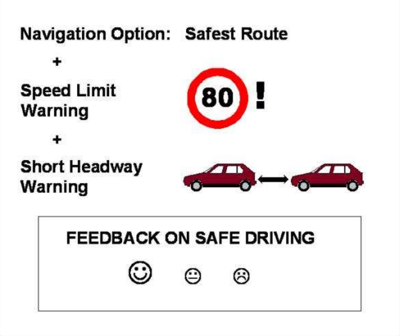
The automotive industry is expected to be mostly driven by what the customer wants, i.e. user needs. Van Driel and Van Arem (2005) performed a user needs survey, which showed that drivers are interested in getting support from their car in congestion and adverse weather conditions. Research on congestion assistance has been done both in the INVENT project (Benz et al., 2003) and by Van Driel (2007). Both consider an integrated system, but with different ADAS components. The INVENT congestion assistant integrated ACC, Stop&Go, Lane Keeping and (possibly) Vehicle-to-Vehicle (V2V) communication. The Stop&Go system extends conventional ACC into the lower speed ranges, making it possible to come to a complete stop, and start-up again automatically. Van Driel designed a congestion assistant integrating Stop&Go, V2V communication and an active accelerator pedal to slow down before a jam. Experiments with this Congestion Assistant, including Stop&Go, an active accelerator pedal and congestion warning, showed positive results for driver acceptance and throughput, especially regarding the Stop&Go functionality (Brookhuis et al., 2009; Van Driel and Van Arem, 2008). Because of these positive effects, and the fact that ACC and Stop&Go have – in combination as Full Speed Range ACC – already been introduced to the market, a *Congestion Assistant* consisting of Full Speed Range ACC will be considered in this dissertation.



Congestion Assistant

5.4.3 ADAS of interest for insurance companies

Insurance companies generally base premiums for car insurance on indicators, such as age, sex, car type and driving experience, derived from statistics based on earlier claims. These indicators may not explain all heterogeneity in risk types of car drivers, and as such could lead to an unfair premium distribution among insurants. Currently, black boxes can be integrated in a car that can monitor driving behavior, from which the risk type of the driver can be derived (Filipova-Neumann and Welzel, 2010). Filipova-Neumann and Welzel suggest that for privacy reasons the information from the black boxes should only



Safe Driving Assistant

be made accessible to insurance companies after an accident. Using the information from the black box may become more acceptable if they are used for pay-as-you-drive premium schemes, in which the user is informed about his driving behavior, and is able to influence it. Speed and headway are two important indicators for safe driving behavior. Information on safe speed and safe headway is found to positively influence safe driving behavior (Adell et al., 2011). In addition, providing rewards was found to increase compliance with safe speed and safe headway (Mazureck and Van Hattem, 2006). In this study, a combination of speed limit warning, short headway warning, and a safest route option on a navigation system[6], is included. Based on the performance of the driver on the three functionalities: safest route, headway, and speed, the driver receives feedback on his driving behavior with respect to safety. This output can also be used to offer a flexible insurance premium based on actual driving behavior. This system will be referred to as *Safe Driving Assistant* in this dissertation. While this system seems to be a combination of the former two, it is essentially different, in that it only issues warnings and does not actively intervene, and as such it gives a different type of assistance to the drivers.

All of the systems mentioned above will be considered for deployment on all vehicle types and all driver types.

5.5 Conclusions

In this chapter, the deployment scenarios addressed in this dissertation were specified. In order to perform the conjoint measurement tasks in the actor and user surveys, the deployment scenarios were translated into actor and user specific attributes. Deployment scenarios consist of the deployment actions taken by the actors (public authorities, the automotive industry, and insurance companies). For each of the actors, three different options for taking deployment actions were defined, which include *doing nothing*, *stimulating adoption* and *forcing adoption* of the ADAS. For users, the deployment scenarios were translated into *ADAS purchase costs* and *insurance premium reduction*. The deployment scenarios were considered for a number of ADAS, a *Speed Assistant*, a *Congestion Assistant*, and a *Safe Driving Assistant*. These ADAS were expected to be particularly interesting for, respectively, public authorities, the automotive industry, and insurance companies.

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[6] The choice to include safest route navigation was prompted by the professional pilot of the Transumo Intelligent Vehicles project, in which a safest route navigation system was tested.

6 Actors’ expectations regarding ADAS deployment

Which deployment actions are actors expected to take, and for which ADAS? How are they influenced by the deployment actions of other actors? This chapter describes the setup of the actor survey regarding ADAS deployment, and designed to collect data in order to estimate models of actors’ decision-making regarding ADAS deployment, given the actions of other actors. For each actor, public authorities, the automotive industry, and insurance companies, separate models were estimated of the probability that they will actually take certain deployment actions, and of the utility individual respondents derive from these deployment actions. Based on these models, most of the relations that were assumed to exist between the actors’ actions could be confirmed.

6.1 Actor survey set-up

The central part of the actor survey is a conjoint measurement task designed to collect data to estimate the probability and utility models of actor decision-making regarding ADAS deployment. Table 6.1 summarizes the attributes, and the attribute levels, to be included in the conjoint measurement task for the respondents, which were introduced in Chapter 5.

Table 6.1: Overview of actor attributes and attribute levels

ADAS	**Attribute levels: ADAS**
ADAS	Speed Assistant Congestion Assistant Safe Driving Assistant
Deployment options/actions	**Attribute levels: deployment options/actions**
Public authority’s deployment options/actions	Do nothing 1,500 euros tax reduction for vehicles with ADAS Mandate ADAS for all vehicles by legislation
Automotive industry’s deployment options/actions	Do nothing ADAS is optional equipment for all new vehicles ADAS is standard equipment for all new vehicles
Insurance company’s deployment options/actions	Do nothing Optional up to 25% premium reduction for safe driving using ADAS Standard up to 25% premium reduction for safe driving using ADAS

In this study, only one time-step is considered, moving from a first – initial – deployment scenario, to a second deployment scenario. This represents an initial decision round, in which it is assumed here that actors can only move to another deployment action from ‘doing nothing’, and otherwise maintain the same action. For the survey, this means that the action of the responding actor in the initial deployment scenarios is constant and ‘do nothing’. Consequently, the respondents’ action was not included in the deployment scenarios presented to the respondents. These deployment scenarios thus include the ADAS and the deployment actions of the other actors.

The remaining steps that need to be taken here in the set-up of the conjoint measurement task for the respondents are (1) to determine the functional form of the probability and utility models to be estimated, which is performed by means of a pilot questionnaire, (2) to combine the attribute levels into profiles, with the number of profiles depending on the functional form, and (3) to define the measurement task for the respondents. Next to the conjoint measurement task, the survey also includes the collection of respondent characteristics and expected impacts of the ADAS and deployment actions on decision criteria.

6.1.1 Pilot questionnaire

The number of profiles to be included in the conjoint measurement task for the respondents depends upon the functional form of the probability and utility models to be estimated. The functional forms considered here are the additive form, a linear combination of the attributes, and the form including two-way interactions, a linear combination of the attributes, and all possible products of two attributes. When the functional form is assumed to be additive, 9 profiles or combinations of three attribute levels (ADAS and deployment actions of two other actors) are necessary. When the functional form also includes two-way interactions, 27 profiles are necessary. It is generally preferred to include the least amount of profiles possible, since this will increase response, but there is a trade-off with a possible gain in accuracy when interactions are included. A pilot study was performed to be able to make this trade-off for the present situation in an informed manner.

Two variants for the functional form of the utility model were included in the pilot study, an additive model and a model including all possible two-way interactions. A pilot questionnaire was set up, completed by five colleagues from Delft University of Technology, University of Twente, and University of Groningen. They were asked to take a role as one of the actors, and evaluate three different deployment options for this actor, given the ADAS and the current deployment scenario. One of them took the role of public authorities, two of the automotive industry, and two of insurance companies. In general, these respondents reported that the questionnaire was very long, and the questions were extremely difficult. The length of the questionnaire is likely to seriously limit the response rate, and the difficulty could imply that the accuracy of the answers may diminish rapidly with an increasing number of questions. These findings increase the need for a relatively simple questionnaire, and as such would justify the use of an additive model. Keeping that in mind, both the additive and the interaction models are assessed on their performance.

Using the data resulting from the pilot questionnaire, utility models were estimated for each of the deployment options, applying both the additive[7] and the interaction functional form. The performance of both functional forms was assessed by the absolute deviation between the utility of a profile based on the models, and the utility of a profile as observed. Furthermore, the performance was assessed by the deviation in the order of preference of the deployment actions resulting from the model, from the observed order of preference. Table 6.2 shows the average absolute deviations from the observed data, and the number of profiles for which the most preferred deployment action coincides with the observed data.

Table 6.2: Performance of model types based on test questionnaire

Respondent	**Deployment option**	**Average absolute deviation from observed data (data on scale 1-10)**			**Number of profiles for which most preferred deployment action coincides with observed data (max. 27 profiles)**	
		Interaction models	Additive models	Difference	Interaction models	Additive models
Public authorities	Do nothing	0.412	0.658	0.246	25	24
	Tax reduction	0.354	0.498	0.144		
	Mandatory	0.406	0.679	0.273		
Automotive industry 1	Do nothing	0.203	1.951	1.748	27	24
	Option	0.535	0.835	0.300		
	Standard	0.686	0.864	0.178		
Automotive industry 2	Do nothing	0.148	0.741	0.593	27	27
	Option	0.148	0.461	0.313		
	Standard	0.000	0.551	0.551		
Insurance companies 1	Do nothing	0.642	1.790	1.148	26	24
	Option	0.730	1.564	0.834		
	Standard	0.768	1.580	0.812		
Insurance companies 2	Do nothing	0.348	0.510	0.162	27	26
	Option	0.521	0.667	0.146		
	Standard	0.433	0.691	0.258		

As expected, the interactions models perform better than the additive, main effects, models. However, since additive models are generally preferable, the question is whether the better performance of the interaction models provides added value over the advantages of the

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[7] From the available data, only the data that were necessary to estimate an additive model were used.

additive model. An acceptable deviation of the model from the data would be 1.000, since this represents a difference in utility of only 10%. Table 6.2 shows that four of the outcomes of the additive models do not comply with this standard. Three of them are reported for one of the respondents though (i.e. insurance companies 1), who could be considered as an outlier, and will not be further taken into account. Regarding the forecasts, it can be concluded that the additive models perform nearly as well as the interaction models, except for one of the respondents, for whom also a relatively large difference in the absolute deviations was reported (i.e. automotive industry 1).

Taking into account the overall performance of the models, and the remarks made by the respondents, it can be concluded that interactions are not expected to play a sufficiently large role to justify the task burden for the respondents, with respect to both the amount of time needed for the questionnaire, and the accuracy by which they will answer.

Consequently, it was decided to use additive models for both the probability and utility models:

$$P(D_{1,a} = y_a \mid D_0 = x) = c + b_1 x_1 + b_2 x_2 + b_3 z + \varepsilon_1 \tag{6.1}$$

$$U(y_a) = k + l_1 x_1 + l_2 x_2 + l_3 z + \varepsilon_2 \tag{6.2}$$

In which:
$D_{1,a}$ = stochastic variable representing deployment action of actor a at time $t=1;$
D_0 = stochastic variable representing deployment scenario at time $t=0;$
y_a = deployment action by actor a at time $t=1;$
x = deployment scenario at time $t=0;$
x_1, x_2 = deployment action by other actors 1 and 2 at time $t=0;$
z = ADAS;
c = constant of probability model;
b_1,b_2,b_3 = coefficients of probability model;
k = constant of utility model;
l_1,l_2,l_3 = coefficients of utility model;
ε_1, ε_2 = error terms.

The error terms describe the amount of probability or utility that cannot be described by the model, for example due to individual differences or attributes not included.

A further finding from the pilot questionnaire was that the effects of ADAS were relatively small, and of low statistical significance. This could be due to the fact that the 27 profiles were presented in three groups. The first nine presented deployment scenarios including the Speed Assistant, the second nine those including the Congestion Assistant, and the last nine those including the Safe Driving Assistant. In this way, it may have been difficult for the respondents to make trade-offs between the different ADAS.

6.1.2 Combination of attribute levels into profiles

Given the choice for an additive functional form for both the probability and utility models, a set of 9 profiles is necessary to collect the data for model estimation. This set of profiles (i.e. the experimental design) needs to be orthogonal, which means that all combinations of two attribute levels occur exactly once. Table 6.3 shows the profiles in the order presented to respondents of public authorities. The ‘attribute levels’ column represents the experimental design, in which attribute levels 0, 1, and 2 for each of the attributes are combined into profiles. The attribute levels are specified in the subsequent columns for the attributes ADAS, the automotive industry's deployment action, and insurance companies' deployment action.

Table 6.3: Profiles in the order presented to respondents from public authorities

Profile	Attribute levels			ADAS	Automotive industry's deployment action	Insurance companies' deployment action
1(holdout)	2	2	1	Safe Driving Assistant	Standard	Option
2	0	0	0	Speed Assistant	Do nothing	Do nothing
3	1	1	0	Congestion Assistant	Option	Do nothing
4	2	2	0	Safe Driving Assistant	Standard	Do nothing
5(holdout)	1	0	2	Congestion Assistant	Do nothing	Standard
6	0	1	2	Speed Assistant	Option	Standard
7	1	2	2	Congestion Assistant	Standard	Standard
8(holdout)	0	1	0	Speed Assistant	Option	Do nothing
9	2	0	2	Safe Driving Assistant	Do nothing	Standard
10	0	2	1	Speed Assistant	Standard	Option
11	1	0	1	Congestion Assistant	Do nothing	Option
12	2	1	1	Safe Driving Assistant	Option	Option

Three extra, redundant, profiles were added to the design. One was added as profile 1 in the questionnaire, in order to let the respondents get used to the type of questions, which are complicated. The answers to this profile were not included in model estimation, or any other further analysis. Another two profiles were added in between the other profiles, the answers to which were not included in model estimation, but were used to validate the model by comparing them with the outcomes of model simulations. These so-called holdout profiles (they are held out of model estimation) consisted of different combinations of attribute levels than those already included in the design. In this particular case the holdout profiles were used to determine the level of statistical significance at which attributes should be included the models that were to be used for simulation of scenarios.

Given the experience in the test questionnaire with the small effects of the ADAS, the profiles were presented in such an order that the ADAS alternated for each question. Furthermore, the order of presentation of the attributes is deliberately chosen. First, the ADAS, since these are the subjects on which the deployment actions apply. Then, second, the industry's deployment action, since they are a crucial actor in ADAS deployment, and finally the deployment action of the remaining actor. If the industry is the responding actor, public authorities are the first actor whose deployment action is presented.

6.1.3 Measurement task

The remaining question regarding the setup of the conjoint measurement is how to measure (1) the probability that actors will actually take a deployment action and (2) the utility of deployment actions for the individual respondents. Possible measurement tasks include ranking profiles, choice between profiles, and rating of profiles. In the definition of the models in Chapter 4, it was already determined that probability and utility are to be measured directly, which would be on a rating scale.

Both the probability and utility measurement were performed for each profile at the same time (see Figure 6.1). It was considered most logical for the respondents to first give their own opinion by means of the utility measurement, and follow up with their expectations of the sector, by means of the probability measurement.

<table>
<tr><th colspan="12">SITUATION 4</th></tr>
<tr><td>
</td><td colspan="11">Public authorities: Mandate Safe Driving Assistant on all vehicles by legislation
Insurance companies: Do nothing</td></tr>
<tr><td colspan="12">How would you, as an individual stakeholder, rate application of the following instruments[8] in this situation?</td></tr>
<tr><td></td><td>Very low 0</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>Very high 10</td></tr>
<tr><td>Do nothing</td><td>○</td><td>○</td><td>○</td><td>○</td><td>○</td><td>○</td><td>○</td><td>○</td><td>○</td><td>○</td><td>○</td></tr>
<tr><td>Safe Driving Assistant is optional equipment for all new vehicles</td><td>○</td><td>○</td><td>○</td><td>○</td><td>○</td><td>○</td><td>○</td><td>○</td><td>○</td><td>○</td><td>○</td></tr>
<tr><td>Safe Driving Assistant is standard equipment for all new vehicles</td><td>○</td><td>○</td><td>○</td><td>○</td><td>○</td><td>○</td><td>○</td><td>○</td><td>○</td><td>○</td><td>○</td></tr>
<tr><td colspan="12">What would be the chance that automotive industry actually applies the following instruments in this situation?</td></tr>
<tr><td colspan="6"></td><td colspan="6">Percentage %
(sum = 100%)</td></tr>
<tr><td colspan="6">Do nothing</td><td colspan="6"></td></tr>
<tr><td colspan="6">Safe Driving Assistant is optional equipment for all new vehicles</td><td colspan="6"></td></tr>
<tr><td colspan="6">Safe Driving Assistant is standard equipment for all new vehicles</td><td colspan="6"></td></tr>
<tr><td colspan="6">Other (please specify):</td><td colspan="6"></td></tr>
</table>

Figure 6.1: Example of utility measurement for respondents from industry

For the utility measurement, a rating task is included for each of the responding actors' deployment options. An 11-point scale has been applied to this end. This scale is detailed enough to make a distinction between the 12 profiles included, and is still capable of being understood, since it is a commonly applied system for grading.

For the probability measurement, a different type of rating task was included. The respondents had to allocate probabilities to the different deployment instruments. In order to keep the task realistic, the deployment option "other" was added, so the sum of probabilities

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[8] In the questionnaire, the term "instrument" was used instead of "deployment option". Subsequently it was found that deployment option is a more appropriate term, and is therefore used throughout this dissertation.

could be fixed at 100%. The advantage of this form of measurement is that the respondent has to make a trade-off between the deployment options.

Some of the 12 profiles may prove to be unrealistic, or in some of them certain deployment actions are not feasible. For example, if public authorities mandate an ADAS, the automotive industry cannot ‘do nothing’. In the questionnaire, the respondents were instructed to rate a deployment option with ‘0,’ if such a case occurred in their opinion.

6.1.4 Respondent characteristics

Respondent characteristics are included in the questionnaire to verify if the respondents who reacted to the questionnaire are part of the target group of this investigation. These characteristics were also used to explain potential differences among the observed probabilities and utilities. The most important characteristic to be measured is the extent to which the respondents are familiar with the ADAS included in the questionnaire. Familiarity gives an indication of the validity of the respondents’ expectations regarding ADAS deployment. In addition, differences in familiarity may also explain differences in expectations. Further characteristics included are the country of residence, the type of organization, and the role of the respondent within this organization. The country of residence is important to report since the focus of this research project is on the Netherlands, while the automotive industry can reside in different countries. The type of organization the respondent works for within a sector, may influence their opinion with respect to ADAS deployment. For example, automotive suppliers have a different customer to sell their products to than car manufacturers, and as such have different interests. Finally, it is also interesting to know what the role is of the respondents within their organizations. The actual decision-makers, or people involved in decision-making, could have different opinions than, for example, researchers who are knowledgeable about ADAS, but do not have to decide.

Summarizing, the background questions include (1) the familiarity of the respondent with the functionality of the three ADAS included in the investigation, (2) the country of residence of the organization the respondent works for, (3) the type of organization or area of operation (actor dependent), and (4) the role the respondent has within the organization.

6.1.5 Expected impacts on decision criteria

Next to the respondent characteristics, the expectations of respondents regarding the impact of the ADAS, and deployment actions on (important) decision criteria, can explain potential differences among the observed utilities and probabilities.

The decision criteria to be included in the survey were defined using the list of 20 important decision criteria that resulted from the preliminary exploration of decision criteria (see Chapter 2). This list was condensed by removing criteria that were hierarchically related to other criteria on the list (such as driver distraction which is related to safety), and criteria that referred to prerequisites, or conditions to be met, before ADAS deployment can be put into effect (such as standardization). The remaining decision criteria are: *safety, driver acceptance, liability, costs, environment, profitability, and travel time/network efficiency*.

What effect would large scale deployment of the ***Speed Assistant***, to your opinion, have in general on the following three criteria?

	Definitely negative						*Definitely positive*
	−3	−2	−1	0	1	2	3
Traffic safety	○	○	○	○	○	○	○
Traffic flow	○	○	○	○	○	○	○
Environment	○	○	○	○	○	○	○

What is, to your opinion, the ***acceptability*** of the ADAS by users?

	Definitely unacceptable						*Definitely acceptable*
	−3	−2	−1	0	1	2	3
Speed Assistant	○	○	○	○	○	○	○
Congestion Assistant	○	○	○	○	○	○	○
Safe Driving Assistant	○	○	○	○	○	○	○

What is, to your opinion, the effect of ***ADAS as optional equipment for all new vehicles*** on the following four criteria, if doing nothing is neutral (=0)?

	Definitely negative						*Definitely positive*
	−3	−2	−1	0	1	2	3
User costs of the ADAS	○	○	○	○	○	○	○
Costs for industry	○	○	○	○	○	○	○
Investment risk	○	○	○	○	○	○	○
Liability risk	○	○	○	○	○	○	○

What is, to your opinion, the ***acceptability*** of the following instruments by users, if doing nothing is neutral (=0)?

	Definitely unacceptable						*Definitely acceptable*
	−3	−2	−1	0	1	2	3
ADAS is optional equipment for all new vehicles	○	○	○	○	○	○	○
ADAS is standard equipment for all new vehicles	○	○	○	○	○	○	○

Figure 6.2: Expected impacts measurement for respondents from the automotive industry

It was assumed that both the ADAS and deployment actions influence the expected impacts on decision criteria. However, the impacts on some of the criteria are expected to be mainly influenced by the type of ADAS (e.g. safety), and the impacts on others more by deployment actions (e.g. costs). Consequently, it was decided to separately measure the expected impacts of the ADAS on ADAS related criteria, and the expected impacts of the deployment actions on deployment actions related criteria. Some of the criteria were split, and the majority were renamed to enable better understanding by the respondents (see e.g. Wiethoff et al., 2006). ADAS related criteria included were (1) traffic safety, (2) environment, (3) traffic flow, and (4) user acceptance of the ADAS. Deployment actions related criteria included were (1) user costs, (2) actor costs, (3) investment risk, (4) liability risk, and (5) user acceptance of the deployment option.

With respect to the measurement of the expected impacts, it is important to have a common reference point for all actors. To that end, a bipolar Likert scale is applied, so that negative and positive expected impacts with respect to the current situation (= 0) can be measured. In case of the deployment actions, the respondents are asked to label their 'do nothing' action as equal to 0. Since there are three deployment actions, and three ADAS, for which criteria will be valued, a 7-point scale (-3/-2/-1/0/+1/+2/+3) is applied, so the respondent can always distinguish between the deployment actions or the ADAS. While the measurement scale is the same for all decision criteria, questioning for acceptance was different (see Figure 6.2). The questions regarding deployment actions were different for each actor; the example presented in Figure 6.2 is for the automotive industry.

6.2 Questionnaire and data collection

A questionnaire was designed, based on the measurement tasks described in Section 6.1, to be completed by respondents of the three actor groups included in this investigation, i.e. industry, public authorities and insurance companies. For each of these groups, a separate questionnaire was designed, since a large number of the questions were different. With regard to the order of the three main tasks, it seems to be important for the consistency of the model that the respondents have had some time to think about the ADAS and deployment options before engaging in the most important task, the utility and probability measurement. Consequently, it was decided to place the expected impact measurement before the utility and probability measurement in the questionnaire. The questionnaire began with the background questions. This was designed to discourage respondents that clearly do not fit in the general picture of the target group of this questionnaire, from continuing with the questionnaire.

There are a number of options available to collect data by means of a questionnaire, including a face-to-face interview, a phone interview, sending the questionnaire by mail, and using an internet-based questionnaire. The questions included in the questionnaire, especially those of the utility measurement, are quite complex, and respondents may need some time to master the scenarios before answering the questions. This makes the questionnaire particularly unsuitable for a face-to-face or a phone interview. The question whether to send the questionnaire by mail, or publish it on an internet website, should be answered by the expected response and the administration of the data. On the one hand, the expected response of a questionnaire by mail could be higher, since conventional mail may be given higher importance than electronic mail. On the other hand, it may be outranked in response by the ease of completing the questionnaire on a website. In addition, the data administration of an internet-based questionnaire can be automated, and is therefore preferable for the researcher. It was therefore decided to apply an internet-based questionnaire, designed with

NetQuestionnaire (http://netq.nl). Data collection was performed during the second half of 2008.

Respondents were invited by personalized e-mails, generated by *NetQuestionnaire,* including a unique URL to the questionnaire for each respondent, and by general invitations, including a general URL to the questionnaire. The former has the advantage of an automated administration of response, which includes sending reminders to those respondents that have not yet completed the questionnaire. Although the respondents could be identified in the system, their personal information and their answers were disconnected in the resulting data file. The questionnaire was made available both in English and in Dutch to facilitate accurate answering.

Table 6.4: Total response to the questionnaire

Actor	Invited via NetQ	Initial response		Total response after extra invitations
	#	#	Percentage of invited	#
Public authorities	53	18	34%	20
Automotive industry	169	47	28%	47
Insurance companies	1	1	100%	8
TOTAL	223	66	30%	75

The respondents that were invited with a unique URL represented the automotive industry, public authorities or insurance companies. They were selected based upon their expected knowledge in the field from contacts in the researcher's network or those of colleagues, and contributors and participants of two events in the field of intelligent vehicles that took place in the Netherlands in 2007 and 2008 respectively. The total number of respondents invited was 223, of which 66 completed it, which is 30% (see Table 6.4). Taking into account the difficulty of the questionnaire (that was sometimes reported by respondents), the response is satisfactory, although lower than desirable.

Only one respondent for insurance companies was invited to the questionnaire with a unique URL. It was not easy to find contacts within the used networks, and the best option to find respondents was to use known contacts within insurance companies to invite their colleagues to respond to the questionnaire. This was done by providing these contacts with a general URL that they could pass on. As a result, the number of invited respondents is not precisely known. A total of 7 extra responses representing insurance companies were received in this way. Using the same general URL, 2 extra responses representing public authorities were received (see Table 6.4).

The majority (60%) of the respondents needed 10-30 minutes to complete the questionnaire, the remainder needed more time. This indicates that completing the questionnaire was an intensive task. Of the 120 respondents that started the questionnaire, 45 did not finish, of which 37 quit before the most difficult and important part of the questionnaire (conjoint measurement). This means that 90% of the respondents that started the conjoint measurement part also finished it, which shows their commitment to the research topic.

While the quantity of the response is satisfactory, the experienced difficulty of the questions raises some concern about the internal consistency of the responses, especially regarding the conjoint measurement part of the questionnaire. The internal consistency of the response is important to generate reliable simulations of scenarios not included in the questionnaire. It can be checked by simulating the data for the holdout scenarios, and comparing these to the actual data, together with visual inspection of the data. Since inconsistencies could also reflect the influence of factors that were not included in the conjoint measurement, applying strict thresholds for inconsistent cases would not be expedient. The answers of three respondents were considered as outliers, based on their performance on the conjoint measurement part of the questionnaire. These cases were internally inconsistent, to such an extent that they affected the internal consistency of aggregated models (1 case, insurance companies), or no underlying opinion could be identified (2 cases, the automotive industry). The internal consistency is valued as important, since reliable simulations of deployment scenarios that were not included in the questionnaire are needed in the next research step. These three cases were therefore not included in further analysis.

In summary, the answers of 72 respondents will be included in further analysis, 20 from public authorities, 45 from the automotive industry, and 7 from insurance companies.

6.3 Results: general explanatory variables

6.3.1 Respondent characteristics

In order to assess the response to the questionnaire and explain possible differences in the answers, general characteristics of the respondents were collected. These characteristics included familiarity of the respondents with the ADAS included in the questionnaire (Speed Assistant, Congestion Assistant and Safe Driving Assistant), the country of residence of the organization the respondent works for, the type of organization, and the role the respondent has within the organization.

Table 6.5: Familiarity with the systems

	General		**Public Authorities**		**Automotive Industry**		**Insurance Companies**	
	Familiarity*	SD**	Familiarity	SD	Familiarity	SD	Familiarity	SD
Speed Assistant	1.35	*1.15*	1.80	*0.41*	1.33	*1.15*	0.14	*1.78*
Congestion Ass.	1.63	*0.85*	1.70	*0.66*	1.73	*0.69*	0.71	*1.60*
Safe Driving Ass.	0.96	*1.27*	0.80	*1.70*	1.04	*0.98*	0.86	*1.68*

* Applied measurement scale: -2 (definitely not familiar)/-1/0/+1/+2 (definitely familiar)
** Standard deviation

The familiarity of the respondents with the functionality of the three ADAS was measured on a 5 point Likert scale from -2 to 2, in which -2 was assigned to "definitely unfamiliar" and 2 to "definitely familiar". Table 6.5 shows the average familiarity of the actor groups with the ADAS. The most important finding is that respondents from insurance companies were, generally, less familiar with ADAS than the other respondents. In addition, the high standard deviation also indicates a large spread in familiarity among the insurance companies' respondents. More generally, the respondents were reasonably familiar with the ADAS. Public authorities' respondents were slightly more familiar with the Speed Assistant, automotive industry respondents were most familiar with the Congestion Assistant, and insurance companies' respondents were slightly more familiar with the Safe Driving Assistant.

Table 6.6: Country of residence

Country	Total		Public Authorities		Automotive Industry		Insurance Companies	
	#	%	#	%	#	%	#	%
Belgium	6	8%	5	25%	1	2%	0	0%
France	4	6%	0	0%	4	9%	0	0%
Germany	20	28%	1	5%	19	42%	0	0%
Italy	10	14%	0	0%	10	22%	0	0%
Japan	2	3%	0	0%	2	4%	0	0%
Sweden	3	4%	0	0%	3	7%	0	0%
The Netherlands	27	38%	14	70%	6	13%	7	100%
Total	72	100%	20	100%	45	100%	7	100%

Table 6.6 presents the country of residence of the respondents by actor group. Most of the respondents to the questionnaire were from the Netherlands (38%), representing the majority of public authorities' and all insurance companies' respondents. For both these actor groups, mainly respondents from the Netherlands were invited, since the Netherlands is used as a case study in this research project. Six respondents from public authorities were from Belgium and Germany, and three of the Belgians were EU representatives. It is expected that the opinions of the Netherlands' neighbors is not too divergent, but in the analysis, attention was paid to potential differences with respect to the EU and national level. With respect to the automotive industry, a broader selection of respondents was necessary. Most respondents from the automotive industry were from Germany (42%) and Italy (22%), which can be explained by the fact that they are involved in many (European) research projects, and therefore widely represented in the networks of the research colleagues that were used to invite the respondents.

The majority of public authorities' respondents were, as expected, from national authorities (70%). The majority of respondents from the automotive industry were from private vehicle manufacturers (38%) and automotive suppliers (36%).

Table 6.7: Roles of respondents within organizations

Role	General		Public Authorities		Automotive Industry		Insurance Companies	
	#	%	#	%	#	%	#	%
Decision-maker	5	7%	0	0%	2	4%	3	38%
Decision advisor	20	28%	12	60%	7	16%	1	13%
R&D	40	56%	4	20%	33	73%	3	38%
Other	7	10%	4	20%	3	7%	0	13%
Total	72	100%	20	100%	45	100%	7	100%

Table 6.7 presents the roles of the respondents within their organizations per actor group. The majority of the respondents were working as decision advisors, or in research and development (56%). For public authorities the majority work as a decision advisor (60%). For the automotive industry, the large majority of the respondents work in research and development (73%). This is probably due to the fact that the respondents were invited based on networks of research colleagues and congress participants. In addition, researchers could be relatively more willing to participate in a questionnaire. The respondents of insurance companies included a relatively large share of decision-makers, when compared to the other actor groups (38%).

6.3.2 Expected impacts on criteria

The impacts of the ADAS and deployment options on criteria, as expected by the actors, were measured on a 7 point Likert scale[9] from -3 to 3, in which -3 was assigned to definitely negative, and 3 to definitely positive. For the criterion user acceptance -3 was assigned to definitely not acceptable, and 3 to definitely acceptable. This scale is chosen to give the respondents enough range to report possible differences in impact between the three ADAS and three deployment actions.

Table 6.8 presents the average values of the impacts of the ADAS on the four criteria: safety, congestion, environment, and user acceptance. Generally, the scores are high, indicating positive impacts on all criteria, and the most positive impacts are expected on safety. Insurance companies seem to have much higher expectations about the impacts than the other actor groups. Furthermore, the higher safety expectations of the Speed Assistant by public authorities, as compared to the automotive industry, correspond to the known positions of these actors with respect to speed assistance. User acceptance of the Speed Assistant was expected to be relatively low by all actor groups, but the standard deviation is also relatively high, revealing substantial differences in expectations.

Table 6.8: Impacts of ADAS on criteria

Criterion	**ADAS**	**General**		**Public Authorities**		**Automotive Industry**		**Insurance Companies**	
		Impact*	SD**	Impact	SD	Impact	SD	Impact	SD
Safety	Speed Assistant	1.64	*1.15*	2.00	*0.92*	1.44	*1.24*	1.86	*1.07*
	Congestion Assistant	1.90	*0.84*	1.85	*0.75*	1.87	*0.89*	2.29	*0.76*
	Safe Driving Assist.	1.78	*0.86*	1.80	*0.77*	1.69	*0.90*	2.29	*0.76*
Congestion	Speed Assistant	0.93	*1.13*	0.85	*1.31*	0.82	*1.03*	1.86	*0.90*
	Congestion Assistant	1.44	*1.24*	1.25	*1.52*	1.44	*1.16*	2.00	*0.82*
	Safe Driving Assist.	1.04	*1.04*	0.65	*1.09*	1.04	*0.95*	2.14	*0.69*
Environment	Speed Assistant	1.35	*1.06*	1.25	*0.79*	1.31	*1.18*	1.86	*0.90*
	Congestion Assistant	1.26	*1.09*	1.00	*1.03*	1.31	*1.10*	1.71	*1.11*
	Safe Driving Assist.	0.92	*1.03*	0.80	*0.83*	0.80	*1.04*	2.00	*1.00*
Acceptance	Speed Assistant	0.47	*1.48*	0.50	*1.50*	0.42	*1.53*	0.71	*1.25*
	Congestion Assistant	1.94	*0.89*	1.75	*1.07*	1.98	*0.81*	2.29	*0.76*
	Safe Driving Assist.	1.40	*1.13*	1.40	*1.35*	1.40	*1.05*	1.43	*1.13*

* Applied measurement scale: -3 (definitely negative/not acceptable)/-2/-1/0/+1/+2/+3 (definitely positive/acceptable)

** Standard deviation

With respect to the impacts of the deployment actions on related criteria (user costs, actor costs, investment risk, liability risk, and user acceptance), the expectations of the actors do not point clearly in a certain direction. In most cases, the average impact is expected to be fairly neutral (around 0), but the standard deviation is also high, meaning that some of the actors expect the impacts to be negative, while others expect them to be positive. These impacts are not addressed further here.

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[9] Though it is advisable to use the same measurement scale throughout a questionnaire, two different scales were used here (a 5 point and a 7 point scale). Since the type of questions was very different this is not expected to have influenced the answers. The different scales were used to match the answering space for the question concerned.

The relative impacts of the ADAS and deployment actions, as expected by the respondents, deviates from current knowledge on the relative impacts, indicating a limited level of knowledge about the impacts among the respondents.

6.4 Model estimation

The main part of the questionnaire included a conjoint measurement task, in which different scenarios were presented to the respondents, consisting of an ADAS, and the deployment actions regarding that ADAS of the two other actors involved, for which they were asked to rate application of their deployment options (utilities), and indicate the probability that their sector will actually apply these deployment options. Based on the data collected by the conjoint measurement, utility and probability models can be estimated for each of the deployment options of the decision-making actor. These models show the influence of different types of ADAS (*A*) and current actions of the other actors ($D_{0,a}$) on the overall utility of the decision-makers to take a certain deployment action regarding an ADAS, and the probability the decision-maker's actor group will actually take this deployment action. The models that were defined earlier in this chapter (see section 6.1.1) are repeated here.

$$P(D_{1,a} = y_a \mid D_0 = x) = c + b_1 x_1 + b_2 x_2 + b_3 z + \varepsilon_1 \tag{6.1}$$

$$U(y_a) = k + l_1 x_1 + l_2 x_2 + l_3 z + \varepsilon_2 \tag{6.2}$$

In which:
$D_{1,a}$ = stochastic variable representing deployment action of actor a at time $t=1$;
D_0 = stochastic variable representing deployment scenario at time $t=0$;
y_a = deployment action by actor a at time $t=1$;
x = deployment scenario at time $t=0$;
x_1, x_2 = deployment action by other actors 1 and 2 at time $t=0$;
z = ADAS;
c = constant of probability model;
b_1,b_2,b_3 = coefficients of probability model;
k = constant of utility model;
l_1,l_2,l_3 = coefficients of utility model;
ε_1, ε_2 = error terms.

The values of the independent variables in these models, x_1, x_2 and z, are on an ordinal or nominal scale. Consequently, their values cannot be directly included in model estimation, making some form of dummy coding necessary. In this case, effect coding was chosen as a method to code the values of the independent variables (see Table 6.9).

Table 6.9: Effect codes for attributes with three levels

Attribute Level	**Indicator variable 1 (X_1)**	**Indicator variable 2 (X_2)**	**Part-worth Utility**
0	1	0	β_1
1	0	1	β_2
2	-1	-1	$-\beta_1-\beta_2$
Parameter:	$\boldsymbol{\beta_1}$	$\boldsymbol{\beta_2}$	

Each independent variable can take the value of the attribute levels 0, 1 and 2. In Table 6.9 these values are coded as the values of two indicator variables, X_1 and X_2. The coefficients b_1-b_3, are each coded as the parameters β_1 and β_2. This results in the following models to be estimated:

$$P(D_{1,a} = y_a \mid D_0 = x) = c + \sum_{i \in \{1,2,3\}} (\beta_{i,1} X_{i,1} + \beta_{i,2} X_{i,2}) + \varepsilon \tag{6.3}$$

$$U(y_a) = k + \sum_{i \in \{1,2,3\}} (\lambda_{i,1} X_{i,1} + \lambda_{i,2} X_{i,2}) + \varepsilon \tag{6.4}$$

In which:
$X_{1,1}$ and $X_{1,2}$ correspond with x_1;
$X_{2,1}$ and $X_{2,2}$ correspond with x_2;
$X_{3,1}$ and $X_{3,2}$ correspond with z;
$\beta_{1,1}$ and $\beta_{1,2}$ correspond with b_1;
$\beta_{2,1}$ and $\beta_{2,2}$ correspond with b_2;
$\beta_{3,1}$ and $\beta_{3,2}$ correspond with b_3;
$\lambda_{1,1}$ and $\lambda_{1,2}$ correspond with l_1;
$\lambda_{2,1}$ and $\lambda_{2,2}$ correspond with l_2;
$\lambda_{3,1}$ and $\lambda_{3,2}$ correspond with l_3.

Model estimation involves the estimation of the constants c and k, and the coefficients β and λ. Since the dependent variable (probabilities/utilities) is measured on a rating scale, the models can be estimated by multiple linear regressions (Ordinary Least Squares method). As a result of the use of effect coding, the estimated constants c and k represent the average probability/utility of the deployment action y_a. The coefficients β and λ represent the deviations of the average probability/utility as a result of the three attribute levels of each independent variable. The sum of the coefficients over all attribute levels for one variable equals 0.

The resulting analysis design is presented in Table 6.10 for public authorities. The analysis design is the same for all actors, except for the names of the attribute levels and variables.

Table 6.10: Analysis design (public authorities)

Profile[*]	**Attribute levels**			**ADAS**		**Industry's deployment action**		**Insurance companies' deployment action**	
	ADAS	IND[**]	INS[***]	adas1 $X_{3,1}$	adas2 $X_{3,2}$	ind1 $X_{1,1}$	ind2 $X_{1,2}$	ins1 $X_{2,1}$	ins2 $X_{2,2}$
2	0	0	0	1	0	1	0	1	0
3	1	1	0	0	1	0	1	1	0
4	2	2	0	-1	-1	-1	-1	1	0
6	0	1	2	1	0	0	1	-1	-1
7	1	2	2	0	1	-1	-1	-1	-1
9	2	0	2	-1	-1	1	0	-1	-1
10	0	2	1	1	0	-1	-1	0	1
11	1	0	1	0	1	1	0	0	1
12	2	1	1	-1	-1	0	1	0	1

* Not all profile numbers are included in the analysis since 1, 5 and 8 were holdout tasks
** IND = industry's deployment action
*** INS = insurance companies' deployment action

The models can be estimated from individual data, as well as from average data over all respondents of an actor group. Here, the models were estimated from average data, since this fits the current case better. First of all, we are mainly interested in the differences between the deployment actions, and not in the individual differences of respondents on one of the options. Second, due to personal style, there is a high probability that the respondents' answers systematically deviate from the overall average. This spread in the data influences the performance of the models, but is relatively meaningless. Finally, the respondents are usually not individual decision makers with respect to taking deployment actions. Thus they are neither within the organization they are part of, nor within the corresponding actor group. Consequently, it is expected that the general average over the data give a more representative view of the general prospects with respect to ADAS deployment than the individual data.

6.5 Results: utility and probability of ADAS deployment actions

6.5.1 How to read the models

Each of the tables presented in this section includes the utility or probability models of all deployment actions of one actor. The respective models are represented in the columns of the tables. The left side of the columns presents the coefficients of the models, which are explained in the first column, and the right side of the column presents the statistical significance of the models. The first coefficient is the constant, which represents the average utility or probability of a certain deployment action. The remaining nine coefficients represent the three attribute levels for each of the three attributes. In case all attribute levels of an attribute were not statistically significant across the models for an actor, they were not included in the tables. The last value in the left side of the column is the explained variance R^2. The value of R^2 should be interpreted as a relative measure (i.e. a model with a higher R^2 fits the data better), but not as an absolute measure, since its absolute value heavily depends on the experimental design.

The coefficients indicate the deviations from the constant and, therefore, the sum of the coefficients of the attribute levels for one attribute is equal to zero. Positive coefficients positively influence the overall utility or probability, in scenarios that include the corresponding attribute levels. Negative coefficients negatively influence the overall utility or probability. The statistical significance of the attribute levels is presented in terms of the p-value. Attribute levels with $p \leq 0.1$ are considered to be statistically significant (see also 6.5.5.). The statistical significance is only presented for the first and second attribute level, since these were included in the regression analysis. The third attribute level was calculated as the complement of the other two.

6.5.2 Public authority models

In the public authority utility models, the constants contribute most to overall utilities of their deployment actions (see Table 6.11). However, the values of 4.783 and 4.406, and the largest utility that can be derived from the models (6.133 for doing nothing), are quite low on the 10-point scale used. If this apparently low utility of ADAS deployment is disregarded, the models show a relative preference of the respondents towards doing nothing or tax reduction. The overall utility is influenced most by the deployment actions of the automotive industry, particularly when it offers an ADAS as standard equipment on all new vehicles. The ADAS types have only a minor effect on overall utility, and only some of the values are statistically significant. No statistically significant relation with the deployment actions of insurance companies can be observed.

Table 6.11: Public authorities' overall utilities to take ADAS deployment actions

PUBLIC AUTHORITIES	**Do nothing**		**Tax reduction**		**Mandate**	
Overall utilities	coeff	*sig*	coeff	*sig*	coeff	*sig*
Constant	4.783	*0.000*	4.406	*0.001*	2.850	*0.000*
ADAS						
Speed Assistant	-0.367	*0.046*	0.078	*0.746*	0.383	*0.025*
Congestion Assistant	0.167	*0.178*	0.261	*0.338*	-0.067	*0.397*
Safe Driving Assistant	0.200		-0.339		-0.317	
Industry action						
Do nothing	-0.567	*0.020*	0.644	*0.091*	0.650	*0.009*
Option	-0.400	*0.039*	0.744	*0.071*	0.350	*0.030*
Standard	0.967		-1.389		-1.000	
Insurance action						
Do nothing	0.000	*1.000*	0.094	*0.696*	0.150	*0.138*
Option	-0.183	*0.154*	-0.039	*0.870*	-0.150	*0.138*
Standard	0.183		-0.056		0.000	
R Square	0.988		0.959		0.994	

An overall interpretation of these results is that the respondents from public authorities find that the automotive industry should take the lead in ADAS deployment, but if this is not the case, they are willing to stimulate ADAS deployment, probably being most interested in the Speed Assistant.

Table 6.12: Public authorities' overall probabilities in (%) to take ADAS deployment actions

PUBLIC AUTHORITIES	**Do nothing**		**Tax reduction**		**Mandate**		**Other**	
Overall probabilities	coeff	*sig*	coeff	*sig*	coeff	*sig*	coeff	*sig*
Constant	62.333	*0.000*	20.000	*0.004*	8.161	*0.001*	9.506	*0.016*
ADAS								
Speed Assistant	-2.583	*0.277*	0.917	*0.652*	0.822	*0.146*	0.844	*0.671*
Congestion Assistant	-0.250	*0.899*	0.750	*0.709*	0.339	*0.440*	-0.839	*0.673*
Safe Driving Assistant	2.833		-1.667		-1.161		-0.006	
Industry action								
Do nothing	-4.750	*0.113*	3.417	*0.189*	1.172	*0.081*	0.161	*0.934*
Option	-7.833	*0.046*	5.833	*0.079*	0.339	*0.440*	1.661	*0.435*
Standard	12.583		-9.250		-1.511		-1.822	
Insurance action								
Do nothing	0.000	*1.000*	-0.333	*0.866*	-0.411	*0.366*	0.744	*0.707*
Option	-1.583	*0.460*	1.083	*0.598*	-0.344	*0.434*	0.844	*0.671*
Standard	1.583		-0.750		0.756		-1.589	
R Square	0.966		0.938		0.947		0.561	

The public authority probability models (Table 6.12) show that the respondents' expectations with respect to what public authorities will do are more conservative. The average probability of doing nothing is relatively high, and that of mandatory deployment very low. The probabilities of doing nothing and tax reduction are influenced by industry offering ADAS as optional or standard equipment, but not to an extent that the rank order of the deployment actions changes. The ADAS and the deployment actions of insurance companies have no statistically significant effect on the probabilities. The probability of other deployment actions is comparable to that of mandatory equipment, but the explained variance is relatively low. The low probability and explained variance are due to the relatively small amount of respondents that used the possibility to choose for this option (4 out of 20 on average).

An overall interpretation of these results is that the respondents from public authorities are the most likely to expect public authorities to do nothing with respect to ADAS deployment.

6.5.3 The automotive industry's models

Table 6.13: The automotive industry's overall utilities to take ADAS deployment actions

AUTOMOTIVE INDUSTRY	**Do nothing**		**Option**		**Standard**	
Overall utilities	coeff	*sig*	coeff	*sig*	coeff	*sig*
Constant	1.926	*0.002*	5.704	*0.000*	5.442	*0.001*
ADAS						
Speed Assistant	0.261	*0.178*	-0.251	*0.278*	-0.092	*0.653*
Congestion Assistant	-0.149	*0.364*	0.266	*0.259*	0.148	*0.490*
Safe Driving Assistant	-0.112		-0.014		-0.056	
Authorities' action						
Do nothing	1.214	*0.011*	0.056	*0.775*	-1.872	*0.009*
Tax reduction	-0.319	*0.130*	1.342	*0.016*	-0.049	*0.807*
Mandate	-0.896		-1.398		1.921	
Insurance action						
Do nothing	0.588	*0.044*	-0.548	*0.085*	-0.359	*0.178*
Option	-0.226	*0.219*	0.289	*0.232*	0.201	*0.372*
Standard	-0.362		0.259		0.158	
R Square	0.984		0.980		0.988	

In the automotive industry models, the constants contribute most to the overall utilities of their deployment actions optional and standard equipment (see Table 6.13). The highest values of utility that can be derived from the model are 7.601 for optional equipment, and 7.712 for standard equipment, which, together with the higher constants, indicates that respondents from the automotive industry derive more utility from ADAS deployment than public authorities. In most deployment scenarios, they derive more utility from optional equipment than to standard equipment. The overall utility of the automotive industry's deployment actions is most influenced by the deployment actions of public authorities. This influence is most prominent on the utility of standard equipment. Some minor influence of insurance companies' deployment actions can be observed, showing that if insurance companies provide premium reductions, the overall utility of taking action for the automotive industry increases. The effects of the ADAS are generally not statistically significant.

An overall interpretation of these results is that the automotive industry derives relatively more utility from taking action than to doing nothing with respect to ADAS deployment. Which action they eventually prefer, may depend upon the action of the authorities.

Table 6.14: The automotive industry's overall probabilities in (%) to take ADAS deployment actions

AUTOMOTIVE INDUSTRY	**Do nothing**		**Option**		**Standard**		**Other**	
Overall probabilities	coeff	*sig*	coeff	*sig*	coeff	*sig*	coeff	*sig*
Constant	19.576	*0.006*	43.543	*0.001*	34.004	*0.000*	2.877	*0.002*
ADAS								
Speed Assistant	3.151	*0.291*	-2.600	*0.263*	-0.114	*0.920*	-0.433	*0.126*
Congestion Assistant	-1.096	*0.670*	1.233	*0.541*	-0.264	*0.817*	0.123	*0.545*
Safe Driving Assistant	-2.056		1.367		0.379		0.310	
Authorities' action								
Do nothing	13.668	*0.025*	5.010	*0.097*	-18.138	*0.003*	-0.543	*0.086*
Tax reduction	-2.092	*0.444*	10.680	*0.024*	-8.044	*0.015*	-0.543	*0.086*
Mandate	-11.576		-15.690		26.182		1.087	
Insurance action								
Do nothing	5.561	*0.129*	-3.197	*0.198*	-1.748	*0.224*	-0.617	*0.069*
Option	-2.872	*0.324*	1.347	*0.508*	0.996	*0.426*	0.530	*0.090*
Standard	-2.689		1.850		0.752		0.087	
R Square	0.963		0.980		0.997		0.969	

The automotive industry probability models (Table 6.14) generally show the same picture as the utility models. The probability constants for ADAS as optional and standard equipment show more difference than the corresponding utility constants. The overall probability is influenced by public authorities only, and seemingly to a larger extent than utility is influenced. Their influence is highest when applying mandatory deployment. The probability of other deployment actions is very low, which is due to the small amount of respondents who used this option (5 out of 45, on average).

An overall interpretation of these results is that the probability that the automotive industry is taking action is high, offering an ADAS as optional equipment being preferred to standard equipment. Authority actions can influence these probabilities.

6.5.4 Insurance companies' models

For insurance companies, the models also show a high contribution of the constants to overall utilities (see Table 6.15). Similar to the public authorities' utilities, the overall utilities that can be derived from the model are very low, with 5.512 as the highest value for optional premium reduction. The utilities of the three options available are comparable, while insurance companies seem to derive more utility from taking action. The utility of 'doing nothing' is most influenced by the actions of public authorities, indicating that they might be stimulated to provide premium reductions if public authorities are taking action. The influence of the ADAS type is generally not statistically significant, except for the Speed Assistant, which increases the utility of doing nothing, and the Safe Driving Assistant, which decreases it. No statistically significant relations with industry's deployment actions can be observed.

Table 6.15: Insurance companies' overall utilities to take ADAS deployment actions

INSURANCE COMPANIES	Do nothing		Option		Standard	
Overall utilities	coeff	*sig*	coeff	*sig*	coeff	*sig*
Constant	3.016	*0.000*	5.032	*0.000*	4.447	*0.001*
ADAS						
Speed Assistant	0.271	*0.080*	0.064	*0.629*	-0.063	*0.813*
Congestion Assistant	0.174	*0.167*	-0.129	*0.375*	-0.157	*0.574*
Safe Driving Assistant	-0.446		0.064		0.220	
Industry action						
Do nothing	0.128	*0.259*	-0.272	*0.139*	-0.350	*0.275*
Option	-0.016	*0.867*	0.208	*0.210*	0.080	*0.766*
Standard	-0.112		0.064		0.270	
Authorities' action						
Do nothing	0.794	*0.010*	-0.032	*0.804*	0.223	*0.443*
Tax reduction	-0.496	*0.026*	0.208	*0.210*	0.080	*0.766*
Mandate	-0.299		-0.176		-0.303	
R Square	0.985		0.850		0.720	

An overall interpretation of these results is that insurance companies prefer to take action, while they are hardly influenced by the ADAS and the deployment actions of other actors. They may prefer to take action with respect to the Safe Driving Assistant.

The insurance companies' probability models show that their probabilities are substantially more conservative than their utilities (see Table 6.16). Compared to the preference for action shown by the utility models, the probability models show a preference for doing nothing. The probabilities of the different deployment actions are not influenced by the ADAS or deployment actions of other actors.

Table 6.16: Insurance companies' overall probabilities in (%) to take ADAS deployment actions

INSURANCE COMPANIES	Do nothing		Option		Standard		Other	
Overall probabilities	coeff	*sig*	coeff	*sig*	coeff	*sig*	coeff	*sig*
Constant	47.302	*0.002*	28.572	*0.001*	16.668	*0.011*	7.462	*0.008*
ADAS								
Speed Assistant	0.078	*0.982*	0.954	*0.599*	0.476	*0.868*	-1.509	*0.243*
Congestion Assistant	2.461	*0.508*	-0.952	*0.600*	-2.381	*0.446*	0.874	*0.442*
Safe Driving Assistant	-2.539		-0.002		1.906		0.634	
Industry action								
Do nothing	4.128	*0.312*	-0.476	*0.787*	-1.664	*0.578*	-1.986	*0.164*
Option	-1.826	*0.613*	0.714	*0.689*	-0.004	*0.999*	1.111	*0.351*
Standard	-2.302		-0.239		1.669		0.874	
Authorities' action								
Do nothing	2.934	*0.441*	-1.906	*0.342*	0.952	*0.743*	-1.986	*0.164*
Tax reduction	-2.776	*0.462*	3.571	*0.147*	-1.428	*0.629*	0.634	*0.562*
Mandate	-0.159		-1.666		0.476		1.351	
R Square	0.658		0.753		0.488		0.860	

6.5.5 General observations

The overall utility values of the deployment actions are relatively low, taking into account that they were measured on a 10-point scale. Comparing the data, the automotive industry derives more utility from applying (certain) deployment actions to ADAS than public authorities and insurance companies.

From comparing the constants of the utilities and the probabilities, it is generally found that the probabilities are more conservative with respect to ADAS deployment than the utilities. However, for the automotive industry the differences are small, while for public authorities and insurance companies the difference is more substantial.

For all actors, and all deployment actions, the constants represent the most important part of overall utility and probability. The effects of the attributes are in all cases relatively small, and their influence on preference for a certain deployment action is limited, except for the influence of public authorities and the automotive industry on each others' overall utility and probability of deployment actions. The overall utility and probability of insurance companies' deployment actions is hardly influenced by the other actors, and in turn they do not influence the overall utility or probability of the other actors.

The models include a large number of terms with a very low statistical significance. For the simulations to be used in the explorations with the model of actors' interactions in ADAS deployment (see Chapter 9), it is more appropriate to include only the statistically significant terms. Consequently, the models were re-estimated including those terms with a significance level of 0.05. If terms with a significance level of 0.10 led to a substantial increase of the explained variance R^2, and better forecasts of the data collected for the holdout profiles (better with respect to proximity to the data as well as with respect to correct order of preference), these terms were also included in the model. In the revised models, the statistical significance levels of these factors often reach the 0.05 level. These revised models are included in Appendix A. In some of the models, coefficients are represented with the statistical significance value left blank, these coefficients have a zero value, and were not included in the estimation of the revised models. For some models, none of the coefficients is statistically significant, except (on most occurrences) the constant. In these cases, no R^2 can be calculated, which is therefore left blank.

6.6 Discussion

Respondents: general

It could be argued that the sample is biased, since researchers were relatively over represented. In a case like this, it is nearly impossible to draw a random sample, since respondents with a certain knowledge about the subject are required, and there is no ‘actor phonebook’ available. Finding respondents then depends, for instance, on the network of the researcher, and the availability of contact information of congress participants. All possible respondents were invited, since the population is relatively small. This is not an uncommon procedure when performing this type of research, as there is hardly an alternative way to do it. The fact that the questions to assess probabilities involved the assessment of ‘someone else taking action’ (i.e. the sector the respondent works for) does help to overcome the problem of representation. The results of this part of the investigation showed a slightly more conservative attitude with respect to taking deployment actions, but the same patterns as in the utility models were recognized. These findings, combined with the fact that the results from the utility models generally correspond to known opinions, increase confidence in the results.

Respondents: insurance companies

The number of respondents from insurance companies was quite low, which requires an explanation. First of all, people from insurance companies were often not represented in the relevant networks of people involved in ADAS research and deployment. To overcome this problem, the few contacts that were available were asked to disseminate the questionnaire in their own network or company. However, this has not led to many responses, which was found to be primarily caused by company’s concerns about their message to the outside world when participating in the questionnaire (although we did guarantee their anonymity), and the experienced difficulty of the questionnaire, which was more often reported by insurance company respondents than other respondents.

Respondents: public authorities

With respect to the background of the respondents from public authorities, it may be argued that there could be a large influence from respondents from countries other than the Netherlands, and respondents from the EU. To check this influence, separate models were estimated for respondents from national and local authorities in the Netherlands, and respondents from the EU. This analysis showed that the EU can be a little more influenced by the actions of other actors than the Dutch authorities, but the patterns of utilities and probabilities of both groups were comparable to the overall average. Only the probability of “other” deployment actions was substantially higher for Dutch authorities (around 12%), than for the EU (around 0%). This may indicate that the given deployment actions match the EU decision framework better than the Dutch. Other options mentioned by the Dutch respondents were, for instance, a lower tax reduction, other ways of stimulation, public authorities as a first user, retrofitting, or European regulations. For further steps in the analysis, it was decided to use the average model of public authorities as a satisfactory representation of opinions from different backgrounds. However, it should be kept in mind that in the case of ADAS, it is not yet completely clear whether national authorities or the EU should be the most important deployment agency.

Difficulty of the questionnaire
The questionnaire was reported as being difficult by the test respondents, and also by several of the respondents. This may have influenced the model outcomes. The deployment scenarios may have been difficult to interpret for the respondents, which made them focus more on their own deployment actions, causing a relatively low influence of the decision scenarios. It can be argued that if deployment scenarios are this complicated in reality, the respondent reaction will correspond to reality as well. However, it can also be argued that in reality there is more time to consider deployment scenarios before deciding, at least in theory.

Validity of the results for making forecasts
In subsequent analyses, the probability models are used to make forecasts of actor deployment actions. While forecasts always carry a certain amount of uncertainty, this uncertainty can be increased when models based on stated preference data are used, since respondents in stated preference surveys have been reported to overestimate hypothetical alternatives (e.g. Murphy et al., 2005). What might reduce the bias is that the data used are based on respondent evaluations of what their sector would do. The fact that the probability models were more conservative than the utility models supports this assumption.

6.7 Conclusions and relevance for ADAS deployment

6.7.1 Conclusions regarding the actor models

Utility of deployment actions is relatively low
The actors seem to derive relatively low utilities from their deployment actions. A straightforward explanation for this would be that the deployment actions they derive most utility from were not included in the survey. However, if that were to be the case, it would have been expected that the probability of the 'other' deployment actions would be much higher than the results show. Another explanation would be the presence of widely different strategies among the respondents, and that these were averaged out in the models, causing relatively low overall utilities. This is further explored in Chapter 7.

Probabilities are more conservative than utility
It was found that the probabilities for public authorities and insurance companies were substantially more conservative than their utilities, in the sense that they are less likely to take action than would be expected, based on the utility they derive from their deployment actions individually. For the automotive industry, these differences were considerably smaller, and may have been due to the different type of measurement scale.

These results could be interpreted as an 'interested but awaiting' attitude among public authorities and insurance companies. Moreover, the automotive industry seems to be more likely to actually pursue the actions from which they derive most utility. As such, the automotive industry can be seen as the most important actor, and in order to know something about the possible future of ADAS, one should study industry deployment actions. However, it has to be taken into account that the respondents of the automotive industry were predominantly research employees.

Model constants account for most of the utility and probability
For all models the constants were relatively high, showing a focus of the respondents on their own deployment action, while the effects of the deployment scenarios are relatively low. With respect to the ADAS, an explanation of the small effects could be that the expected impacts of the ADAS on safety, congestion, environment, and user acceptance are all positive, and do not diverge enough to make a clear distinction (see also Table 6.8). With respect to the deployment actions of the other actors, it may have been difficult for the respondents to interpret the influence of what others do on how they should act, but otherwise it can also just be concluded that the influence is rather small.

Many attributes have a low statistical significance: ADAS
In the set-up of the investigation, it was assumed that public authorities would probably take the lead in deployment of the Speed Assistant, the automotive industry in deployment of the Congestion Assistant, and insurance companies in the deployment of the Safe Driving Assistant. However, the results show that in most scenarios the ADAS attributes are not statistically significant. In addition, if they are statistically significant, their effects on the overall utility or probability are relatively small, and would rarely make a difference in the preference for a deployment action.

Despite these results, patterns could be observed across the models that do match with the expectations. The pattern across public authorities' utility models shows that doing nothing is preferred for the Safe Driving Assistant, tax reduction for the Congestion Assistant, and mandatory deployment for the Speed Assistant. For the automotive industry's utilities, the pattern includes the finding that doing nothing seems to be most preferred for the Speed Assistant, and optional and standard equipment for the Congestion Assistant. Insurance companies' utilities show a pattern in which doing nothing is most preferred for the Speed Assistant, an optional premium reduction for the Speed Assistant and the Safe Driving Assistant, and a standard premium reduction for the Safe Driving Assistant. These patterns were not statistically significant, and no conclusions can thus be drawn upon these results. But it is an interesting observation, which might be further explored.

Many attributes have a low statistical significance: other actors' deployment actions
The expectations regarding the influence of other actors' deployment actions would be that public authorities are less expected to take action if industry and insurance companies take action, and industry is more expected to take action if other actors take action. There were no clear expectations on how insurance companies would react on other actors' actions. While generally the effects are in the expected direction, few of them are actually statistically significant.

In many cases, the influence of public authorities and the automotive industry on each others' deployment actions is statistically significant. However, the influence of insurance companies on the utility or probability of other actors' deployment actions is generally not statistically significant, as is the influence of the deployment actions of these actors on the utility, or probability, of insurance companies' deployment actions.

6.7.2 Relevance of the results for ADAS deployment

Structure of the model of actors' interactions in ADAS deployment
Based on the models resulting from this survey, there is evidence that the relations between public authorities and the automotive industry, as assumed, do exist. However, it was found

that there is not enough evidence to confirm the relationship between the deployment actions of insurance companies and the other two actors. Figure 6.3 shows an update of the model of actors' interactions in ADAS deployment, based on the results of the actor survey. In this update the arrows between insurance companies and automotive industry, and insurance companies and public authorities, were removed.

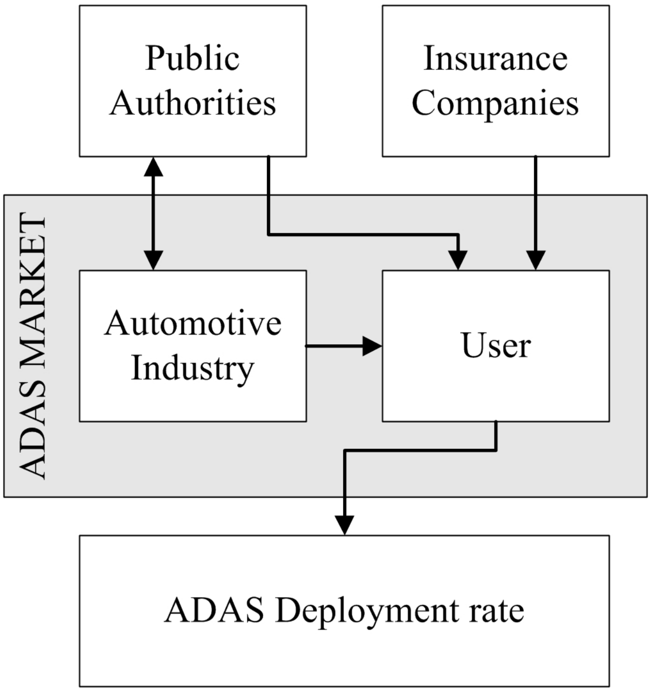


Figure 6.3: Model of actors' interactions in ADAS deployment: update after actor survey

Expectations regarding ADAS deployment

In summary, what do the results of this investigation teach us about the future of ADAS deployment? The most important conclusion is that the automotive industry and public authorities are the main actors, and that they are mainly influencing each others' utilities and probabilities to take action. However, the probability of public authorities to take action is expected to be low, and relatively insensitive to what the automotive industry is doing. The automotive industry can be expected to take action first; which specific action depends on the action of public authorities. Insurance companies are relatively insensitive to the actions of other actors, and the other actors are insensitive to their actions. The probability that they will take action is fairly low.

It must be said that all of these conclusions were drawn based upon the average utilities and probabilities over all respondents for the three actor groups. However, it was found that subgroups of respondents with different strategies regarding ADAS deployment are present within these groups. These subgroups have been identified by means of a cluster analysis, and are described in Chapter 7. In this chapter, the consequences of the existence of these subgroups for the conclusions on the overall utilities and probabilities are also to be discussed.

7 Subgroups of respondents with different strategies regarding ADAS deployment

Is it feasible to identify different strategies of actors based on the actor survey data? In addition, what types of strategies then can be distinguished? Based upon the data collected by the actor survey, a cluster analysis was performed to identify possibly diverging strategies among the respondents. For each group of actors, i.e. public authorities, the automotive industry, and insurance companies, clearly different strategies could be identified, with a substantial influence on deployment scenarios. Some characteristics of strategy subgroups give surprising potential clues about the existence of different strategies.

7.1 Introduction

It is presumed that different strategies are present among the respondents, which are averaged out in the overall utilities and probabilities (see Chapter 6). This presumption is based on the relatively low values for the overall utilities. The overall actor models may as such be hiding interesting details about ADAS deployment. An analysis of the results by grouping the respondents by country, organization, role, or familiarity with the systems, could not identify clearly different strategies. Nevertheless, based on a visual inspection of the data, it was considered to be likely that different strategies did exist among the respondents. The data were therefore analyzed to reveal the existence of subgroups of respondents with similar strategies regarding ADAS deployment, using a cluster analysis. Cluster analysis aims to group cases based on the distances between the respondents' answers, to those questions that are expected to characterize their main differences.

A cluster analysis was performed separately for each of the actor groups, and for utility and probability data. The latter analysis was conducted, since the utilities and probabilities previously were found not to be related clearly in all cases. For each of the relevant subgroups identified, a separate model was estimated.

The main steps to be taken in the preparation of a cluster analysis are (e.g. Hair et al., 2006):

1. Decide by which data the cases should be clustered;
2. Select heterogeneity measure to be applied;
3. Select standardization measure to be applied;
4. Select cluster algorithm to be applied.

After the analysis was performed, the following steps were taken:

5. Select a number of potential clusterings;
6. Choose one clustering for further analysis.

Below, each step is specified, and the choices made for the present analysis are explained.

7.2 Cluster analysis set-up

1. Decide by which data the cases should be clustered

The objective of the cluster analysis is to identify subgroups of respondents within each of the three actor groups that have similar utilities, or probabilities for deployment actions. This means that the respondents whose answers to the questionnaire were most similar were to be clustered. The data included in the cluster analysis are the reported utility ratings (scale 0-10) for all three deployment options, in all nine scenarios measured (i.e. 27 variables), and the reported probabilities (scale 0%-100%) for all four deployment options in all nine scenarios (i.e. 36 variables).

2. Select heterogeneity measure to be applied

Euclidian distance measures were selected for heterogeneity measurement, since this is an objectively understandable measure, which can well be applied to the available interval scale data. Euclidian distance measurement calculates the shortest distance between two points in a multidimensional space (the number of dimensions is determined by the number of data included for each case), which in a two- and three-dimensional space can be visualized as a straight line.

3. Select standardization measure to be applied

The size of the utility and probability ratings can be due to personal style. Since the main aim is to cluster by the order of preference resulting from the ratings, these style effects should not affect the outcomes of the cluster analysis. Thus the utility and probability data were standardized *within* the case, so the cases become comparable. Z-scores are used to standardize the ratings. The probability data are already standardized, since the sum for each of the profiles had to equal 100%.

4. Select cluster algorithm to be applied

The clustering algorithm applied is Average Linkage, which was selected for its transparency. Since the data are simple, positive, interval data, more complex and less transparent algorithms could be avoided. Two types of Average Linkage clustering were applied, between groups and within groups, the algorithms are briefly described here.

Average linkage between clusters

The algorithm calculates for each possible pair of clusters the Euclidian distances between all members of one cluster, and all members of the other cluster. The pair of clusters for which the average of the Euclidian distances is smallest, is merged in that stage of the clustering process. This procedure is repeated until one single cluster remains.

Average linkage within clusters

The algorithm calculates for each possible pair of clusters the Euclidian distances between all members of the potential merger of a pair of clusters. The main difference with average linkages between clusters is that the distances between the members within the existing clusters are also included. The pair of clusters for which the average of the Euclidian distances is smallest, is actually merged in that stage of the clustering process. This procedure is repeated until one single cluster remains.

The results of the clusterings using both algorithms will be further analyzed.

5. Select a number of potential clusters

The amount of cases included in the cluster analysis is relatively small, and since we are looking for the main differences in opinion within the actor groups, some limitation is applied to the number of clusters to be included in further analysis. After a preliminary exploration, it was found that the main differences could be captured in a maximum of two clusters for insurance companies, and five for public authorities and the automotive industry. Since the collected data are suitable to estimate individual models, there are no limitations with respect to minimum cluster size. However, very small clusters can also indicate outliers.

After each combination of clusters, the cluster analysis produces an agglomeration coefficient. This agglomeration coefficient shows the heterogeneity in the clusters. It is calculated as the average of the distances between all members of a cluster within all clusters. For example, consider two clusters of more than one member, one consisting of A, B, and C, and the other of E and F. The agglomeration coefficient in this situation is the average of the Euclidian distances A-B, A-C, B-C and E-F. It generally increases with the number of cases included in clusters. When the increase in the coefficient is relatively high, as opposed to the previous stages, this indicates a large increase in heterogeneity, and therefore a combination of clusters that have a relatively low similarity. A relatively large increase in the coefficient can therefore be used as a stopping rule.

6. Choose one clustering for further analysis
The final decision about which of the potential clusterings (e.g. which algorithm? how many clusters?) are further analyzed, based on two main criteria, the statistical significance of the differences between the potential clusters, and the performance of the models of the cluster averages.

The statistical significance of the differences between the cluster averages of the potential clusters was determined, using non-parametric tests, since the samples are small and not normally distributed. A first selection of clusters was carried out, based on the number of statistically significant differences at the 0.05 level, while these should be spread as much as possible across all pairs of clusters compared. This way of working introduces a bias towards more and larger clusters, but helps to select those clusters that are most different.

Preliminary models were estimated for the remaining clusters, based on the cluster averages of the utilities and probabilities. The performance of these models was analyzed by means of simulation of the outcomes of the holdout scenarios. A model is assumed to perform well if these simulations are reasonably close to the data for the holdout scenarios, and if the order of preference among the deployment actions is maintained. Regarding the latter, it is most important that the most preferred deployment action is the same. Some small clusters performed relatively poorly on these simulations, but were not immediately considered as outliers. Most of these small clusters represented a similar strategy as larger clusters, which led to the decision to include a smaller number of clusters that performed better on the models, with no loss of information regarding different strategies.

7.3 Results: subgroups of respondents and their characteristics

Table 7.1 presents the resulting number of subgroups of similar utility and probability patterns for each of the actor groups, including the algorithm on which the subgroups were based. For public authorities’ probabilities, potential subgroups were not substantially different, and a single cluster (overall average) remains.

Table 7.1: Results of the cluster analysis

Actor	**Utilities**		**Probabilities**	
	N° of subgroups	Algorithm	N° of subgroups	Algorithm
Public authorities	2	Average linkage within clusters	1	-
Automotive industry	5	Average linkage within clusters	3	Average linkage within clusters
Insurance companies	2	Average linkage between clusters	2	Average linkage between/within clusters

For each of these subgroups, the models have been estimated based on the subgroup means (see Table 7.2 to 7.15). Figures 7.1 to 7.5 present the main characteristics of the differences between the subgroups. These characteristics are the average utility or probability (the model constant), and the deviation from the average due to the influence of other actors. Similar to the overall models, the effects of the ADAS do not play an important role, and are therefore not included in these Figures.

7.3.1 Public authorities' utility subgroup models

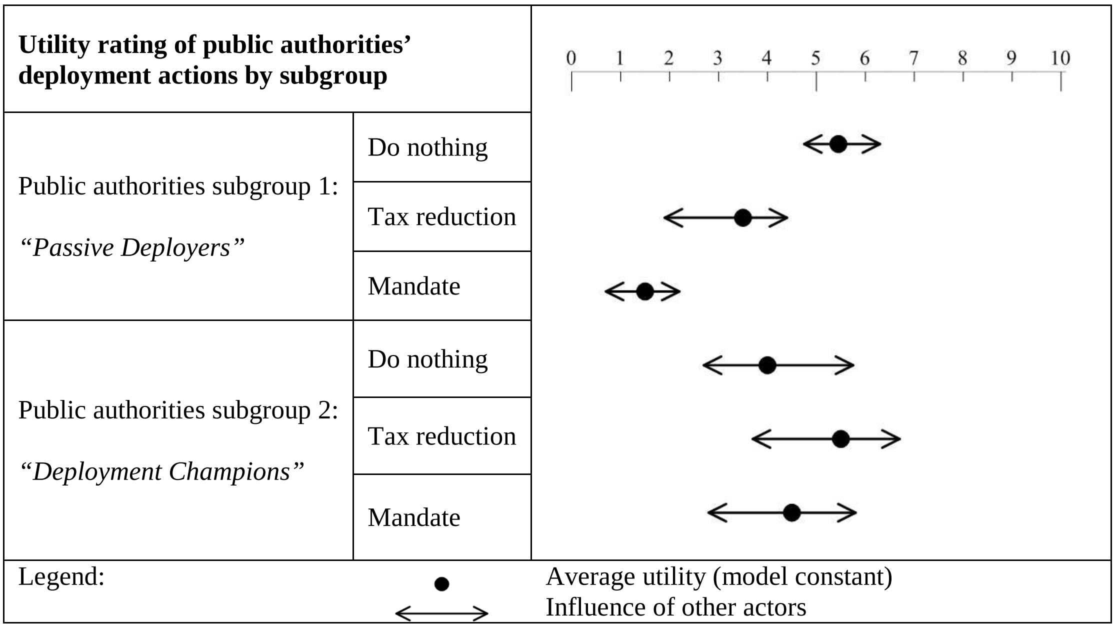


Figure 7.1: Utility rating of public authorities' deployment actions by subgroup

Public authorities' utility subgroup 1 (n=11, Table 7.2)
The respondents in this subgroup generally derive most utility from doing nothing, and this does not change due to other actor's actions or different ADAS. An overall interpretation of these results is that the respondents in this subgroup represent the strategy that authorities should not be actively involved in ADAS deployment, while taking action is more preferred if other actors do nothing. This subgroup is labeled *Passive Deployers*.

Table 7.2: Public authorities' utilities to take ADAS deployment actions – Passive Deployers

PUBLIC AUTHORITIES	**Do nothing**		**Tax reduction**		**Mandate**	
Utilities Cluster 1	coeff	*sig*	coeff	*sig*	coeff	*sig*
Constant	5.463	*0.000*	3.426	*0.004*	1.414	*0.002*
ADAS						
Speed Assistant	-0.193	*0.035*	0.151	*0.679*	0.406	*0.036*
Congestion Assistant	0.293	*0.016*	0.121	*0.738*	-0.111	*0.296*
Safe Driving Assistant	-0.100		-0.272		-0.294	
Industry action						
Do nothing	-0.253	*0.021*	0.454	*0.286*	0.372	*0.043*
Option	-0.280	*0.017*	0.728	*0.147*	0.132	*0.237*
Standard	0.533		-1.182		-0.504	
Insurance action						
Do nothing	0.293	*0.016*	0.211	*0.572*	0.316	*0.058*
Option	-0.403	*0.008*	0.091	*0.800*	-0.114	*0.286*
Standard	0.110		-0.302		-0.201	
R Square	0.995		0.889		0.978	

Public authorities' utility subgroup 2 (n=9, Table 7.3)
The respondents in this subgroup derive more utility from taking action than from doing nothing, and this utility increases if industry is doing nothing or deploying ADAS as an option on new vehicles. If industry deploys ADAS as a standard on all new vehicles, most utility is derived from doing nothing. Consequently, the respondents in this subgroup represent the strategy that authorities should actively stimulate deployment, if ADAS are not offered as a standard on all new vehicles by industry. This subgroup is labeled *Deployment Champions*.

Table 7.3: Public authorities' utilities to take ADAS deployment actions – Deployment Champions

PUBLIC AUTHORITIES	**Do nothing**		**Tax reduction**		**Mandate**	
Utilities Cluster 2	coeff	*sig*	coeff	*sig*	coeff	*sig*
Constant	3.950	*0.001*	5.606	*0.001*	4.606	*0.000*
ADAS						
Speed Assistant	-0.580	*0.113*	-0.012	*0.969*	0.358	*0.016*
Congestion Assistant	0.010	*0.967*	0.431	*0.259*	-0.016	*0.766*
Safe Driving Assistant	0.570		-0.419		-0.342	
Industry action						
Do nothing	-0.950	*0.047*	0.878	*0.086*	0.988	*0.002*
Option	-0.543	*0.126*	0.764	*0.110*	0.618	*0.005*
Standard	1.493		-1.642		-1.606	
Insurance action						
Do nothing	-0.357	*0.237*	-0.049	*0.876*	-0.049	*0.397*
Option	0.087	*0.725*	-0.199	*0.546*	-0.199	*0.049*
Standard	0.270		0.248		0.248	
R Square	0.969		0.952		0.999	

7.3.2 The automotive industry's utility subgroup models

The automotive industry's utility subgroup 1 (n=20, Table 7.4)
The respondents in this subgroup derive most utility from taking action, with optional deployment being preferred to standard deployment, except when authorities mandate deployment of ADAS. The utility of doing nothing increases when authorities and insurance companies are doing nothing, but is never higher than that of taking action.

An overall interpretation of these results is that the respondents in this subgroup prefer to take action to deploy ADAS, and which action they prefer to take depends on what authorities do. This subgroup is labeled *Active Deployers*.

The automotive industry's utility subgroup 2 (n=5, Table 7.5)
The respondents in this subgroup are generally relatively indifferent to the deployment actions, deriving slightly more utility from doing nothing than to the other options. The actions taken by authorities have large impacts on the utilities, most utility is derived from doing nothing when authorities are doing nothing, to optional deployment when authorities apply tax reductions, and to standard deployment when authorities mandate deployment.

An overall interpretation of these results is that the respondents in this subgroup are generally indifferent; their preference depends on what action authorities are taking. Authorities should take action first. This subgroup is labeled *Restrained Deployers*.

Table 7.4: The automotive industry's utilities to take ADAS deployment actions – Active Deployers

AUTOMOTIVE INDUSTRY	**Do nothing**		**Option**		**Standard**	
Utilities Cluster 1	coeff	*sig*	coeff	*sig*	coeff	*sig*
Constant	1.656	*0.001*	6.711	*0.001*	6.128	*0.000*
ADAS						
Speed Assistant	0.078	*0.333*	-0.161	*0.588*	-0.111	*0.181*
Congestion Assistant	-0.056	*0.461*	0.406	*0.249*	0.072	*0.320*
Safe Driving Assistant	-0.022		-0.244		0.039	
Authorities' action						
Do nothing	0.861	*0.005*	-0.594	*0.142*	-1.728	*0.001*
Tax reduction	-0.356	*0.029*	0.872	*0.074*	0.306	*0.031*
Mandate	-0.506		-0.278		1.422	
Insurance action						
Do nothing	0.528	*0.013*	-0.944	*0.064*	-0.378	*0.021*
Option	-0.056	*0.461*	0.472	*0.202*	0.139	*0.127*
Standard	-0.472		0.472		0.239	
R Square	0.993		0.936		0.998	

Table 7.5: The automotive industry's utilities to take ADAS deployment actions – Restrained Deployers

AUTOMOTIVE INDUSTRY	**Do nothing**		**Option**		**Standard**	
Utilities Cluster 2	coeff	*sig*	coeff	*sig*	coeff	*sig*
Constant	4.222	*0.002*	3.222	*0.006*	3.978	*0.004*
ADAS						
Speed Assistant	0.444	*0.226*	-0.556	*0.257*	0.156	*0.715*
Congestion Assistant	0.044	*0.879*	0.378	*0.398*	0.356	*0.439*
Safe Driving Assistant	-0.489		0.178		-0.511	
Authorities' action						
Do nothing	3.111	*0.007*	0.511	*0.286*	-3.044	*0.014*
Tax reduction	0.111	*0.708*	1.711	*0.040*	-2.311	*0.025*
Mandate	-3.222		-2.222		5.356	
Insurance action						
Do nothing	0.378	*0.280*	-0.156	*0.703*	0.022	*0.958*
Option	-0.089	*0.763*	0.111	*0.783*	0.156	*0.715*
Standard	-0.289		0.044		-0.178	
R Square	0.991		0.958		0.991	

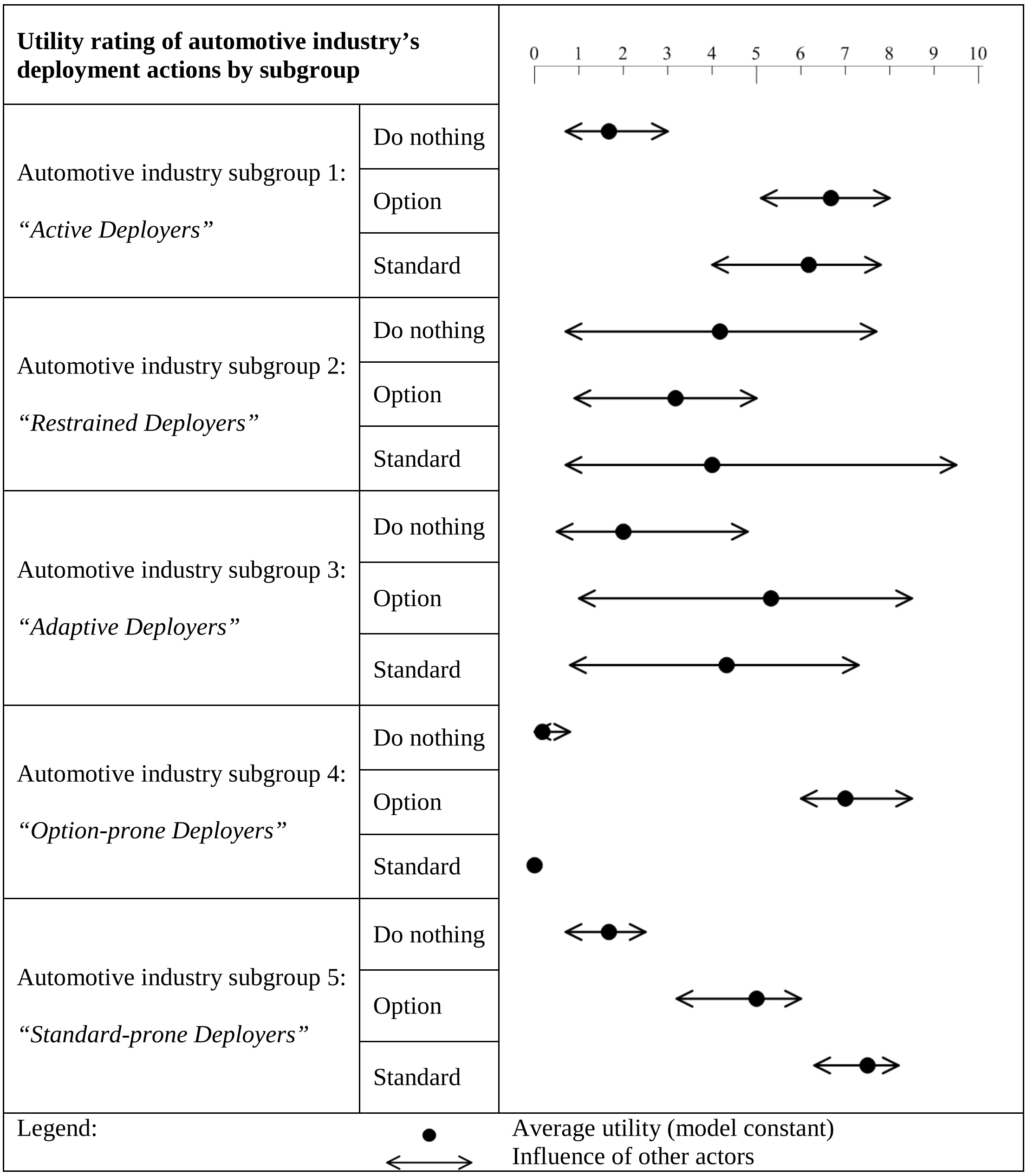


Figure 7.2: Utility rating of the automotive industry's deployment actions by subgroup

The automotive industry's utility subgroup 3 (n=10, Table 7.6)
This subgroup is comparable to subgroup l, but the effects of the actions of authorities on the utilities are much higher. There is more difference in utility between optional and mandatory equipment, depending on the action taken by the authorities.

An overall interpretation of these results is that the respondents in this subgroup generally prefer to take action to deploy ADAS, but the utility they derive from their deployment actions depends to a large extent on the deployment actions of public authorities. This subgroup is labeled *Adaptive Deployers*.

Table 7.6: The automotive industry’s utilities to take ADAS deployment actions – Adaptive Deployers

AUTOMOTIVE INDUSTRY	**Do nothing**		**Option**		**Standard**	
Utilities Cluster 3	coeff	*sig*	coeff	*sig*	coeff	*sig*
Constant	1.933	*0.007*	5.311	*0.002*	4.256	*0.004*
ADAS						
Speed Assistant	0.333	*0.293*	-0.111	*0.741*	0.411	*0.394*
Congestion Assistant	-0.400	*0.232*	-0.078	*0.816*	0.044	*0.918*
Safe Driving Assistant	0.067		0.189		-0.456	
Authorities' action						
Do nothing	1.767	*0.017*	1.022	*0.073*	-2.956	*0.016*
Tax reduction	-0.900	*0.062*	2.822	*0.011*	0.144	*0.741*
Mandate	-0.867		-3.844		2.811	
Insurance action						
Do nothing	1.133	*0.041*	-0.411	*0.296*	-0.489	*0.328*
Option	-0.633	*0.115*	0.289	*0.429*	0.278	*0.542*
Standard	-0.500		0.122		0.211	
R Square	0.976		0.989		0.976	

Table 7.7: The automotive industry’s utilities to take ADAS deployment actions – Option-prone Deployers

AUTOMOTIVE INDUSTRY	**Do nothing**		**Option**		**Standard**	
Utilities Cluster 4	coeff	*sig*	coeff	*sig*	coeff	*sig*
Constant	0.167	*0.423*	7.056	*0.002*	0.000*	-
ADAS						
Speed Assistant	0.333	*0.293*	-0.389	*0.468*	-	-
Congestion Assistant	-0.167	*0.553*	0.778	*0.217*	-	-
Safe Driving Assistant	-0.167		-0.389		-	
Authorities' action						
Do nothing	-0.167	*0.553*	-0.556	*0.332*	-	-
Tax reduction	0.333	*0.293*	-0.222	*0.662*	-	-
Mandate	-0.167		0.778		-	
Insurance action						
Do nothing	-0.167	*0.553*	-0.222	*0.662*	-	-
Option	-0.167	*0.553*	-0.556	*0.332*	-	-
Standard	0.333		0.778		-	
R Square	0.750			0.832	-	-
* = The preferences measured were all equal to zero, no model could be estimated						

The automotive industry's utility subgroup 4 (n=2, Table 7.7)
The respondents in this subgroup generally derive most utility from offering ADAS as an option. This is not further influenced by any action of other actors. This subgroup is labeled *Option-prone Deployers*.

The automotive industry's utility subgroup 5 (n=8, Table 7.8)
The respondents in this subgroup derive most utility from taking action and to standard deployment in particular. Their utilities are influenced by the actions of authorities, but this does not change the order of preference. This subgroup is labeled *Standard-prone Deployers*.

Table 7.8: The automotive industry's utilities to take ADAS deployment actions – Standard-prone Deployers

AUTOMOTIVE INDUSTRY	Do nothing		Option		Standard	
Utilities Cluster 5	coeff	*sig*	coeff	*sig*	coeff	*sig*
Constant	1.601	*0.005*	4.891	*0.000*	7.488	*0.000*
ADAS						
Speed Assistant	0.486	*0.101*	-0.431	*0.079*	-0.861	*0.048*
Congestion Assistant	-0.181	*0.392*	0.156	*0.352*	0.389	*0.186*
Safe Driving Assistant	-0.304		0.276		0.472	
Authorities' action						
Do nothing	0.569	*0.077*	0.362	*0.107*	-0.611	*0.090*
Tax reduction	0.069	*0.721*	0.819	*0.024*	0.222	*0.375*
Mandate	-0.638		-1.181		0.389	
Insurance action						
Do nothing	0.359	*0.165*	-0.054	*0.715*	-0.488	*0.131*
Option	-0.221	*0.317*	0.152	*0.360*	0.346	*0.221*
Standard	-0.138		-0.098		0.142	
R Square	0.939		0.980		0.947	

7.3.3 The automotive industry's probability subgroup models

The automotive industry's probability subgroup 1 (n=25, Table 7.9)
The respondents in this subgroup consider it to be most likely that the automotive industry takes action, optional deployment being most probable. If authorities mandate deployment, they expect industry to be almost indifferent between optional and standard deployment. This subgroup is interpreted as seeing the automotive industry as an *Active Deployer*.

The automotive industry's probability subgroup 2 (n=10, Table 7.10)
The respondents in this subgroup consider it to be most probable that the automotive industry does nothing, especially when authorities are doing nothing. They expect industry to be almost indifferent between doing nothing and optional equipment if authorities apply tax reduction. Only if authorities mandate deployment, taking action (standard deployment on all vehicles) is more probable than doing nothing. This subgroup is interpreted as seeing automotive industry as a *Reluctant Deployer*.

The automotive industry's probability subgroup 3 (n=10, Table 7.11)

The respondents in this subgroup expect it to be most probable that the automotive industry takes action, standard deployment being most probable. If authorities are doing nothing or apply a tax reduction, optional deployment and doing nothing becomes most probable. If public authorities mandate, there is no discussion: the automotive industry is expected to apply standard deployment. This subgroup is interpreted as seeing the automotive industry as an *Adaptive Deployer*.

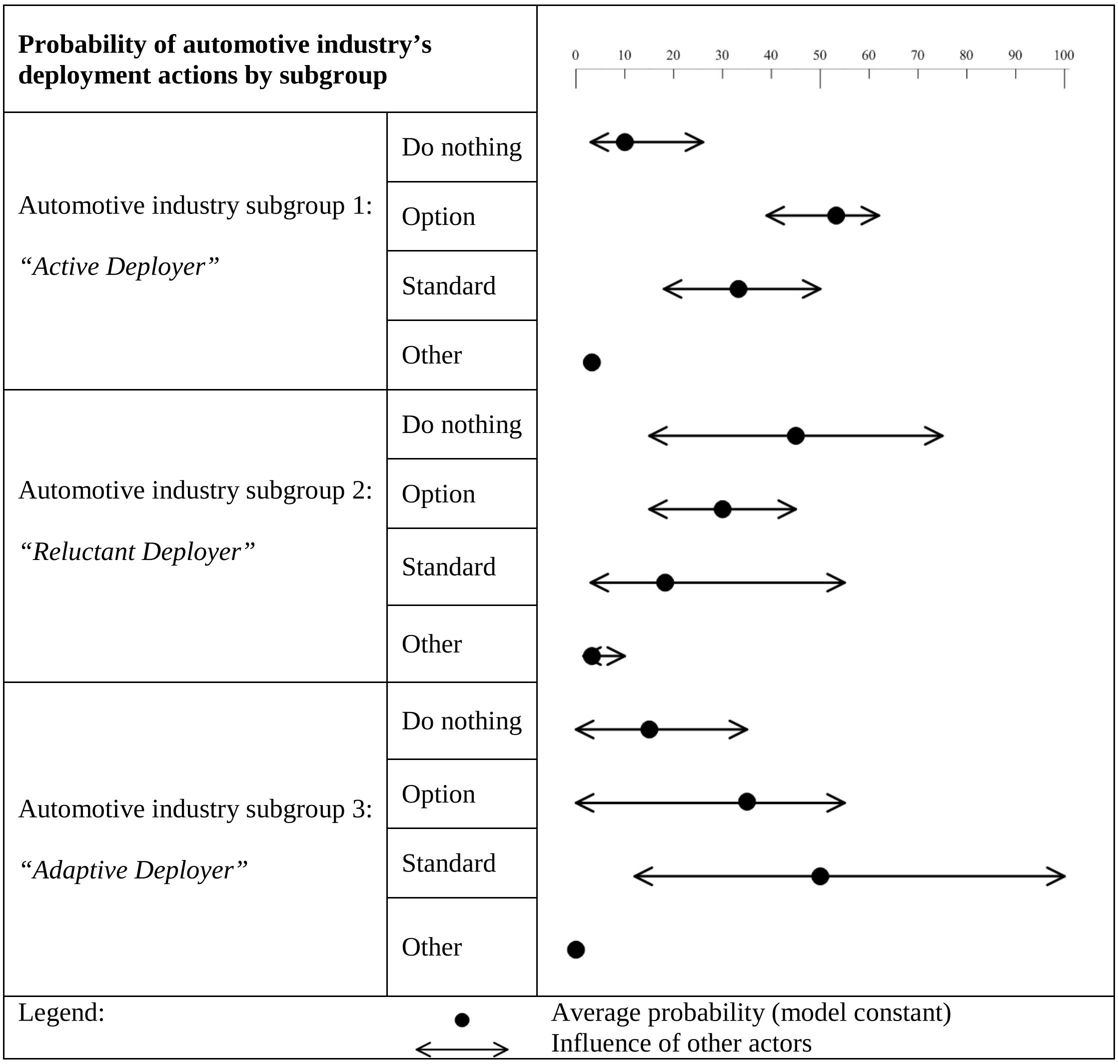


Figure 7.3: Probability of the automotive industry's deployment actions by subgroup

Table 7.9: The automotive industry's probabilities in (%) to take ADAS deployment actions – Active Deployer

AUTOMOTIVE INDUSTRY	**Do nothing**		**Option**		**Standard**		**Other**	
Probabilities Cluster 1	coeff	*sig*	coeff	*sig*	coeff	*sig*	coeff	*sig*
Constant	11.356	*0.012*	52.422	*0.001*	32.756	*0.001*	3.467	*0.002*
ADAS								
Speed Assistant	4.244	*0.144*	-2.956	*0.287*	-1.222	*0.394*	-0.067	*0.766*
Congestion Assistant	-1.622	*0.465*	1.378	*0.572*	0.311	*0.810*	-0.067	*0.766*
Safe Driving Assistant	-2.622		1.578		0.911		0.133	
Authorities' action								
Do nothing	8.378	*0.044*	3.711	*0.213*	-12.289	*0.008*	0.200	*0.415*
Tax reduction	-3.556	*0.189*	6.578	*0.086*	-2.889	*0.126*	-0.133	*0.567*
Mandate	-4.822		-10.289		15.178		-0.067	
Insurance action								
Do nothing	6.311	*0.073*	-2.822	*0.304*	-2.356	*0.173*	-1.133	*0.029*
Option	-3.689	*0.178*	1.378	*0.572*	1.511	*0.314*	0.800	*0.055*
Standard	-2.622		1.444		0.844		0.333	
R Square	0.952		0.937		0.990		0.948	

Table 7.10: The automotive industry's probabilities in (%) to take ADAS deployment actions – Reluctant Deployer

AUTOMOTIVE INDUSTRY	**Do nothing**		**Option**		**Standard**		**Other**	
Probabilities Cluster 2	coeff	*sig*	coeff	*sig*	coeff	*sig*	coeff	*sig*
Constant	44.089	*0.004*	29.500	*0.004*	22.800	*0.001*	3.611	*0.002*
ADAS								
Speed Assistant	2.511	*0.570*	-1.933	*0.520*	0.533	*0.691*	-1.111	*0.033*
Congestion Assistant	-2.422	*0.582*	2.500	*0.422*	-0.467	*0.726*	0.389	*0.202*
Safe Driving Assistant	-0.089		-0.567		-0.067		0.722	
Authorities' action								
Do nothing	24.511	*0.022*	-4.333	*0.225*	-16.900	*0.005*	-3.278	*0.004*
Tax reduction	0.578	*0.891*	13.833	*0.031*	-11.967	*0.009*	-2.444	*0.007*
Mandate	-25.089		-9.500		28.867		5.722	
Insurance action								
Do nothing	5.844	*0.257*	-4.600	*0.207*	-1.967	*0.232*	0.722	*0.074*
Option	-3.922	*0.403*	2.167	*0.477*	2.700	*0.145*	-0.944	*0.045*
Standard	-1.922		2.433		-0.733		0.222	
R Square	0.969		0.948		0.997		0.998	

Table 7.11: The automotive industry's probabilities in (%) to take ADAS deployment actions – Adaptive Deployer

AUTOMOTIVE INDUSTRY	**Do nothing**		**Option**		**Standard**		**Other**	
Probabilities Cluster 3	coeff	*sig*	coeff	*sig*	coeff	*sig*	coeff	*sig*
Constant	15.611	*0.012*	35.389	*0.001*	48.333	*0.000*	0.667	*0.184*
ADAS								
Speed Assistant	1.056	*0.704*	-2.389	*0.267*	2.000	*0.267*	-0.667	*0.293*
Congestion Assistant	1.556	*0.584*	-0.389	*0.827*	-1.500	*0.371*	0.333	*0.553*
Safe Driving Assistant	-2.611		2.778		-0.500		0.333	
Authorities' action								
Do nothing	16.056	*0.022*	17.611	*0.008*	-34.000	*0.001*	0.333	*0.553*
Tax reduction	-1.111	*0.689*	17.778	*0.008*	-17.000	*0.006*	0.333	*0.553*
Mandate	-14.944		-35.389		51.000		-0.667	
Insurance action								
Do nothing	3.389	*0.294*	-2.722	*0.224*	0.000	*1.000*	-0.667	*0.293*
Option	0.222	*0.935*	0.444	*0.803*	-2.000	*0.267*	1.333	*0.106*
Standard	-3.611		2.278		2.000		-0.667	
R Square	0.968		0.996		0.999		0.857	

Remarks

Subgroups corresponding with option-prone and standard-prone deployers are not identified here. This reveals that, while a substantial number of respondents (10) did support such a strategy, they do not expect deployment to occur in such a way. Furthermore, an interesting observation is that for industry as an Active or a Reluctant Deployer, the probability that they offer ADAS as standard equipment when public authorities mandate the ADAS is high, but well short of 100%. This could mean that they may expect the automotive industry to be successful in preventing such an action by public authorities.

7.3.4 Insurance companies' utility subgroup models

Insurance companies' utility subgroup 1 (n=5, Table 7.12)

The respondents in this subgroup generally derive most utility from taking action, as opposed to doing nothing. A little more utility is derived from optional premium reduction than to standard premium reduction. They are hardly influenced by the actions of other actors. This subgroup is labeled *Active Deployers*.

Insurance companies' utility subgroup 2 (n=2, Table 7.13)

The respondents in this subgroup generally derived more utility from doing nothing than to taking action. They are influenced by the actions of other actors, but this influence is not statistically significant. This subgroup is labeled *Non-deployers*.

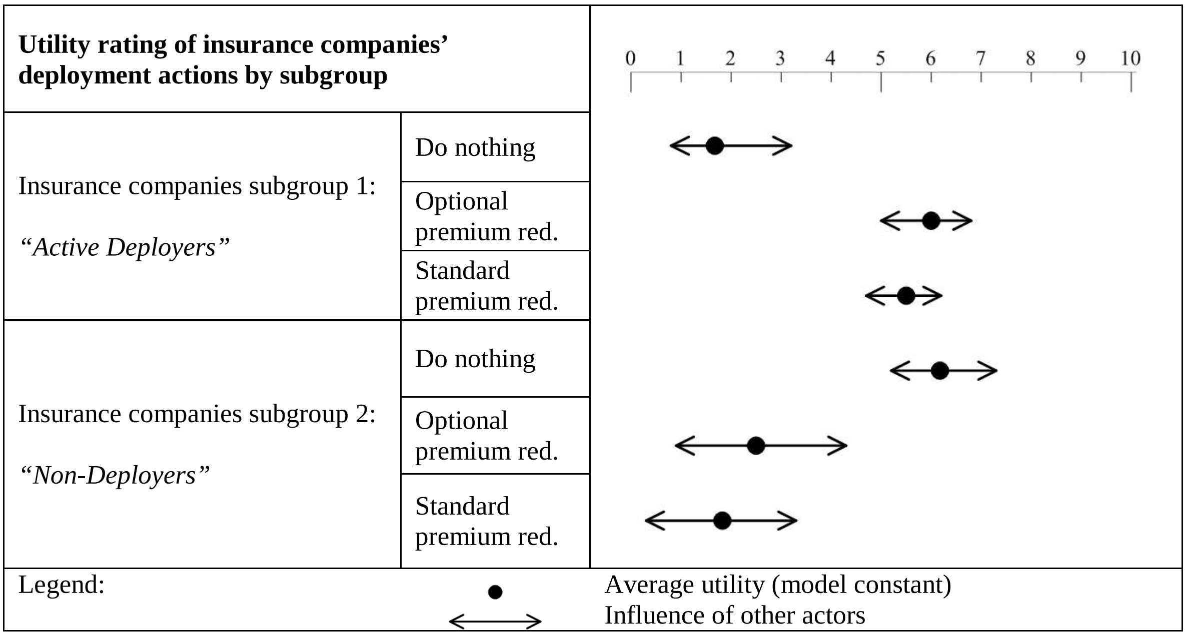


Figure 7.4: Utility rating of insurance companies' deployment actions by subgroup

Table 7.12: Insurance companies' utilities to take ADAS deployment actions – Active Deployers

INSURANCE COMPANIES	Do nothing		Option		Standard	
Utilities Cluster 1	coeff	*sig*	coeff	*sig*	coeff	*sig*
Constant	1.733	*0.025*	6.067	*0.001*	5.511	*0.001*
ADAS						
Speed Assistant	0.533	*0.307*	-0.133	*0.689*	-0.244	*0.501*
Congestion Assistant	0.133	*0.766*	0.067	*0.838*	0.022	*0.948*
Safe Driving Assistant	-0.667		0.067		0.222	
Industry action						
Do nothing	0.400	*0.415*	-0.467	*0.247*	-0.578	*0.194*
Option	0.067	*0.881*	0.200	*0.559*	0.089	*0.795*
Standard	-0.467		0.267		0.489	
Authorities' action						
Do nothing	1.000	*0.126*	-0.667	*0.147*	-0.244	*0.501*
Tax reduction	-0.467	*0.357*	0.467	*0.247*	0.222	*0.536*
Mandate	-0.533		0.200		0.022	
R Square	0.851		0.810		0.748	

Table 7.13: Insurance companies' utilities to take ADAS deployment actions – Non-Deployers

INSURANCE COMPANIES	**Do nothing**		**Option**		**Standard**	
Utilities Cluster 2	coeff	*sig*	coeff	*sig*	coeff	*sig*
Constant	6.222	*0.007*	2.444	*0.024*	1.778	*0.045*
ADAS						
Speed Assistant	-0.389	*0.656*	0.556	*0.419*	0.389	*0.553*
Congestion Assistant	0.278	*0.746*	-0.611	*0.382*	-0.611	*0.382*
Safe Driving Assistant	0.111		0.056		0.222	
Industry action						
Do nothing	-0.556	*0.536*	0.222	*0.725*	0.222	*0.725*
Option	-0.222	*0.795*	0.222	*0.725*	0.056	*0.929*
Standard	0.778		-0.444		-0.278	
Authorities' action						
Do nothing	0.278	*0.746*	1.556	*0.106*	1.389	*0.127*
Tax reduction	-0.556	*0.536*	-0.444	*0.504*	-0.278	*0.664*
Mandate	0.278		-1.111		-1.111	
R Square	0.497		0.842		0.813	

7.3.5 Insurance companies' probability subgroup models

Insurance companies' probability subgroup 1 (n=4, Table 7.14)
The respondents in this subgroup expect the probability of optional premium reduction to be the highest, followed by standard premium reduction and doing nothing having equal probabilities. They expect only minor influence of the other actors on these probabilities. This results in a large probability towards taking action. This subgroup is interpreted as seeing insurance companies as an *Active Deployer*.

Insurance companies' probability subgroup 2 (n=3, Table 7.15)
The respondents in this subgroup expect the probability of doing nothing to be the highest, other probabilities are only small. They do not expect any influence of the other actors. This subgroup is interpreted as seeing insurance companies as a *Non-deployer*.

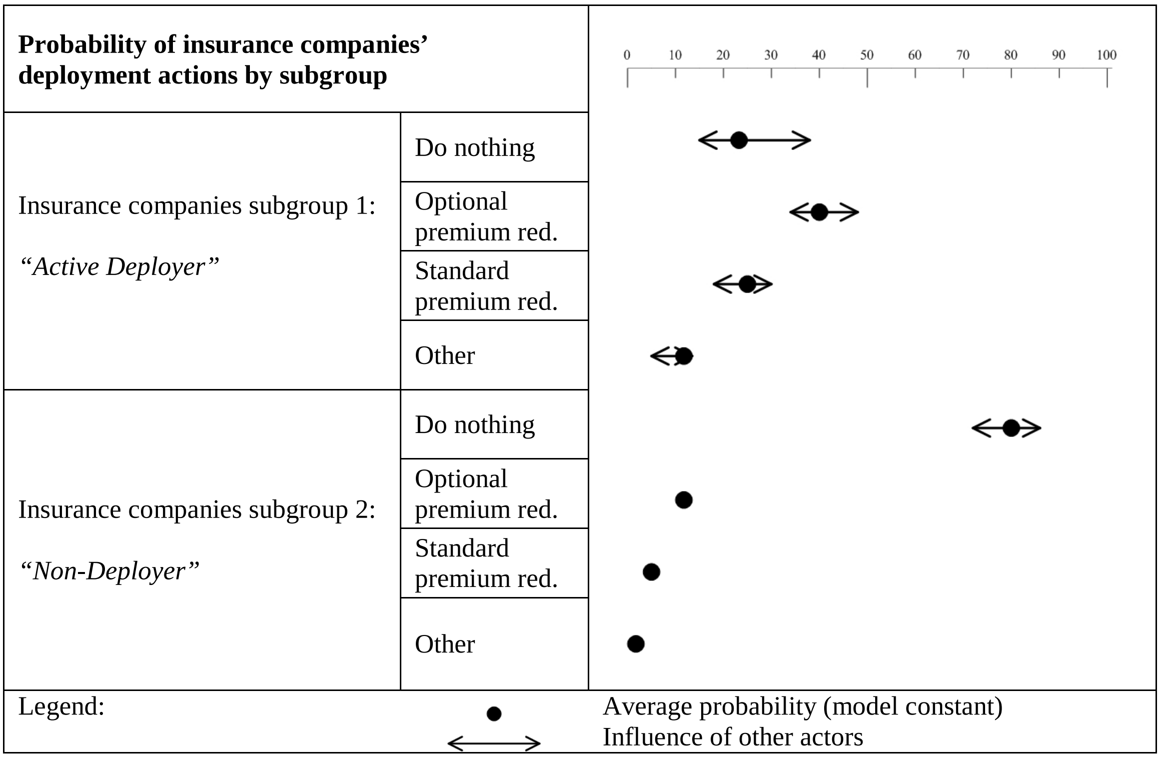


Figure 7.5: Probability of insurance companies' deployment actions by subgroup

Table 7.14: Insurance companies' probabilities in (%) to take ADAS deployment actions – Active Deployer

INSURANCE COMPANIES	Do nothing		Option		Standard		Other	
Probabilities Cluster 1	coeff	*sig*	coeff	*sig*	coeff	*sig*	coeff	*sig*
Constant	23.333	*0.016*	40.694	*0.001*	24.167	*0.013*	11.806	*0.009*
ADAS								
Speed Assistant	-0.833	*0.863*	2.222	*0.293*	0.833	*0.851*	-2.222	*0.301*
Congestion Assistant	2.083	*0.672*	-0.694	*0.702*	-2.917	*0.535*	1.528	*0.442*
Safe Driving Assistant	-1.250		-1.528		2.083		0.694	
Industry action								
Do nothing	5.417	*0.330*	0.139	*0.938*	-2.500	*0.589*	-3.056	*0.198*
Option	-1.250	*0.796*	0.139	*0.938*	-0.417	*0.925*	1.528	*0.442*
Standard	-4.167		-0.278		2.917		1.528	
Authorities' action								
Do nothing	9.167	*0.164*	-6.528	*0.053*	0.417	*0.925*	-3.056	*0.198*
Tax reduction	-5.000	*0.360*	7.222	*0.044*	-2.917	*0.535*	0.694	*0.708*
Mandate	-4.167		-0.694		2.500		2.361	
R Square	0.770		0.933		0.484		0.827	

Table 7.15: Insurance companies' probabilities in (%) to take ADAS deployment actions – Non-Deployer

INSURANCE COMPANIES	**Do nothing**		**Option**		**Standard**		**Other**	
Probabilities Cluster 2	coeff	*sig*	coeff	*sig*	coeff	*sig*	coeff	*sig*
Constant	79.258	*0.001*	12.407	*0.008*	6.667	*0.035*	1.669	*0.000*
ADAS								
Speed Assistant	1.296	*0.740*	-0.740	*0.688*	0.000	*1.000*	-0.556	*0.000*
Congestion Assistant	2.962	*0.476*	-1.297	*0.502*	-1.667	*0.455*	0.001	*0.553*
Safe Driving Assistant	-4.258		2.037		1.667		0.554	
Industry action								
Do nothing	2.409	*0.553*	-1.297	*0.502*	-0.557	*0.788*	-0.556	*0.000*
Option	-2.594	*0.526*	1.483	*0.451*	0.557	*0.788*	0.554	*0.000*
Standard	0.186		-0.187		0.000		0.001	
Authorities' action								
Do nothing	-5.371	*0.256*	4.260	*0.116*	1.667	*0.455*	-0.556	*0.000*
Tax reduction	0.186	*0.962*	-1.297	*0.502*	0.557	*0.788*	0.554	*0.000*
Mandate	5.186		-2.963		-2.223		0.001	
R Square	0.736		0.836		0.590		1.000	

7.3.6 Overall results

Table 7.16 summarizes the identified subgroup and its given labels for each of the actors.

Table 7.16: Identified subgroups for each actor

Actor	**Subgroups based on utility data**	**Subgroups based on probability data**
Public authorities	Passive deployers Deployment champions	-
Automotive industry	Actiive deployers Restrained deployers Adaptive deployers Option-prone deployers Standard-prone deployers	Active deployer Reluctant deployer Active deployer
Insurance companies	Active deployer Non-deployer	Active deployer Non-deployer

Generally, it can be concluded that, for each of the actors, subgroups of respondents can be identified that are predominantly prone towards taking action, and subgroups that are predominantly passive or unwilling to take action. These differences were as expected, based on the relatively low maximum utilities for each of the actors observed in the overall models (See Chapter 6). The highest utilities for the different subgroups are 6.6-7.2 as compared to 6.1 for public authorities, 8.5-9.8 as compared to 7.7 for the automotive industry, and 6.9-7.6 as compared to 5.5 for insurance companies.

From this and other figures, it can also be concluded that the subgroups within the automotive industry respondents show very clear differences in strategies. The average utility/probability (constants) and the influence of other actors, public authorities in particular, are very different across the subgroups. Insurance companies' subgroups are clearly different in their average utilities/probabilities, but other actor influence does not play a role. The differences between public authorities' subgroups are smaller, and the relative homogeneity of the respondent answers is underlined by the inability to find clear subgroups based on the probability data.

The existence of subgroups has a different meaning for actors that can be considered as a single decision-maker (i.e. public authorities), and actors that include multiple decision-makers (i.e. the automotive industry and insurance companies). In the case of a single decision-maker, the different characteristics of the subgroups represent an internal heterogeneity, that may have to be sorted out before a decision is made. The relative size of subgroups based on utility data may tell us something about the commonness of the related strategies. The relative size of the subgroups, based on probability data, may tell us something about the probability that the related decision pattern will eventually be followed. In the case of multiple decision-makers, the different characteristics of the subgroups represent an external heterogeneity, which means that different companies may have different strategies. Heterogeneity within companies may also be present, but cannot be revealed from the data.

The number of respondents within a subgroup gives an indication of the relevance of the subgroups as compared to other subgroups. Most differences can be observed between the automotive industry subgroups. With respect to the utilities, the active deployers are the largest group (44% of the respondents), followed by adaptive deployers (22%), standard-prone deployers (18%), restrained deployers (11%) and option-prone deployers (4%). From this, it is clear that the majority of the automotive industry respondents has a preference towards taking action, while being moderately to strongly influenced by public authorities. Based on the probability data, we can conclude that the majority would expect the automotive industry to act as an active deployer (56%), with a relatively small influence of public authorities. Smaller groups expect industry to be a reluctant deployer (22%) or an adaptive deployer (22%), both groups being more influenced by public authorities. These percentages may indicate how likely the occurrence of the action and reaction patterns related to the subgroups are. For public authorities, the size of the subgroups based on their utilities is comparable (55% for passive deployers, and 45% for deployment champions). For insurance companies the differences are larger (71% for active deployers and 29% for non-deployers based on utilities, and 57% vs. 43% based on probabilities), but given the small number of respondents, only seven, these figures have a limited statistical significance.

Using the same procedure as in 6.5.5 the subgroup models were revised by re-estimating them without the attributes that were not statistically significant in the original model (see Table B.1 to B.14 in Appendix B). These models can be used to simulate the utilities and probabilities for all deployment scenarios.

7.4 Influence of background characteristics and expected impacts

Can the differences between the subgroups be explained by the background characteristics of the respondents, or their expected impacts of the ADAS and the deployment actions? In the following, explanations for some characteristic differences between the subgroups' strategies are discussed, based on differences in respondent characteristics and expected impacts. In most of the cases, these differences are not statistically significant, probably caused by the relatively small number of respondents included in the subgroups. The explanations should therefore be seen as indicative.

What could explain the result that the first subgroup of ***public authorities'*** *respondents is more passive regarding ADAS deployment than the second one?*
It was found that the second subgroup (deployment champions) expects the impacts of the ADAS on average to be higher than the first subgroup (1.40 vs. 1.15), while they indicate they are less familiar with the ADAS (1.19 vs. 1.64). It is not clear whether this would be the explanation for the difference, but if it is, it means that actors who are more familiar with ADAS have more conservative expectations regarding the impacts, and are less willing to stimulate deployment. In addition, it means that those who are less familiar still have high expectations, and are very willing to stimulate ADAS deployment. In the first subgroup, EU representatives and research & development employees are slightly over represented. These may be people who are relatively more familiar with ADAS.

What could explain the result that the average utilities for taking action are higher for some subgroups of the **automotive industry** *respondents than for others?*
There could be a relationship between the utility derived from taking action and the familiarity with the ADAS. The second subgroup (restrained deployers) has the lowest average familiarity (1.13), while the fourth (option prone deployers) has the highest (2.00). This relationship does not explain all deviations in average utilities, but it does give some indication in this direction. It suggests that if the industry actors are more familiar with ADAS, they are more willing to take action. This is the opposite from what was found for public authorities.

Taking into account the large number of subgroups, respondent characteristics are only considered relevant for the largest groups represented (i.e. German and Italian respondents, private vehicle manufacturers and automotive suppliers, and R&D representatives). Regarding the average utilities, the only interesting figure is that in the fifth subgroup (standard-prone deployers) Italian respondents are relatively more represented than in subgroup 1 (active deployers). This may suggest a difference in opinion between countries or a reflection of the different markets that the Italian (mainly mass market) and German (mainly top end) automotive industry serve.

What could explain the result that the utilities of the second and third subgroup of the ***automotive industry*** *respondents were more influenced by other actors than the other subgroups?*
Both the second and the third subgroup expected a slightly lower average impact of the ADAS (1.28 and 1.08 as opposed to 1.38, 1.41 and 1.30). This could be an explanation, since because of the lower impacts, they may be less willing to deploy ADAS on their own. Furthermore, it is an interesting finding that both these groups expect negative impacts of standard equipment on investment risk, liability risk and user acceptance, while all others expect these as neutral or positive. The explanation then is that they need to be forced more to take this deployment action. With regard to the respondent characteristics, private vehicle manufacturers are relatively more represented in the third subgroup (adaptive deployers) than automotive suppliers. This could indicate that vehicle manufacturers need more stimulation by public authorities than is deemed necessary by automotive suppliers.

What could explain the result that the average probabilities for taking action are higher for the first and third subgroup of the **automotive industry** *respondents than for the second one?*
As opposed to the subgroups based on utilities, the familiarity cannot serve as an explanation here. The only clear difference to be found is that the second subgroup (that sees industry as a reluctant deployer) expects the user acceptance of the deployment actions to be more positive

than the other subgroups. This seems awkward, since it would not be expected that such a fact would lead to reluctance. It has to be taken into account though, that the acceptance is the opinion of the respondents, who may expect the automotive industry to act otherwise. As such, there is not a clear explanation for the existence of these different strategies. It is also worth bearing in mind that the members of the second subgroup, based on utilities, are not all the same as the second subgroup based on probabilities.

What could explain the result that the probabilities of the second and third subgroup of the ***automotive industry*** *respondents are more influenced by other actors than the first subgroup?*
It can be found that the first subgroup (who sees industry as an active deployer) has a higher average familiarity with the ADAS (1.45 vs. 1.26 and 1.26) and higher expectations with respect to the average impacts of the ADAS (1.38 vs. 1.26 and 1.10). The explanation for the large influence of public authorities (and to a lesser extent insurance companies), could then be that the relative unfamiliarity and less positive expected effects lead to the expectation that stimulation by public authorities is necessary to increase the probability of deployment. Another interesting finding is that there are relatively more automotive suppliers in subgroup 1 (active deployer) than in subgroup 3 (adaptive deployer). This could mean that those suppliers who are positive about deployment, do not expect support from public authorities to be necessary. Another interesting finding is that relatively more Italian respondents are present in the subgroups that are influenced by public authorities than German respondents. Their different expectations may be due to differences in culture, and it underlines that the automotive industry includes different perspectives regarding ADAS deployment.

What could explain the result that the first subgroup of ***insurance companies'*** *respondents is more willing and expected to take action than the second subgroup?*
In the case of insurance companies, the subgroups based on utilities and those based on probabilities are almost similar. The same holds for the explanation of their difference in opinion. In both cases, the (active) first subgroup has a much lower average familiarity than the second (non-deploying) subgroup (0.13 vs. 1.67 and 0.00 vs. 1.33). Furthermore, the expected impacts of the ADAS by the first subgroup are higher (2.00 vs. 1.54 and 2.25 vs. 1.36). Note that the expected impacts by the second subgroup are still high as compared to the other actors. A third finding is that the impacts of the deployment actions are generally expected to be more negative by the second subgroup. Compared to the other actors, the respondent characteristics and expected impacts more clearly give an explanation for the differences between the subgroups. The respondents that are on average unfamiliar with the ADAS have high expectations about the impacts of the ADAS and the deployment actions. This could explain their active attitude regarding ADAS deployment. The respondents that are on average familiar with the ADAS have much lower expectations about the ADAS impacts, and are negative about the impacts of the deployment actions. This could explain their passive attitude regarding ADAS deployment. Apparently, when insurance companies are knowledgeable about ADAS, they will probably decide not to take action.

Concluding remarks
For public authorities, and especially insurance companies, it seems that the more familiar they are with the ADAS, the less positive they expect the impacts to be, and the less willing they are to take action towards ADAS deployment. This seems to be the other way around for the automotive industry, the more familiar they are, the more positive they expect the impacts to be, and the more willing they are to take action. It is interesting to ponder what might happen when actors become more familiar with ADAS in the future. The findings above may

indicate that the automotive industry then will be the main decision-maker, while public authorities and insurance companies will become passive.

7.5 Discussion

A cluster analysis involves many choices to be made, which means that the researcher has a large number of possibilities to influence the results. Different choices do not necessarily lead to different results, but there is a possibility that they do. Here, it was taken into account that the choices made fit the nature of the available utility and probability data, focusing on the patterns rather than the absolute values of the data, and keeping data processing as transparent as possible. Multiple clustering algorithms are available, of which only two were chosen as alternatives. Other algorithms could have led to different clusterings, the two applied algorithms already did, but these were not considered to fit the interval scale data, and were not transparent enough. In most of the cases, the *Average Linkage Within* algorithm prevailed, since the differences between the clusters found were more statistically significant. This may not be surprising, since this algorithm will result in relatively more homogeneous subgroups. About the homogeneity, it must be said that despite the normalization of the data, heterogeneity within the subgroup increased quite fast with the number of subgroup members. This shows that, while clear differences were found between subgroups that were eventually selected, the differences between the subgroup members are still large.

These findings have certain consequences for the interpretation of the results. Firstly, conclusions should only be drawn on the utility and probability patterns across the models, since the choices made in the cluster analysis were directed to this type of conclusion. Furthermore, the group size should not be interpreted too precisely, and the identified subgroups should be interpreted as an indication of important strategies of the actors, but not necessarily all of them.

Regarding statistical significance, it was found that some of the coefficients that were not statistically significant in the average models presented in Chapter 6, were statistically significant for several subgroups, and the other way around. This shows that the low statistical significance of the average models is not always caused here by the limited number of respondents, but also by the heterogeneity of the response. The general conclusion on the limited statistical significance and relevance of the ADAS and insurance companies' deployment actions remains unchanged, based upon this new information.

7.6 Conclusions and meaning for ADAS deployment

7.6.1 Conclusions regarding the subgroups of respondents

Subgroups with different strategies exist among the respondents
The results indicate that there are likely to be different strategies with respect to ADAS deployment present among public authorities, the automotive industry and insurance companies.

The automotive industry's subgroups can be distinguished by their preference for deployment actions and influence of other actors
Based on the utility data, five subgroups were identified: *Active Deployers* (20 respondents), *Restrained Deployers* (5), *Adaptive Deployers* (10), *Option-prone Deployers* (2), and *Standard-prone Deployers* (8). Active Deployers and Adaptive Deployers derive most utility from taking action as opposed to doing nothing, and this utility is influenced by the

deployment actions of public authorities, with Adaptive Deployers being substantially more influenced than Active Deployers. The Option-prone and Standard-prone Deployers derive most utility from deployment of ADAS as optional and standard equipment respectively, which is not substantially influenced by the deployment actions of public authorities. The Restrained Deployers derive about the same utility from all deployment actions on average, but this strongly depends upon the deployment actions of public authorities. In general, they derive more utility from taking action, as opposed to doing nothing when public authorities have taken action first.

Based on the probability data, three subgroups were identified, expecting automotive industry to act as an *Active Deployer* (25 respondents), a *Reluctant Deployer* (10), or an *Adaptive Deployer* (10). The characteristics of these subgroups largely correspond to those of the Active, Restrained and Adaptive Deployers, based on the utility data. Moreover, the differences between these subgroups are even clearer. The fact that such large differences do exist between the subgroups' expectations regarding ADAS deployment, may reveal that different networks exist within the automotive industry, with different attitudes towards ADAS deployment. This interpretation is based on the idea that respondents base their expectations on what they experience in their surrounding network.

Insurance companies' subgroups can be distinguished by their preference for deployment actions

Based on both the utility and the probability data, two subgroups of insurance companies' respondents could be identified: the *Active Deployers* (5 respondents utility/2 probability), with a preference for taking action, and the *Non-deployers* (4/3), with a preference for doing nothing. Neither of these groups was influenced by either the automotive industry or public authorities. Despite the very small sample, these subgroups are so clearly different, that there is enough confidence in their existence.

Public authorities' subgroups can be distinguished by their preference for deployment actions, no subgroups are identified based on probability data

Based on the utility data, two subgroups of public authorities' respondents could be identified: *Passive Deployers* (11 respondents) and *Deployment Champions* (9). Passive Deployers derive most utility from doing nothing, and Deployment Champions derive most utility from taking action. The utility of both these subgroups is not substantially influenced by the actions of the automotive industry. Despite these differences, no clearly different subgroups were identified based on the probability data. This supports the general expectation that public authorities will be passive in ADAS deployment (see Chapter 6). However, nearly half of the respondents would probably support a more active attitude.

A possible explanation for the existence of subgroups can be found in the respondents' familiarity with ADAS, and their expectations of the ADAS' impacts

For public authorities' and (especially) insurance companies' respondents, it seems that if they are more familiar with the ADAS, they expect less positive impacts, and they are less inclined to take action towards ADAS deployment. This seems to be the other way around for respondents from the automotive industry. If they are more familiar, they expect more positive impacts, and are more inclined to take action.

The existence of the subgroups gives a possible explanation for the low utilities that resulted from the average models
The highest utilities that were observed from the subgroups were all between 0.5 and 2.1 points higher (on a scale of 10) than the average utilities over all respondents (see Chapter 6). This means that the existence of subgroups may well be an explanation for the generally observed low utilities. Nevertheless, with the utilities of public authorities and insurance companies still remaining rather low, the explanation of a limited interest in ADAS deployment also still holds.

7.6.2 Relevance of the results for ADAS deployment

In addition to the general conclusion on ADAS deployment that the automotive industry is expected to take action first, and public authorities are willing to stimulate, but not very likely to actually do so, what does the knowledge about the subgroups teach us about ADAS deployment?

Most importantly, the automotive industry is heterogeneous with respect to decision-making regarding ADAS deployment. This heterogeneity manifests itself in different preferences for deployment actions and susceptibility to influence of (mainly) public authorities. This means that it can be expected that, in first instance, different parts of the automotive industry will show different strategies regarding ADAS deployment. The parts of the automotive industry that correspond to these different strategies could not be specified based on the respondent characteristics. Possibly, the brand image and market visions of different companies play a role. Based on the subtle findings that the automotive industry respondents, who are more familiar with ADAS, expect its impacts to be more positive, and expect a more active role for the automotive industry in ADAS deployment, a possible future development could be that, when familiarity with ADAS increases, the automotive industry is even more likely to be the main driving force in ADAS deployment.

On average, public authorities were not expected to take action by the respondents (see Chapter 6). Given the result that no different subgroups based on the probability data could be identified, this increases the confidence in this conclusion as a general expectation. Based on the findings that public authority respondents who are more familiar with ADAS expect its impacts to be less positive, and expect not to take action, a possible future development could be that when familiarity with ADAS increases, public authorities are less likely to take action.

Insurance companies are not straightforwardly expected to take any action in the near future, although a large percentage of the respondents do expect that they will. However, based on the quite clear findings that insurance company respondents, who are more familiar with ADAS, expect its impacts to be less positive, and expect a very inactive role of insurance companies, a possible future development could be that when familiarity with ADAS increases, insurance companies are not likely to play a part in ADAS deployment.

In summary, the results of the cluster analysis, to identify subgroups of respondents with different strategies, have increased the confidence in the expectation that the automotive industry will be the leading actor in ADAS deployment, while little influence can be expected from public authorities and insurance companies.

8 User reactions to ADAS deployment actions

How many users will choose to buy an ADAS under the various deployment scenarios? What characteristics influence this choice? This chapter describes a user survey designed to collect data on the choices of users regarding ADAS, and how they are influenced by incentives that result from the deployment actions of public authorities and insurance companies. The data were used to estimate a choice model, in which a difference was made between choosing an ADAS as an option on a new car, and choosing an ADAS to be built in the users' current car. The results show a large influence of the deployment actions, and a substantial heterogeneity with respect to user, car use, and car characteristics.

8.1 User survey set-up

The central part of the user survey is a conjoint measurement task to collect data to estimate the probability that users will buy an ADAS on their new car. Table 8.1 summarizes the attributes and attribute levels to be included in this conjoint measurement, which were introduced in Chapter 5.

Table 8.1: Overview of user survey attributes and attribute levels

ADAS	**Attribute levels: ADAS**
ADAS	Speed Assistant Congestion Assistant Safe Driving Assistant
Deployment actions	**Attribute levels: deployment actions**
ADAS purchase costs	0 euros 750 euros 1,500 euros
Insurance premium reduction	0% 25% 50%

The remaining steps that need to be taken in the set-up of the conjoint measurement task are (1) to combine the attribute levels into profiles, and (2) to define the measurement task. Next to the conjoint measurement task, the survey also includes the collection of respondent characteristics and reported influence of decision criteria.

8.1.1 Combination of attribute levels into profiles

The number of profiles necessary to estimate the model depends upon the assumed functional form of the utility function. When assuming an additive model, an orthogonal set of profiles is enough to estimate the model, while a full factorial design is needed when the model includes all two-way interactions. For the current case, an additive model was assumed, since no statistically significant interactions were assumed to be present, given the attributes (see Chapter 4).

$$V_{1,y} = q + \sum_a r_a y_a + r_z z \tag{4.19}$$

$V_{1,y}$ = observed utility of buying an ADAS, given deployment scenario y;
y_a = deployment action of actor a;
q = constant of the utility model;
z = ADAS;
r_a, r_z = coefficients of the utility model.

In an orthogonal set of profiles, each combination of two attribute levels occurs only once. In this case, with three attributes and three attribute levels, the orthogonal set includes 9 profiles. When using an orthogonal set of profiles to estimate an additive model, the underlying assumption is that the effects of the (two-way) interactions are zero. The disadvantage of using an orthogonal model is that if these interactions are not zero, the main effects are distorted. However, the advantages of an orthogonal set, being the minimization of the amount of time spent to complete the questionnaire, and the increase in the accuracy of the answers, have prevailed here.

Table 8.2: Profiles in the order presented to the respondents

Profile	Attribute levels ADAS	 Cost*	 Red**	ADAS	Cost	Reduction
1	2	2	1	Safe Driving Assistant	1,500 euros	25%
2 (holdout)	1	0	0	Congestion Assistant	100 euros	No reduction
3	0	2	2	Speed Assistant	1,500 euros	50%
4	2	1	0	Safe Driving Assistant	750 euros	No reduction
5	1	0	1	Congestion Assistant	100 euros	25%
6	0	1	1	Speed Assistant	750 euros	25%
7	1	2	0	Congestion Assistant	1,500 euros	No reduction
8	0	0	0	Speed Assistant	100 euros	No reduction
9	2	0	2	Safe Driving Assistant	100 euros	50%
10	1	1	2	Congestion Assistant	750 euros	50%
11 (holdout)	1	2	2	Speed Assistant	1,500 euros	25%

* cost = purchase costs of the ADAS
** red = monthly insurance premium reduction

Table 8.2 shows the profiles included in the investigation in the order, as presented to the respondents. Two profiles were included that will not be included in model estimation, but will be used later to validate choice forecasting by the model, the so-called holdouts. The profiles are deliberately placed in an order that avoids the occurrence of the same attribute levels in consecutive profiles as far as possible, to stimulate the respondent to compare the different attribute levels.

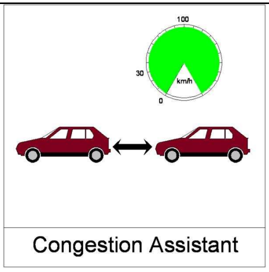
8.1.2 Choice of measurement task

The objective of this investigation is to estimate the percentage of users that will actually adopt an ADAS, given certain deployment actions of actors. There are two steps in the adoption of ADAS: obtaining the ADAS, and actually (and correctly) using the ADAS. Since the focus of this research project is on ADAS deployment as an increase in market penetration, only the first part of the adoption decision is being considered here.

This objective involves determining the actual choice that users report to make, whether they will adopt an ADAS or not, and under what conditions. This specific objective influences the type of measurement task chosen. A rating task would give detailed information about the user preferences regarding ADAS deployment actions, but is not suitable to forecast the actual choice of the user. For that reason, a choice task is adopted here, since the main objective is to determine this choice.

A choice task can be designed in different ways, for example by letting the respondents choose between two or more different profiles, possibly including a base alternative representing the current situation, when none of the alternatives is chosen. In order to obtain the desired results, the choice task should resemble the type of choice being investigated. The main aim of the present survey is to investigate whether car users will, or will not, purchase an ADAS, given different types of ADAS and deployment incentives. Consequently, it was decided to design the choice task as a choice between one of the profiles and the base alternative, which means choosing between a car with an ADAS, and a car without an ADAS. This was specified by answering categories ‘yes’ or ‘no’ to a question on whether the respondent is going to buy the ADAS.

The specific question posed to the respondents depends on the target group approached. The target group in this investigation consists of private car users from the Netherlands, who can make their own decision on purchasing ADAS or not. Taking into account the integration with the results of the actor investigation, in which the deployment actions were mainly focused on equipment of new vehicles with ADAS, it is most interesting to include car users who consider buying a new car on a reasonably short term (here: two years). It could also be an option to equip cars with an ADAS afterwards (i.e. retrofitting), which is probably not feasible for all types of ADAS due to integration with other vehicle components. Nevertheless, it is interesting to investigate if users would react differently to that type of deployment. Thus it was decided to split up the target group into car users who consider buying a new car within two years, and car users who do not consider buying a car, but do currently own one.



- Congestion Assistant
- Purchase costs 100 euros
- 25% reduction on car insurance premium

(For respondents who indicated to consider buying a car within two years)
Do you choose this option when buying your next new car? (task type A)

○ Yes
○ No

(For respondents who indicated not to consider buying a new car but owning one)
Do you choose to buy this option? (task type B)

○ Yes
○ No

Figure 8.1: Example question

Both groups are presented with the same profiles, called options, with a slightly different choice task. The ‘car buyers’ are presented with choice task type A, which poses the question if they would choose the present option when buying a new car. The ‘non car buyers’ are presented with choice task type B, which poses the question if they would choose the present option to be built into their current car. Figure 8.1 shows an example question for both parts of the target group.

8.1.3 Respondent characteristics

Next to the questions related to the choice task, a number of respondent characteristics that were expected to explain part of the individual variation in choice were included in the questionnaire. The questions were limited to some basic respondent characteristics. These included specific respondent characteristics (age, gender, income, attitude towards electronic equipment in cars), characteristics of the respondents’ car use (frequency, mileage), and characteristics of the respondents’ cars (financing of purchase and insurance costs, car price, and whether ADAS is built into a new or current car). In this sub-section, the presumed relations of these characteristics and criteria with the choice for ADAS are explained.

Characteristics of the respondents

Age

It has been observed that older people are more likely to adopt some form of assistance in the vehicle than younger people (e.g. Marchau, 2001). In the questionnaire the respondents were asked to indicate their year of birth.

Gender

It has been observed that men and women may have different preferences with respect to type of driving assistance and level of support (e.g. van Driel and Van Arem, 2005). In the questionnaire the respondents were asked to indicate their gender.

Income

People with a higher income are expected to be more willing to purchase ADAS. In the questionnaire the respondents were asked to indicate their yearly household income (categories: 0 – 30,000 euros, 30,000 – 60,000 euros, 60,000 euros and more; based on the Dutch median household income of 31.930 in 2009).

Attitude

People with a positive attitude towards electronic equipment in vehicles are expected to adopt ADAS earlier than people with a more negative attitude. Two statements were presented to the respondents referring to attitude: “I am open towards electronic equipment in the car” and “I will purchase a new electronic device for in the car only if there is no other choice”. In the questionnaire the respondents were asked to indicate to what extent they agreed with these statements (categories: agree, slightly agree, neutral, slightly disagree, and disagree).

Characteristics of the respondents’ car use

Frequency of car use

People who drive more often may value in-car assistance by ADAS more than people who drive less often, because of the annoyance of congestion or speeding tickets. It could also be the other way around, since people who drive less often could be less confident in their driving skills. In the questionnaire, the respondents were asked to indicate their frequency of car use (categories: daily, several days a week, several days a month, several days a year).

Yearly mileage

The same reasoning as for the former question holds for mileage. In the questionnaire the respondents were asked to indicate their yearly mileage (categories: 0 – 5,000 km, 5,000 – 10,000 km, 10,000 – 20,000 km, 20,000 – 30,000 km, 30,000 km and more).

Characteristics of the respondents’ car

Purchase financing

The way in which the purchase of a new car is financed may influence the choice for an ADAS. If the employer pays for the car, people could be more likely to choose an ADAS. In the questionnaire, those respondents who indicated that they consider purchasing a new car were asked to indicate the way in which the purchase will be financed (categories: payment for car by themselves, payment by employer, employer contributes, otherwise).

Monthly insurance and tax payment financing

In addition, financing of the additional monthly costs, such as insurance premiums and vehicle taxes, could influence respondents’ choices. For example, respondents for whom these costs are paid by their employer, may be relatively insensitive to insurance premium reductions. In the questionnaire, the respondents were asked to indicate how they finance these monthly costs (categories: they pay themselves, their employer pays, otherwise).

Price of car

For people buying more expensive cars, the additional expense for an ADAS may be less of a barrier, so it is interesting to know the price of the car that people are driving, or expect to buy. In the questionnaire, the respondents who indicated that they are considering purchasing a new car, were asked to indicate the price category in which they expect to look for a car. The respondents who indicated that they own a car, but are not considering buying a new one shortly, were asked to indicate the price of their current car (categories: 0 – 5,000 euros, 5,000 – 15,000 euros, 15,000 – 25,000 euros, 25,000 – 35,000 euros, 35,000 euros and more).

ADAS on a new or current car

People may decide differently on buying an ADAS as an option for a new car, or buying an ADAS to be fitted in their current car. If they buy a new car, the price for an ADAS may be perceived as being relatively lower. While the main purpose of the survey is to assess users’ choice to have an ADAS in their new car, the questionnaire differentiates between these two types of car users (see 8.1.2).

8.1.4 Reported influence of decision criteria

The choice of a respondent for an ADAS was expected to be motivated by the impact of the ADAS on certain criteria. In the questionnaire, the respondents were asked to indicate to what extent they took several criteria into consideration when making a choice for an ADAS (categories: definitely not, probably not, neutral, probably yes, definitely yes). The criteria included in the survey were based on a literature review of important user criteria (Walta et al., 2007), i.e. safety, costs, travel time, societal and environmental influence, user-friendliness, privacy, and driving comfort.

8.2 Questionnaire and data collection

In order to collect the data, a web questionnaire was set-up in cooperation with *I&O research*[10]. This questionnaire was in Dutch, since it was aimed at respondents from the Netherlands. It started with the question as to whether the respondents would consider buying a car within two years, and if not, whether they currently own a car. When their answer was negative to both, the questionnaire ended. When the respondents indicated that they would consider buying a car, they were routed to the choice task of type A, otherwise they were routed to the choice task of type B. Before answering these questions, it was explained to them about the ADAS types included in the questionnaire. An example question was given to prepare them for the choice task they had to perform. After completion of the choice task, the background questions were posed to the respondents, first the criteria questions, since they were related to the choice task, followed by the questions on user characteristics, car use characteristics, and car characteristics.

The questionnaire was sent to the members of a large online panel that is generally representative for the Dutch population, and specifically includes individual consumers with a

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[10] I&O research is a Dutch research agency having access to panels of traffic and transport related respondents

driving license who have a vehicle at their disposal. The members of this panel receive a reward each time they participate in a questionnaire. In order to keep the costs of the investigation under control, a fixed number of completed questionnaires had to be agreed upon with the panel organization, which numbered 250. A total of 1030 invitations were randomly sent to the panel, of which 348 followed the link to the web questionnaire. Of these 348, 65 did not start the questionnaire, 14 did not complete it, 8 did not match the criterion of owning a car or thinking of buying one, and 11 followed the link after the quota of 250 completed questionnaires was already reached. The questionnaire was held in July 2009.

8.3 Results: general explanatory variables

8.3.1 Respondent characteristics

The characteristics of the survey respondents are summarized in Table 8.3, and if possible compared with population characteristics retrieved from the Dutch Central Statistics Agency (CBS; http://statline.cbs.nl).

Characteristics of the respondents

Table 8.2 shows that the age group 40-65 is relatively over represented in the sample (by about 10%), and that the group of 65 years and older is relatively under represented. This could be caused by a decrease in the percentage of people with a driving license and car above 65, and the relatively limited internet access of this group.

The distribution over male and female respondents (51.2% vs. 48.8%) is of the same order of magnitude as the population distribution with respect to driving license possession (53.3% vs. 46.7%). At this point, the sample is considered as representative.

Although the CBS data had to be corrected for the household income categories, it can be concluded that the sample contains a relatively high number of people with a household income between 30,000 and 60,000 euros, and a low amount of people with a household income of higher than 60,000 euros. Presuming that people with a higher income have more time-consuming jobs, it is quite possible that this group is partly excluded, since the survey was performed within three consecutive working days.

On average the respondents slightly agree with the statement that they are open towards electronic equipment in the car. The respondents are more conservative regarding whether they purchase an electronic device for in the car only if there is no other choice. The average score on this statement is neutral or slightly agree, and there is also less agreement about this statement among the respondents, since the standard deviation is higher than for the former. The overall conclusion on these figures is, not surprisingly, that while the respondents are generally open towards electronic equipment, many apply a “wait and see” attitude with respect to purchasing these systems.

Characteristics of the respondents’ car use

Most of the respondents use their car daily, or at least weekly. The majority have an annual mileage of between 5,000 and 20,000 kilometers. It can be concluded that the respondents are on average regular car users, and that the mileage is reasonably well spread.

Table 8.3: Characteristics of the respondents

Characteristics of the respondent	**Categories**	**Response group**		**The Netherlands (Source: CBS)**
Age	18-20	6	2.4%	3.1%[11]
	20-25	15	6.0%	7.6%
	25-30	28	11.2%	7.7%
	30-40	37	14.8%	17.9%
	40-50	56	22.4%	19.9%
	50-60	47	18.8%	17.4%
	60-65	37	14.8%	7.7%
	65-75	23	9.2%	10.2%
	75+	1	0.4%	8.6%
Gender	Male	128	51.2%	53.6%[12]
	Female	122	48.8%	46.4%
Household income	0 – 30,000	93	37.2%	34.1%[13]
	30,000 – 60,000	123	49.2%	32.1%[14]
	60,000 +	34	13.6%	33.8%
I am open towards electronic equipment in the car	1(Agree) – 5(Disagree)	avg: 1.92	sd: 1.067	N/A
I will purchase a new electronic device for in the car only when there is no other choice	1(Agree) – 5(Disagree)	avg: 2.77	sd: 1.206	
Characteristics of the respondents' car use	**Categories**	**Response group**		**The Netherlands (Source: CBS)**
Frequency of car use	Daily	147	58.8%	N/A
	Several days a week	83	33.2%	
	Several days a month	17	6.8%	
	Several days a year	3	1.2%	
Annual mileage	0 – 5,000 km	22	8.8%	Average: 12.144 km
	5,000 – 10,000 km	63	25.2%	
	10,000 – 20,000 km	87	34.8%	
	20,000 – 30,000 km	37	14.8%	
	30,000 km +	41	16.4%	
Characteristics of the respondents' car	**Categories**	**Response group**		**The Netherlands (Source: CBS)**
Purchase financing	You pay yourself	116	89.2%	87.9%[15]
	employer pays/contributes/otherwise	14	10.8%	12.1%
Monthly insurance and tax payment financing	You pay yourself	225	90.0%	N/A
	Employer pays/otherwise	25	10.0%	
Price of car	0 – 5,000 euros	46	18.4%	N/A
	5,000 – 15,000 euros	94	37.6%	
	15,000 – 25,000 euros	53	21.2%	
	25,000 – 35,000 euros	39	15.6%	
	35,000 euros +	18	7.2%	
ADAS on new or current car	New car	130	52.0%	-
	Current car	120	48.0%	-

N/A = figures not available

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[11] Based on driving license possession percentages of 2007 and population figures of 2009

[12] Based on driving license possession percentages of 2007 and population figures of 2009

[13] Based on income figures of 2007

[14] Corrected value based on average trend since CBS categorization stops at 50.000 euros

[15] Based on car ownership figures of 2009 of personal vehicles: total amount and those registered by companies

Characteristics of the respondents' car

Of the people who indicated that they would consider purchasing a car within the next two years, 89.2% will pay for the car themselves, and 90% will pay the monthly insurance costs and taxes themselves. This matches with the CBS data regarding vehicles that are "not registered by a company". Of the remaining respondents, 4.6% answered that their employer pays for the car, and 5.4% answered otherwise. Consequently, it is not completely clear whether or not the amount of drivers in a vehicle registered by a company is under represented in the sample. Nevertheless, since the share of vehicles registered by a company is relatively small (12.1%), this possible under representation is not expected to influence the general results.

The price of the car the respondents expect to buy, or already own, is reasonably well spread among the categories. A relatively small amount indicated that they intend to buy a car that is more expensive than 35,000 euros, which is probably related to the average income being lower than that of the population.

The distribution of the respondents among those who will consider buying a new car within 2 years, and those who do not, but do currently own a car, is 52% against 48%, which gives a good basis for comparing both groups on their willingness to purchase an ADAS.

8.3.2 Reported influence of decision criteria

The average scores of the respondents on the extent to which they took into account a certain criterion in their choice for one of the ADAS, are presented in Figure 8.2.

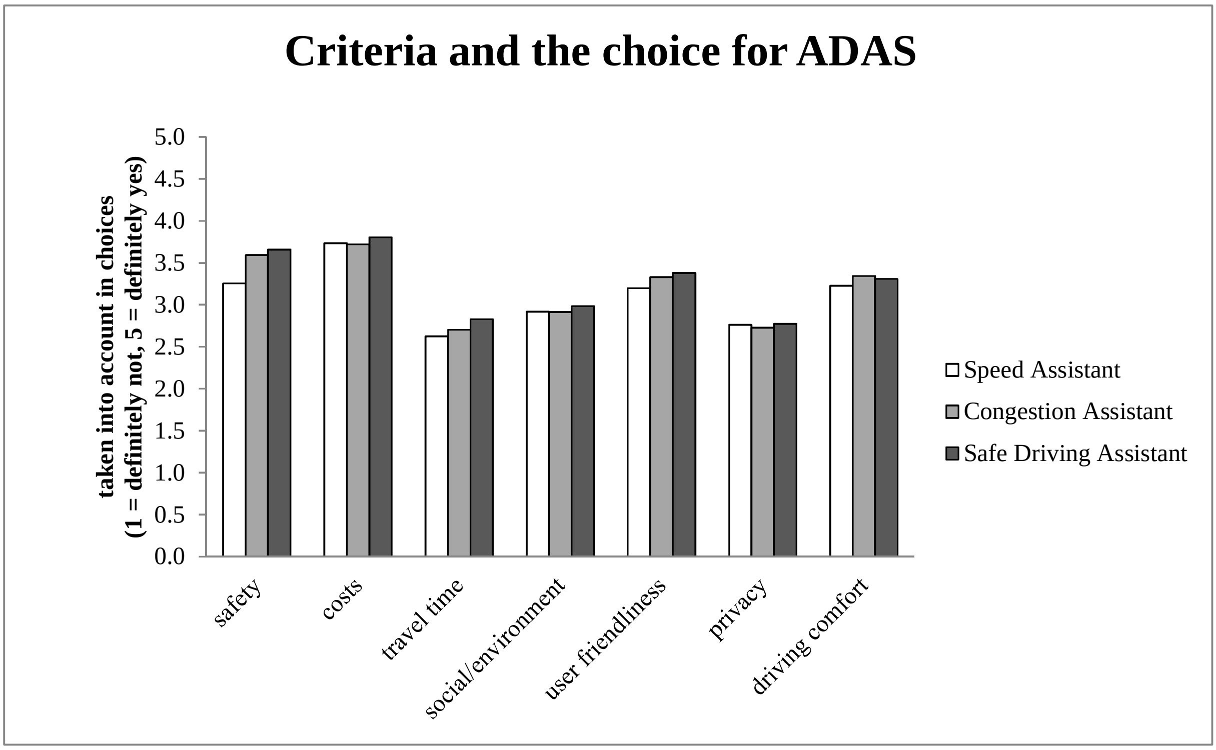

Figure 8.2: Extent to which criteria are taken into account in the choice for an ADAS

Figure 8.2 shows there is relatively little difference between the different ADAS types included in the investigation. The largest difference is observed for the safety criterion. The highest average scores are observed for costs and safety. In addition, user friendliness and driving comfort have an average score of above 3, which means that a majority of the respondents indicated that they would take these criteria into account. Societal and environmental influence, privacy, and travel time received an average score of below 3, which means that these were less likely to be taken into account by the respondents. These results are particularly surprising regarding travel time, since this is often indicated as one of the most important criteria for car drivers regarding ADAS (e.g. Lathrop and Chen, 1997; ADVISORS, 2002). The respondents possibly do not associate the functionality of these three systems with reducing travel time.

8.4 Model estimation

The choice task of the survey resulted in binary choice data on whether or not a respondent chooses a specific ADAS, given the cost and premium reduction involved. With these data, a binomial logit model can be estimated, giving insight into the utility the users derive from the ADAS and deployment actions.

The binomial logit model defines the probability that users choose to have a certain ADAS on their next new car, as a logistic function of the utility users derive from having this ADAS on their next new car:

$$P(C=1 \mid D_1 = y) = \frac{1}{1+e^{-V_{1,y}}} \tag{4.16}$$

In which:
C = stochastic variable representing user choice to buy an ADAS on his next new car (which can take the values 1= yes and 0 = no);
D_1 = stochastic variable representing deployment scenario at time $t=1$;
y = deployment scenario at time $t=1$;
$V_{1,y}$ = observed utility the user derives from buying an ADAS on his next new car, given deployment scenario y.

The utility $V_{1,y}$ is defined as linear function of the actors’ deployment actions at time $t=1$ and the ADAS:

$$V_{1,y} = q + r_1 y_1 + r_2 y_2 + r_3 z \tag{8.1}$$

In which:
$\underline{q}$ = constant of the utility model;
y_1, y_2 = deployment variables 1 and 2, representing cost and premium reduction;
z = ADAS;
r_1, r_2, r_3 = coefficients of the utility model.

The values of the independent variables y_1 and y_2 are considered to be on an ordinal scale. The available data makes it possible to consider them on an interval scale, but it was found that the model fit was better when using the values on an ordinal scale. The values of the independent variable z are considered to be on a nominal scale. In order to include the independent variables y_1, y_2 and z in model estimation some form of dummy coding is necessary. The dummy coding chosen is presented in Table 8.4.

Table 8.4: Dummy codes for attributes with three levels

Attribute Level	Indicator variable 1 (Y_1)	Indicator variable 2 (Y_2)	Part-worth Utility
0	0	0	0
1	1	0	ρ_1
2	0	1	ρ_2
Parameter:	ρ_1	ρ_2	

Each independent variable can take the value of the attribute levels 0, 1 and 2. In Table 8.4 these values are coded as the values of two indicator variables, Y_1 and Y_2. The coefficients r_1 to r_3, are each coded as the parameters ρ_1 and ρ_2. This results in the following utility model to be estimated as part of the logit model presented in (4.16):

$$V_{1,y} = q + \sum_{i \in \{1,2,3\}} (\rho_{i,1} Y_{i,1} + \rho_{i,2} Y_{i,2}) \tag{8.2}$$

In which:
$Y_{1,1}$ and $Y_{1,2}$ correspond with y_1;
$Y_{2,1}$ and $Y_{2,2}$ correspond with y_2;
$Y_{3,1}$ and $Y_{3,2}$ correspond with z;
$\rho_{1,1}$ and $\rho_{1,2}$ correspond with r_1;
$\rho_{2,1}$ and $\rho_{2,2}$ correspond with r_1;
$\rho_{3,1}$ and $\rho_{3,2}$ correspond with r_1.

Model estimation involves the estimation of the constant q, and the coefficients ρ from the logit model, using logistic regression. Table 8.5 shows the coding of the choice attributes for the investigated profiles included in model estimation.

Table 8.5: Analysis design choice attributes

Profile*	**Attribute levels**			**ADAS**		**Cost**		**Premium reduction**	
	ADAS	cost**	prem**	adas1	adas2	cost1	cost2	prem1	prem2
1	2	2	1	0	1	0	1	1	0
3	0	2	2	0	0	0	1	0	1
4	2	1	0	0	1	1	0	0	0
5	1	0	1	1	0	0	0	1	0
6	0	1	1	0	0	1	0	1	0
7	1	2	0	1	0	0	1	0	0
8	0	0	0	0	0	0	0	0	0
9	2	0	2	0	1	0	0	0	1
10	1	1	2	1	0	1	0	0	1

* Not all profile numbers are included in the analysis since 2 and 11 were holdout tasks
** cost = purchase costs of the ADAS prem = monthly insurance premium reduction

It is assumed that the answers to choice task type A (ADAS on next new car) and B (ADAS on current car) are compatible, in that they measure the same thing: if a user chooses to purchase an ADAS or not. Thus the model was based on the data resulting from both task types.

8.4.1 Including respondent characteristics in the model

In order to explain part of the unexplained variance of the model, some respondent characteristics can be included in the model. The available respondent characteristics include age, gender, household income, attitude towards electronic equipment in cars (2 variables), ADAS on new or current car, frequency of car use, mileage, car purchase financing, tax and insurance financing, and car price. Not all of these characteristics are eligible to be entered as variables into the model. The attitudes towards electronic equipment largely refer to the individual taste explained by the error term. As such, including them in the model would distort the model clarity. Furthermore, car purchase financing and tax and insurance financing were shown to have little differentiation among the answering categories (see Table 8.3), so no explanation is expected of them in the model.

Furthermore, correlations were assumed to be present between frequency of car use and mileage, and household income and car price. The correlation between frequency of car use and mileage was calculated at -0.561 (Spearman’s ρ), which is moderately high. The negative value of the correlation is due to the coding of the categories (e.g. high – low frequency = 1 – 5, low – high mileage = 1 – 5). Based on this figure, it was decided to only include one of both variables in the model. As to household income and car price, calculating the correlation would not lead to an interpretable figure, since there were only three broad categories for household income. Since correlation is presumed, it was decided also to include only one of both variables in the model.

Table 8.6: Analysis design respondent characteristics

Variable	**Scale type**	**Categories**	**Value**	
Age	Interval	N/A	[2009 – year of birth]	
Gender	Dichotomous	Male	0	
		Female	1	
Household income	Ordinal -> Nominal		inc1	inc2
		0 – 30,000 euros	0	0
		30,000 – 60,000 euros	1	0
		60,000 euros and more	0	1
ADAS on new/current car	Dichotomous	On new car	0	
		On current car	1	
Frequency of car use	Ordinal	Daily	1	
		Several days a week	2	
		Several days a month	3	
		Several days a year	4	
Mileage	Ordinal	0 – 5,000 km	1	
		5,000 – 10,000 km	2	
		10,000 – 20,000 km	3	
		20,000 – 30,000 km	4	
		30,000 km and more	5	
Price of car	Ordinal	0 – 5,000 euros	1	
		5,000 – 15,000 euros	2	
		15,000 – 25,000 euros	3	
		25,000 – 35,000 euros	4	
		35,000 euros and more	5	

N/A = not applicable

Four models were estimated, all of which included the variables age, gender, and ADAS on new/current car, and in which frequency and mileage and household income and car price were alternately included. Table 8.6 shows the coding of the respondent characteristics used in model estimation. For most of the characteristics, the coding was straightforward, corresponding with the measurement scale. Dummy coding was applied to household income, since it was only measured on three quite broad ordinal levels.

Table 8.7 presents the outcomes of the four estimated models with respect to model fit. It can be concluded that the model including mileage and price of car leads to the best model fit; i.e. lowest -2LogLikelihood (or highest likelihood) and highest Nagelkerke R². Consequently, these characteristics were chosen to be included in the model..

Table 8.7: Performance of potential models

Model including		-2LogLikelihood	Nagelkerke R^2
Frequency of car use	Household income	2608.032	0.192
Frequency of car use	Price of car	2597.420	0.198
Mileage	Household income	2609.712	0.191
Mileage	Price of car	2591.920	0.201

8.5 Results: utility of buying ADAS for private car users

The model presented in Table 8.8 shows the utility that private car drivers derive from an ADAS on their new or current vehicle, influenced by certain deployment incentives, and respondent characteristics. With regard to the interpretation of the coefficients B in this model, these are the part-worth utilities derived from the attribute levels. As a result of the logit model applied, an overall utility of zero corresponds to a 50% probability that the user will buy the corresponding ADAS.

Focusing firstly on the choice attributes, it can be concluded that the cost of the ADAS has the highest effect on utility. The utility decreases most between 100 and 750 euros, and is, not surprisingly, lowest for 1,500 euros. The influence of premium reduction is smaller but still substantial. The utility increases most between 0 and 25%, which could be interpreted as the presence of a reduction being slightly more important than the height of this reduction. In contrast to what was found for the actors, the different types of ADAS do influence the users' utility. More utility was derived from the Safe Driving Assistants as compared to the Speed Assistant and the Congestion Assistant. However, the latter effect is not statistically significant at the $p = 0.05$ level, so the Congestion Assistant and the Speed Assistant were considered to have similar effects in further use of the model.

The user characteristics entered in the model have a moderate effect on the overall utility. The older the users are, the less utility they derive from buying an ADAS. The second finding relating to user characteristics is that women derive less utility from an ADAS than men.

An interesting finding from the car use characteristics is that utility of an ADAS decreases with increasing mileage of the user. The explanation for this depends on what users consider to be the main benefits of ADAS. However, the finding does suggest that the users' confidence in their driving skills, or how comfortable they are in driving a car, could play a role.

Finally, the car characteristics show that users derive less utility from having an ADAS on their current car than on a new car, and that utility increases substantially with the price of the car. The latter can be explained by the fact that the cost of an ADAS is relatively less when buying a more expensive car, but some other background effects like image or status could also play a role. The cost of the ADAS probably also plays a role in the difference between having an ADAS on a new car or on a current car.

Table 8.8: Choice model of private car users

USER MODEL	B	S.E.	Wald	df	Sig.	Exp(B)
Constant	0.136	0.277	0.241	1.000	0.624	1.145
ADAS						
Speed Assistant	-				-	
Congestion Assistant	-0.186	0.120	2.399	1.000	0.121	0.830
Safe Driving Assistant	0.519	0.115	20.342	1.000	0.000	1.680
Cost						
100 euro	-				-	
750 euro	-1.241	0.113	120.199	1.000	0.000	0.289
1500 euro	-1.640	0.122	179.814	1.000	0.000	0.194
Premium reduction						
0%	-				-	
25%	0.644	0.120	28.763	1.000	0.000	1.904
50%	0.854	0.123	47.980	1.000	0.000	2.349
User characteristics						
Age (years)	-0.007	0.004	3.400	1.000	0.065	0.993
Gender (male = 0; female = 1)	-0.209	0.105	3.974	1.000	0.046	0.812
Car use characteristics						
Mileage 0 - 5.000 km = 1 5.000 - 10.000 km = 2 10.000 - 20.000 km = 3 20.000 - 30.000 km = 4 30.000 km and more = 5	-0.110	0.047	5.513	1.000	0.019	0.896
Car characteristics						
ADAS on new or current car ADAS on new car = 0 ADAS on current car = 1	-0.503	0.101	25.085	1.000	0.000	0.604
Car price 0 - 5.000 euro = 1 5.000 -15.000 euro = 2 15.000 - 25.000 euro = 3 25.000 - 35.000 euro = 4 35.000 euro and more = 5	0.209	0.047	19.690	1.000	0.000	1.233
Nagelkerke R square	0.201					
-2 Loglikelihood	2591.920					

What does this all teach us about the probabilities that users are going to purchase an ADAS? To give an idea, a number of simulations are performed with the model from Table 8.8. Three user types and three ADAS were selected, based on those characteristics that lead to the most extremely positive and extremely negative values (except for age: an interval of 25-65 was chosen), and an intermediate value. This results in a total of nine simulations, of which the outcomes are presented in Table 8.9.

Table 8.9: Choice probability simulations with user choice model

		User characteristics		
		man, age 25, 0 – 5,000 km new car: 35,000 euros +	*man, age 45 10,000 – 20,000 km current car: 15,000 – 25,000 euros*	*woman, age 65 30,000 km + current car: 0 – 5,000 euros*
Choice attributes	*Congestion Assistant 1,500 euros no premium reduction*	28.3% (V=-0.930)	9.9% (V=-2.211)	3.9% (V=-3.198)
	Speed Assistant 750 euros 25% premium reduction	57.4% (V=0.299)	27.2% (V=-0.982)	12.2% (V=-1.969)
	Safe Driving Assistant 100 euros 50% premium reduction	90.6% (V=2.269)	72.9% (V=0.988)	50.0% (V=0.001)

Table 8.9 shows that there is considerable heterogeneity in the model outcomes, caused by both the choice attributes and the user characteristics. This means that the influence of different ADAS, and most of all the financial incentives, have an important influence on the user's decision to adopt an ADAS. Furthermore, the user characteristics play an important role in this decision, indicating that there is considerable heterogeneity in that respect.

8.5.1 Use of the model in further analysis

In further analysis, simulations of user choices in different choice situations are to be used, based on this model (see Chapter 9). These simulations should result in the probability that a new car will be equipped with an ADAS, independent of the type of user, and as such an overall average over all users of the probability that they will buy an ADAS on their new car. Based on the respondent characteristics, the current sample can be considered as representative for Dutch car users. This means the overall model can be used for the required simulations.

Since the user, car use, and car characteristics are not varied in the simulations, a revised model is necessary, including only the choice attributes, in order to produce the required simulations. Two revised models were estimated, one including also the new car/current car variable next to the choice attributes, and one only including the choice attributes. In the estimation of these models, only those variables are used that were statistically significant at the p = 0.05 level (see Table 8.10 and 8.11).

Table 8.10: Revised user model including choice attributes and new car/current car variable

REVISED USER MODEL I	B	S.E.	Wald	df	Sig.	Exp(B)
Constant	-				-	
ADAS						
Speed Assistant	-				-	
Congestion Assistant	-				-	
Safe Driving Assistant	0.568	0.097	33.939	1.000	0.000	1.765
Cost						
100 euro	-				-	
750 euro	-1.275	0.100	162.154	1.000	0.000	0.280
1500 euro	-1.639	0.111	216.552	1.000	0.000	0.194
Premium reduction						
0%	-				-	
25%	0.542	0.100	29.573	1.000	0.000	1.720
50%	0.754	0.105	51.926	1.000	0.000	2.126
Car characteristics						
ADAS on new or current car ADAS on new car = 0 ADAS on current car = 1	-0.548	0.088	38.706	1.000	0.000	0.578
Nagelkerke R square	0.263					
-2 Loglikelihood	2624.305					

Table 8.11: Revised user model including choice attributes

REVISED USER MODEL II	B	S.E.	Wald	df	Sig.	Exp(B)
Constant	-0.357	0.106	11.325	1.000	0.001	0.699
ADAS						
Speed Assistant	-				-	
Congestion Assistant	-				-	
Safe Driving Assistant	0.587	0.100	34.225	1.000	0.000	1.798
Cost						
100 euro	-				-	
750 euro	-1.205	0.111	116.810	1.000	0.000	0.300
1500 euro	-1.574	0.119	175.865	1.000	0.000	0.207
Premium reduction						
0%	-				-	
25%	0.596	0.116	26.332	1.000	0.000	1.814
50%	0.802	0.119	45.383	1.000	0.000	2.230
Nagelkerke R square	0.169					
-2 Loglikelihood	2652.358					

In order to determine the quality of these simulations, the choice data resulting from the holdout profiles were compared with simulations by means of these models (see Table 8.12).

Table 8.12: Comparison between model simulations and holdout data of user choice for ADAS

		Data		Model	Difference
		#	%		
Congestion Assistant 100 euros no premium reduction	New car	64	49.2%	50.0%	0.8%
	Current car	49	40.8%	36.6%	-4.2%
	Total sample	113	45.2%	41.2%	-4.0%
Speed Assistant 1,500 euros 25% premium reduction	New car	19	14.6%	25.0%	10.4%
	Current car	15	12.5%	16.2%	3.6%
	Total sample	34	13.6%	20.8%	7.2%

The forecasts of the profiles, including the Congestion Assistant, are better than the forecasts of the profiles including the Speed Assistant. However, the deviations are limited to about 10%, which keeps the probabilities in the same order of magnitude. It has to be taken into account, though, that these differences are present when interpreting the results of the overall analysis with the actor and user models (see Chapter 9).

8.6 Discussion

The main issue of this discussion is whether the data used in this investigation are representative enough, and to what extent they are valid. From Table 8.2, it was previously concluded that the sample is considered representative with respect to gender and age, while the household outcome was lower than the population average. Factors that could have influenced the results were the fact that the survey was performed within only three days, and in the middle of July – which is the holiday season. However, since the variable income was not statistically significant in the model, the relatively low amount of high incomes may not be a major problem with respect to level of representation. The (presumably) income related variable car price is, however, a particularly important variable in the model. Taking the influence of car price into account, the model estimates for the sample average could be slightly conservative with respect to actual users' choice to buy ADAS.

The validity of this survey is mainly influenced by the fact it is a snapshot in time. Possible issues in this respect may be the presence of the credit crisis in the summer of 2009, as a result of which people may be less willing to spend money. In addition, the credit crisis led to less congestion on the roads, which may have influenced users' perceptions of the problem , as a result of which their needs with respect to ADAS, such as the Congestion Assistant, may have decreased. Furthermore, at this moment in time the general knowledge about ADAS is not yet very high, which may lead to very different perceptions of the ADAS, which could be influenced by more information or experience with ADAS. In summary, it should be taken into account that the outcomes of this investigation are most valid in the current situation, which means that the probability that users choose to buy an ADAS, resulting from the model, should be considered as an initial probability.

8.7 Conclusions

8.7.1 Conclusions regarding the user model

Users derive more utility from the Safe Driving Assistant than the Speed Assistant and the Congestion Assistant

A statistically significant difference between the utility users derive from the different ADAS was found, as opposed to what was found as a result of the actor survey. Users were found to derive more utility from buying a Safe Driving Assistant, than to buying a Congestion Assistant or a Speed Assistant. This could be caused by the fact that the latter two are more intervening than the Safe Driving Assistant, since users are reported more often to prefer less intervening systems (e.g. Adell et al., 2008, Van Driel and Van Arem, 2005; Marchau et al., 2001). Users might also have preferred this system as a combination of most of the functionalities of the two other systems.

Financial incentives have a substantial influence on the probability that users will buy an ADAS on their new car
Simulations with the user model show that, depending on the conditional factors, the probability that users choose to buy an ADAS on their new car is between 15% and 80%. If the ADAS is the Safe Driving Assistant, the probability that users choose to buy an ADAS on their new car is between 31% and 80%, and if the ADAS is the Speed Assistant or the Congestion Assistant, this probability is between 15% and 68%. If the cost of an ADAS is lowered to 100 euros, this probability is at least 64% for the Safe Driving Assistant and 50% for the other ADAS. If there is no reduction on the insurance premium, the maximum probability is reduced to 64% for the Safe Driving Assistant and 50% for the other ADAS. Consequently, the cost of the ADAS has a higher impact on the probability that users choose to buy an ADAS, than the monthly insurance premium.

It is more likely that car users purchase an ADAS on a new car than on their current car
It was found that the utility of buying an ADAS was higher for respondents that were asked if they would buy ADAS on a new car, than for respondents that were asked if they would buy an ADAS on their current car. Possible causes could relate to the fact that when already spending a certain amount of money on a car, buying an ADAS is a relatively low investment, compared with the hassle that comes with having the ADAS installed in a current car.

There is a large heterogeneity among users with respect to the choice for an ADAS
It was found that user, car use, and car characteristics – age, gender, mileage, and car price – significantly and substantially influence the probability that a user chooses to buy an ADAS. Consequently, since the explained variance of the model at 0.201 (Nagelkerke R^2) is relatively low, there is still considerable unexplained heterogeneity in the model, which is probably related to individual preferences.

8.7.2 Relevance of the results for ADAS deployment

Structure of the model of actors' interactions in ADAS deployment
The results of the user survey show statistically significant effects of the stimulating deployment actions of public authorities and insurance companies, and as such the relations between these actors' deployment actions and user choice can be confirmed. While only one deployment action of the automotive industry was considered (i.e. ADAS as optional equipment on a new vehicle), the results show that when public authorities and insurance companies do nothing, about 15% of the users choose the ADAS. In addition, the automotive industry is also able to influence the price of ADAS, and as such influence the users' choice. Consequently, the relation between the automotive industry's deployment actions and users' choice can also be confirmed. This means no further changes have to be applied to the model of actors' interactions in ADAS deployment.

Expectations regarding ADAS deployment

Without any specific incentives, and presuming that the price level of an ADAS is indeed around 1,500 euros, the results show that there is a probability of about 15% that users choose to buy a Speed Assistant or Congestion Assistant, and a probability of about 30% that they choose to buy a Safe Driving Assistant. Apparently, users are more interested in informing systems than more intervening systems. However, since the effectiveness of informing systems can be lower than for more intervening systems (e.g. Carsten and Tate, 2005), actors such as public authorities would require a higher probability of choice, and as a result a higher number of cars equipped, in order to achieve their objectives.

If actors seek to stimulate users' choice to buy an ADAS, the results of the user survey show that applying a reduction on the purchase costs may prove to be more effective than a reduction on the monthly insurance premium. In determining the value of the financial incentives to be applied, the reported non-linearity of the utility functions of costs and premium should be taken into account. Since the utility of buying an ADAS on a current car is reported to be lower than on a new car, higher incentives may be necessary if there is a need to pursue retrofitting of ADAS.

The reported heterogeneity in the utility users derive from buying an ADAS, can be addressed by (mixed) strategies of actors to stimulate the adoption rate in the most effective way. If the objective of an actor is to make a profit out of selling ADAS (e.g. the automotive industry), they could aim first at target groups with a high probability of choosing to buy an ADAS, and aim at other groups later, when they have been able to lower the price. If the objective of an actor is to increase traffic safety or reduce congestion (e.g. public authorities), they could stimulate the target groups from which most effect is expected. For example, those target groups that are reported to be more accident prone, or drive more often in congestion than others, and so simultaneously derive a relatively low utility from buying an ADAS (e.g. speed offenders).

Whatever the cause, this means that when the aim of actors is to apply retrofitting, more or higher incentives are needed to reach the same adoption rate among current vehicles, when compared with new vehicles.

9 Application of the model of actors' interactions: expectations regarding ADAS deployment

How is ADAS deployment expected to develop, given the knowledge about the probability of actors' and users' deployment actions? Moreover, how are these expectations influenced by the different deployment strategies that were identified for the automotive industry and insurance companies? This chapter explores deployment scenarios, based on the updated model of actors' interactions in ADAS deployment. The results of the actor and user surveys are used as input to several simulations of deployment scenarios, resulting in the probability of these deployment scenarios, and their outcomes, in terms of the probability that users buy an ADAS. The results show that there is a fair probability that ADAS will be deployed, and deployment options of public authorities can be very effective.

9.1 Introduction

ADAS deployment is conceptualized in this dissertation as a system of interactions between actors, which influences the deployment rate of ADAS. Based on the literature, a conceptual model of this system of actors' interactions in ADAS deployment was established (see Chapter 3 and 4). The existence of the assumed relations between the actors in this model was validated, based on empirical data of actors' interactions, resulting in the updated model of Figure 9.1. Compared to the original model, only the interactions between insurance companies on the one side, and public authorities and the automotive industry on the other side, could not be confirmed by the data.

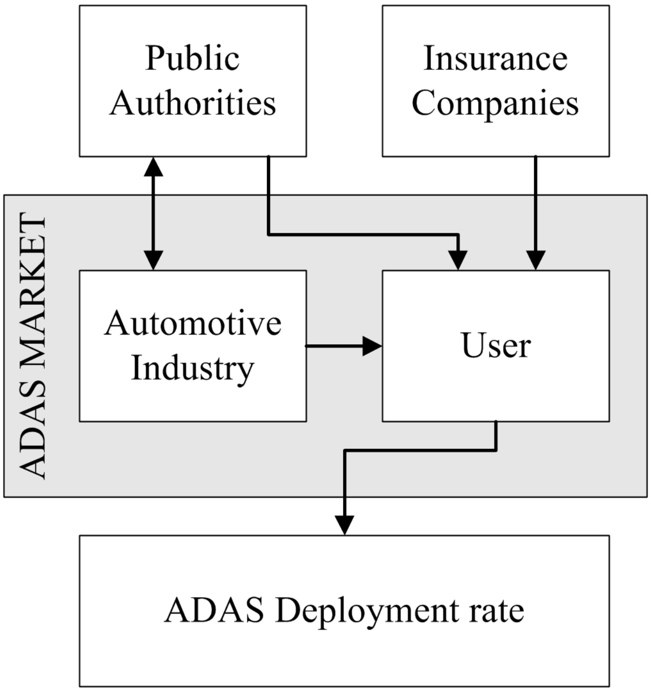

Figure 9.1: Updated model of actors' interactions in ADAS deployment

Based on the stochastic model developed to describe this conceptual model mathematically, deployment scenarios can be simulated. The empirical data of actor and user deployment actions is used as input to these simulations. The purpose of the simulations is to explore the probability of deployment scenarios based on actors' interactions, and the outcomes of these deployment scenarios in terms of the probability that users will buy an ADAS on their next new car.

9.2 Simulations with the model of actors' interactions in ADAS deployment

9.2.1 Methodology

Figure 9.2 presents the steps in the simulation of decision scenarios with the stochastic model of actors' interactions in ADAS deployment (see also Chapter 4).

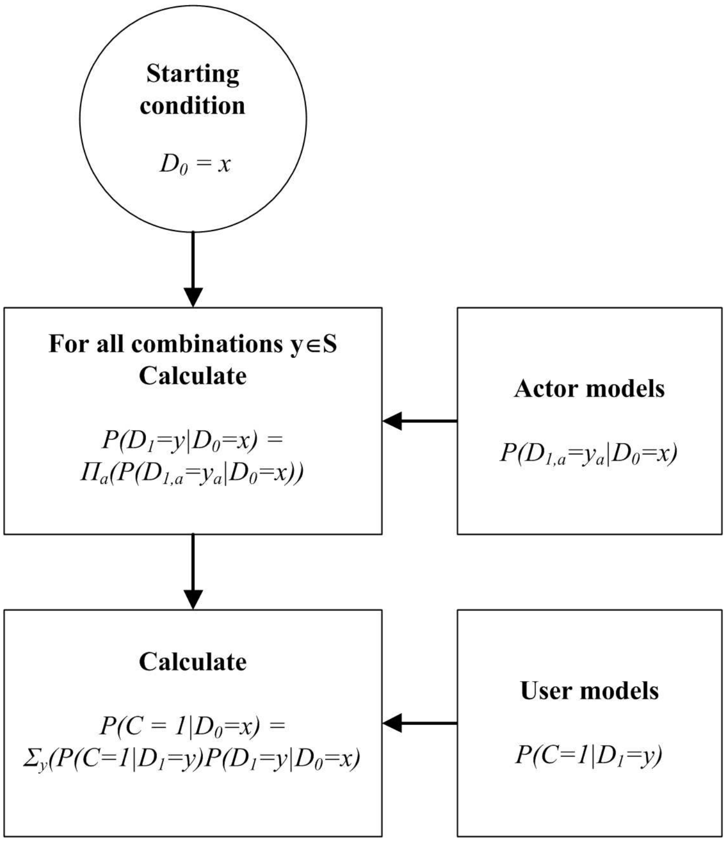

Figure 9.2: Simulation of deployment scenarios

Step 1: Starting condition: deployment scenario $D_0 = x$
The starting condition is the deployment scenario at time $t=0$, represented by the stochastic variable D_0, with outcome x, being a combination of deployment actions of all actors. These deployment actions x_a are drawn from the set of available deployment options $d_{nd}(a)$ (see Chapter 5).

Step 2: Calculate probability of deployment scenario $D_1=y$
This step includes all possible outcomes y of the deployment scenario at time $t=1$, which is represented by the stochastic variable D_1. The time step from $t=0$ to $t=1$ resembles a decision round in which actors can reconsider their first action, knowing the actions of the others. Like x, y is a combination of deployment actions y_a of all actors a, drawn from the set of available deployment options $d_{nd}(a)$.

For each deployment action y_a, the probability $P(D_{1,a}=y_a)|D_0=x)$ that an actor is going to take this deployment action, given the deployment scenario at $t=0$, is derived from the models of actor decision-making (see Chapter 6 and 7). The probability $P(D_1=y|D_0=x)$ that deployment scenario y occurs given the starting condition x, is calculated as the product of the probabilities $P(D_{1,a}=y_a|D_0=x)$.

Step 3: Calculate probability that user will buy ADAS on next new car
For each deployment scenario y, the probability $P(C=1)|D_1=y)$ that users will buy an ADAS on their next new car, given the deployment scenario at $t=1$, is derived from the models of actor decision-making (see Chapter 8). The probability $P(C=1|D_0=x)$ that users will be to buy an ADAS on their next new car, given starting condition x, is calculated as the sum of the products of $P(C=1|D_1=y)$ and $P(D_1=y|D_0=x)$ for all possible deployment scenarios y.

9.2.2 Specification of the simulation input

The necessary input to the simulation consists of the actors' deployment options, the probability that actors take a certain deployment action, given the deployment scenario at $t=0$, and the probability that users will buy ADAS on their next new car, given the deployment scenario at $t=1$.

Actors' deployment options

Table 9.1 shows the actors' deployment options included in the simulations. These are the same as those used in the actor survey, except for insurance companies, for whom optional and standard premium reduction was merged to one deployment option. Note that the option 'other' was only included in the actor survey as a possible reaction, but not as part of the current deployment scenario presented to the respondents.

Table 9.1: Overview of actors' deployment options

Actor	**Deployment options**
Public authorities	Do nothing 1,500 euros tax reduction for vehicles with ADAS Mandate ADAS for all vehicles by legislation[16] Other
Automotive industry	Do nothing ADAS is optional equipment for all new vehicles ADAS is standard equipment for all new vehicles Other
Insurance companies	Do nothing Up to 25% premium reduction for safe driving using ADAS Other

Probability that actors take a deployment action

The probability $P(D_{1,a}=y_a|D_0=x)$ was derived from the models estimated for all deployment actions y_a of actors a, given deployment scenario x. More specifically, the revised models were used that were estimated based on statistically significant attributes only (see Sections 6.5.5 and 7.3). The small effects of the ADAS that were still present in the revised models were ignored in the probability simulations. The probabilities over all deployment options of an actor, given a certain starting condition, were normalized to correct for small inconsistencies in the models.

The starting conditions to be considered for public authorities' reactions can be limited to the deployment actions of the automotive industry only (see Table 9.2).

Table 9.2: Probabilities of public authorities' deployment actions

Automotive industry's action	**Probabilities of public authorities' reaction***			
	Do Nothing	Tax Reduction	Mandate	Other
Do nothing	0.623	0.200	0.082	0.095
Option	0.536	0.283	0.084	0.098
Standard	0.707	0.121	0.079	0.093

* Based on revised model of public authorities' probabilities (Table A.2, Appendix A)

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[16] The 'mandate' deployment option included in the actor models applied to all vehicles, whereas the simulations only applied to new vehicles. This is assumed, however, to be of little influence to the eventual results of the simulations.

The starting conditions to be considered for the automotive industry's reactions can be limited to the deployment actions of public authorities only. Regarding the probabilities of the automotive industry's deployment actions, three different subgroups of respondents expecting a different strategy were identified, characterizing the automotive industry as an Active Deployer, a Reluctant Deployer, or an Adaptive Deployer. Table 9.3 includes the probabilities for each of these strategies, and an overall average based on the magnitude of the subgroups.

Table 9.3: Probabilities of the automotive industry's deployment actions

Automotive industry's strategy	**Public authorities' action**	**Probabilities of automotive industry's reaction***			
		Do Nothing	Option	Standard	Other
Active deployer (56.6% of respondents)	*Do nothing*	0.193	0.564	0.205	0.037
	Tax reduction	0.114	0.524	0.328	0.035
	Mandate	0.044	0.489	0.434	0.032
Reluctant deployer (22.2%)	*Do nothing*	0.658	0.282	0.056	0.003
	Tax reduction	0.453	0.423	0.111	0.012
	Mandate	0.197	0.182	0.527	0.095
Adaptive deployer (22.2%)	*Do nothing*	0.316	0.538	0.146	0.000
	Tax reduction	0.156	0.531	0.313	0.000
	Mandate	0.001	0.000	0.999	0.000
Overall average	*Do nothing*	0.324	0.496	0.159	0.021
	Tax reduction	0.198	0.503	0.276	0.022
	Mandate	0.069	0.312	0.580	0.039

* Based on revised models of automotive industry's probabilities (Table 7.9 – 7.11, Chapter 7)

The reactions of insurance companies are independent of the starting conditions. With regard to the probabilities of insurance companies' deployment actions, three different subgroups of respondents expecting a different strategy were identified, characterizing insurance companies as an Active Deployer or a Non-Deployer. Table 9.4 includes the probabilities for both these strategies, and an overall average based on the magnitude of the subgroups. The probabilities for both optional and standard premium reduction were summarized into one probability for 'premium reduction'.

Table 9.4: Insurance companies' strategies

	Probability of insurance companies' action*		
Insurance company type	Do nothing	Premium reduction	Other
Active deployer (57.1% of respondents)	0.233	0.649	0.118
Non-deployer (42.9%)	0.793	0.191	0.017
Overall average	0.473	0.452	0.075

*Based on revised models of insurance companies' probabilities (Table 7.14 – 7.15, Chapter 7)

Probability that users will buy ADAS on next new car

The probability $P(C=1|D_1=y)$ was derived from the estimated model of users' choice to buy an ADAS on their next new car. More specifically, the revised model that was used was estimated based on statistically significant attributes only, except the variables that explain individual variation from the estimation (see Table 8.10). It was assumed that the user sample is representative, and as such will result in probabilities that can be used as an overall average for individual car buyers in the Netherlands. As opposed to what was found for the actors, the type of ADAS does make a difference in the probability that users will buy an ADAS, which is included in Table 9.5.

The deployment actions of public authorities and insurance companies were included in the model by means of ADAS purchase costs, and reduction on monthly insurance payments. When public authorities do nothing, this is considered to be equivalent to an ADAS cost of 1,500 euros, and a tax reduction with a cost of 100 euros. For insurance companies, doing nothing is considered to be equivalent to a 0% premium reduction, and premium reduction with 25% premium reduction.

Table 9.5: Probabilities of users buying an ADAS on their next new car in different deployment scenarios

Industry	**Public authorities**	**Insurance companies**	**Probability that user buys ADAS on new car**	
			Speed Assistant / Congestion Assistant	Safe Driving Assistant
Do nothing	Do nothing; or Tax reduction; or Other	Any action	0.000	0.000
	Mandate	Any action	1.000	1.000
Option	Do nothing	Do nothing	0.163	0.255
		Premium reduction	0.250	0.371
		Other	0.163*	0.255*
	Tax reduction	Do nothing	0.500	0.638
		Premium reduction	0.632	0.752
		Other	0.500*	0.500*
	Mandate	Any action	1.000	1.000
	Other	Do nothing	0.163*	0.255*
		Premium reduction	0.250*	0.371*
		Other	0.163*	0.255*
Standard	Any action	Any action	1.000	1.000
Other	Any action	Any action	undefined	undefined

* These probabilities are related to deployment scenarios in which at least one of the actors applied the deployment action “other”. The values of these probabilities are assumed to be this value or higher.

All deployment scenarios in which the automotive industry does nothing automatically lead to a probability of 0 that a user buys an ADAS on a new car, since ADAS are then simply not available. Accordingly, all deployment scenarios in which the automotive industry applies an ADAS as standard equipment, and/or in which public authorities mandate an ADAS, lead to a probability of 1 that a user buys an ADAS on a new car. If the automotive industry takes an ‘other’ action this probability is undefined, and if public authorities or insurance companies taken an ‘other’ action the probability is presented as equal to when these actors are doing nothing.

A remark with respect to the figures in Table 9.5 needs to be made. These figures could easily be mistaken for deployment rates, while they represent probabilities that users buy an ADAS. These probabilities equal the deployment rate only under specific conditions: if ADAS are available on every new car, and if all users have bought a new car. As such they represent the maximum deployment rate (or market penetration) that can be reached under certain stable deployment actions and stable user choices over time.

9.2.3 Uncertainties regarding model input

There are several sources of uncertainty related to the model input that can be of influence on the results of the simulations, including the nature of the data based on which the actor and user models were estimated, the operations on the data in the simulation model, and individual variations among the respondents.

The simulation input with respect to the probability that actors take a deployment action, and the probability that users buy an ADAS on their next new car, is based on stated preference data. This type of data is often reported to be too optimistic when compared to actual decision-making, i.e. people overstate their economic valuation of a good (e.g. Murphy et al., 2005). However, the types of questions used in the actor and user surveys are expected to have reduced this potential bias. In the actor survey, respondents were asked to make a probability distribution over 4 deployment actions, adding up to 100%. As such, they were forced to make a trade-off between their deployment actions. This is assumed to have reduced potential bias, which may be supported by the more conservative outcomes of this part of the survey, compared to the individual utility ratings of the respondents (see Chapter 6). In addition, the fact that respondents were asked to indicate the probabilities for their sector, and not for themselves, may have positively contributed to the representativeness of the results. In the user survey, respondents were presented with a choice task, which is expected to result in more realistic data than individual utility ratings (Murphy et al., 2005). It is concluded that bias is probably present in the data, which is as far as possible compensated by the method of questioning. Due to the path finding nature of this research project, realistic data to validate the outcomes are not available. The results should therefore be considered as actor expectations regarding ADAS deployment, rather than as a correct forecast of ADAS deployment. These expectations might be optimistic.

While there is a substantial amount of confidence in the data, a certain degree of error is likely to be present. Thus combination of the data by mathematical operations, such as is performed by the simulations, may magnify errors present in the data. In a similar manner to the outcomes of the stated preference experiments, realistic data are not available to validate the outcomes of the simulations. It was therefore decided not to present the outcomes of the simulations as single probabilities that users will buy an ADAS on their next new car, but as a probability distribution over possible outcomes. This reduces the amount of operations on the data, and avoids the suggestion of a single possible future regarding ADAS. In any case, this approach better fits the available data.

In the actor survey, individual variations were found, from which subgroups of respondents with different deployment strategies could be identified. Since the number of respondents was relatively small, as some of the subgroups were, it is uncertain how much value can be attached to the size of the subgroups; and, as a result, if the overall average is representative for overall deployment development. It was therefore decided to run simulations for both the average, as well as the combinations, of the most conservative and the most progressive strategies of the automotive industry and insurance companies, which then represent a bandwidth of expectations regarding ADAS deployment.

In summary, there is confidence in the stated preference data, but since errors may still be present, it was decided to reduce the amount of operations on the data, and present the simulation outcomes as a distribution, rather than as a single figure of the probability that users will buy an ADAS on their next new car. In addition, since there is uncertainty about the representative character of the subgroups, simulations were run of the combinations of the most conservative and the most progressive strategies, next to the overall average.

9.3 Definition of deployment scenarios to be simulated

It was stated previously that the purpose of these simulations is to explore the probability of deployment scenarios, based on actors' interactions, and the outcomes of these deployment scenarios, in terms of the probability that users will buy an ADAS on their next new car.

As a reference case, the starting condition of the first simulation was that all actors are doing nothing at $t=0$. As a result they can all change their deployment action at $t=1$. This reference case involves no interaction between the actors. In order to explore the effects of single actors' actions, the other starting conditions involved one actor taking action, and the other actors doing nothing at $t=0$. Only those deployment actions are considered that leave options open for other actors to influence ADAS deployment. The other actors can react to this action at $t=1$, while the action of the actor that was acting first remains the same.

It was decided to run the simulations only for the Speed Assistant and Congestion Assistant, since no statistically significant differences between these ADAS were reported for the actors and the users. The results can easily be read for the Safe Driving Assistant, exchanging the probabilities presented in Table 9.5.

Each simulation was run for three different combinations of strategies of the automotive industry and insurance companies, the sample average, conservative strategies, and progressive strategies. The combination of conservative strategies included the automotive industry as a Reluctant Deployer, and insurance companies as a Non-Deployer. The combination of progressive strategies included automotive industry and insurance companies as an Active Deployer.

This leads to a total of six simulations, of which each was run three times to cover the different strategy combinations. Table 9.6 gives an overview of the simulations.

Table 9.6: Simulations with the data

#	ADAS	Starting condition	Deployment scenario	Strategies
1	Speed Assistant/ Congestion Assistant	All: Do Nothing	All: any deployment option	All
				Conservative
				Progressive
2	Speed Assistant/ Congestion Assistant	Public Authorities: Do Nothing Others: Do Nothing	Public Authorities: Do Nothing Others: any deployment option	All
				Conservative
				Progressive
3	Speed Assistant/ Congestion Assistant	Public Authorities: Tax Reduction Others: Do Nothing	Public Authorities: Tax Reduction Others: any deployment option	All
				Conservative
				Progressive
4	Speed Assistant/ Congestion Assistant	Automotive Industry: Option Others: Do Nothing	Automotive Industry: Option Others: any deployment option	All
				Conservative
				Progressive
5	Speed Assistant/ Congestion Assistant	Insurance Companies: Do Nothing Others: Do Nothing	Insurance Companies: Do Nothing Others: any deployment option	All
				Conservative
				Progressive
6	Speed Assistant/ Congestion Assistant	Insurance Companies: premium reduction Others: Do Nothing	Insurance Companies: premium reduction Others: any deployment option	All
				Conservative
				Progressive

9.4 Results: probability that users will buy an ADAS

9.4.1 Presentation of the results

According to the algorithm used for the simulations (see Figure 9.2), the outcomes of the simulations could be given as a single figure, representing the probability that users will buy an ADAS on their next new car, given a certain starting condition. Presenting the outcomes in such a way would conceal the uncertainty related to these outcomes. Consequently, it was decided to show probability distributions over all possible outcomes in terms of the probability that users will buy an ADAS on their next new car. These probability distributions are presented by means of pie-charts.

Presenting all outcomes in one pie-chart, however, would not be a correct representation of the data. The probability of deployment scenarios is based on probability distributions over all actors' deployment actions; whereas the reaction of the users was only measured for a limited number of deployment scenarios (i.e. those that left a possibility to choose for the users). Consequently, the outcomes were presented by means of two pie-charts. The first one represents the probability distribution over deployment scenarios that involve no deployment of ADAS (probability that users will buy an ADAS: P=0), stimulation of ADAS adoption (0<P<1), and forcing of ADAS adoption (P=1). The second one represents the probability distribution over the different probabilities that users will buy an ADAS related to the different stimulation options of public authorities and insurance companies. This is a further specification of the area in the first pie-chart that represents stimulation of ADAS adoption (0<P<1).

In order to explain this, Figure 9.3 is used as an example. The pie-chart on the left in this figure shows that there is a probability of 30% that ADAS will not be deployed (i.e. the automotive industry does nothing), 46% that it will be stimulated by one or more actors, and 23% that adoption will be forced by the automotive industry or public authorities. The remaining 2% represent the deployment scenarios in which the automotive industry takes an unknown 'other' deployment action. The pie-chart on the right specifies the light grey area (46%) of the pie-chart on the left. It shows that if ADAS adoption is stimulated by one or more actors, the probability is 43% that stimulation options are used that result in a probability that users buy an ADAS of 0.163, etc.

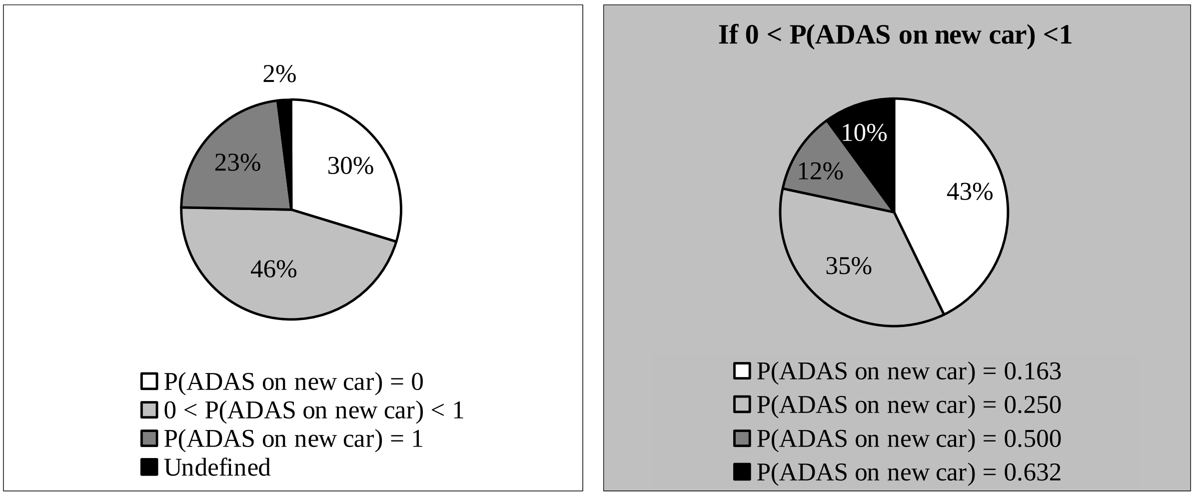


Figure 9.3: Distribution of probability of ADAS on a new car – all actors, all strategies

To avoid confusion, the probabilities of the deployment scenarios, and the probabilities that users will buy an ADAS, are presented on different scales; the probabilities of the deployment scenarios on a scale of 0% to 100%, and the probabilities that users will buy an ADAS on a scale of 0 to 1.

9.4.2 Simulation 1: Reference case

It can be concluded from Figure 9.3 that, according to the actors, there is a fair probability that ADAS will become available as an option (46%) or standard to new cars (23%). If ADAS are available as an option, it is most likely that the probability that users will buy an ADAS on their next new car is 0.163-0.250. Nevertheless, the probability that users will not buy an ADAS on their new car is substantial (30%). Figure 9.4 shows the results for the most conservative strategies of the automotive industry and insurance companies. Figure 9.5 shows the results for their most progressive strategies.

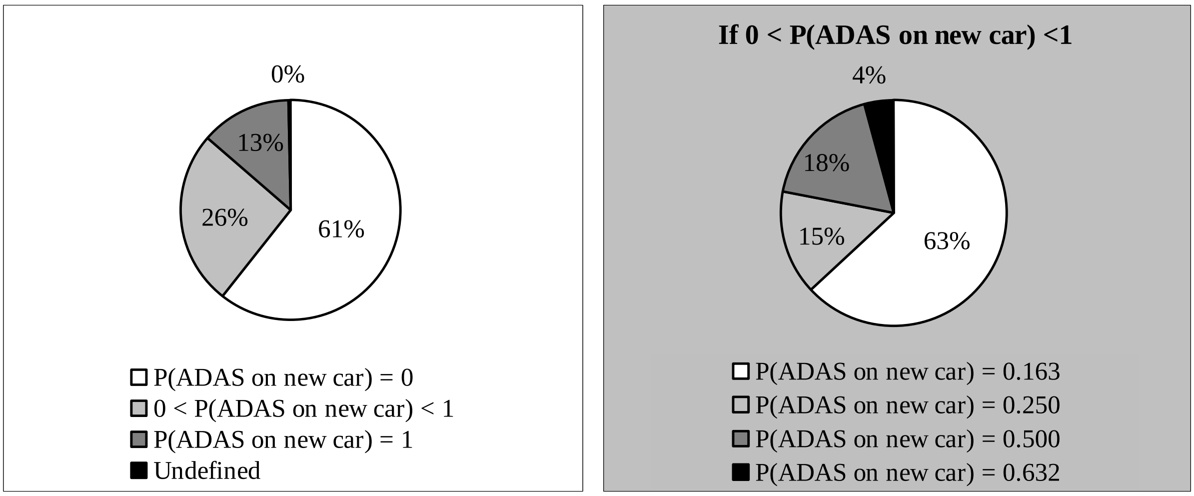


Figure 9.4: Distribution of probability of ADAS on a new car – all actors, conservative strategies

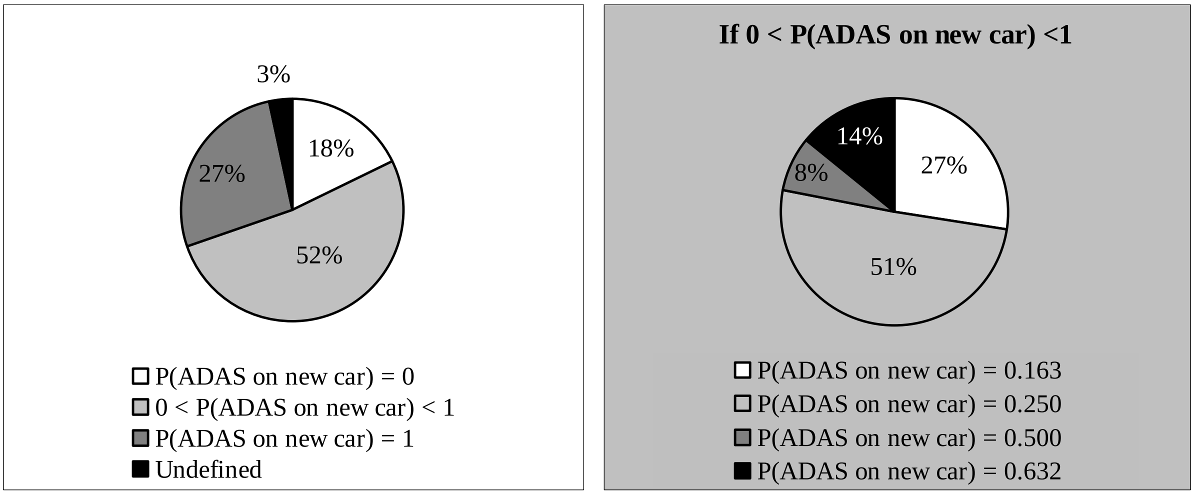


Figure 9.5: Distribution of probability of ADAS on a new car – all actors, progressive strategies

Figure 9.4 and Figure 9.5 show that there is a large spread in the distributions of the probabilities, due to possible different strategies of the automotive industry and insurance companies. The probability that ADAS will not become available varies between 18% and 61%, the probability that ADAS will be available as an option on new cars between 26% and 52%, and the probability that ADAS will be available on each new car between 13% and 27%. The probability that a new car will be equipped with an ADAS varies between 0.163 and 0.250, as the most likely values under conservative and progressive strategies.

In summary, it can be seen that possible strategies applied by the automotive industry and insurance companies can have a substantial impact on the probability of a new car being equipped with ADAS. Nevertheless, an interpretation of these results can be that, in the reference case in which everyone starts with doing nothing, and there are no interactions between the actors, there is a fair probability that ADAS are going to be available as an option.

9.4.3 Simulation 2: Public authorities do nothing

Figures 9.6 – 9.8 show that the distribution of probabilities is very similar to that of the reference case (see 9.3.2). This is due to the fact that results of the actor survey reported a large probability that public authorities will do nothing (see input Table 9.2). However, it can also be observed that the probability that users will buy an ADAS on their next new car, when this ADAS is provided as an option, is expected to be lower.

In summary, the results of the simulation, based on public authorities doing nothing, do not differ significantly from the reference case, since public authorities were not expected to play an important role.

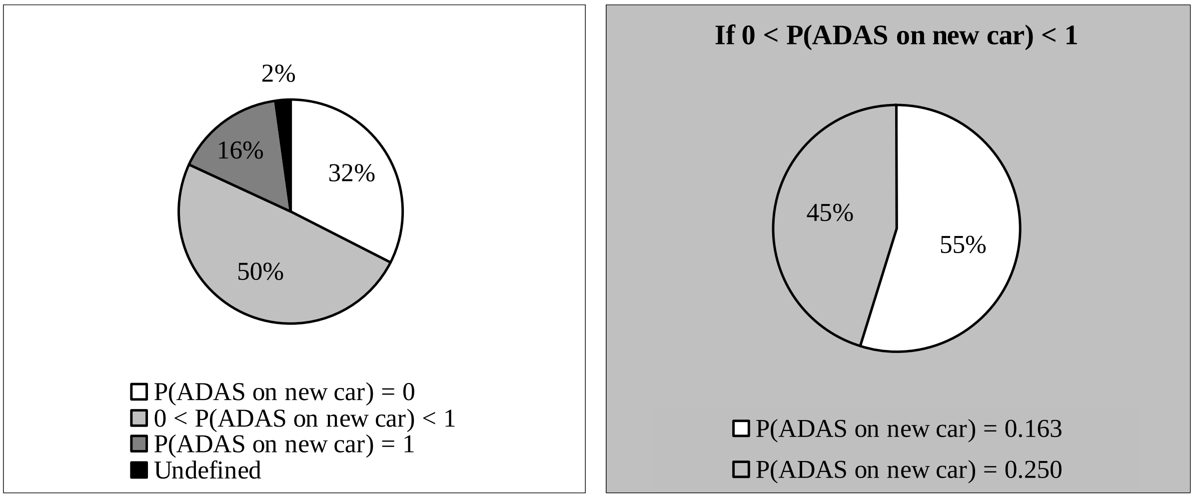


Figure 9.6: Distribution of probability of ADAS on a new car – public authorities do nothing, all strategies

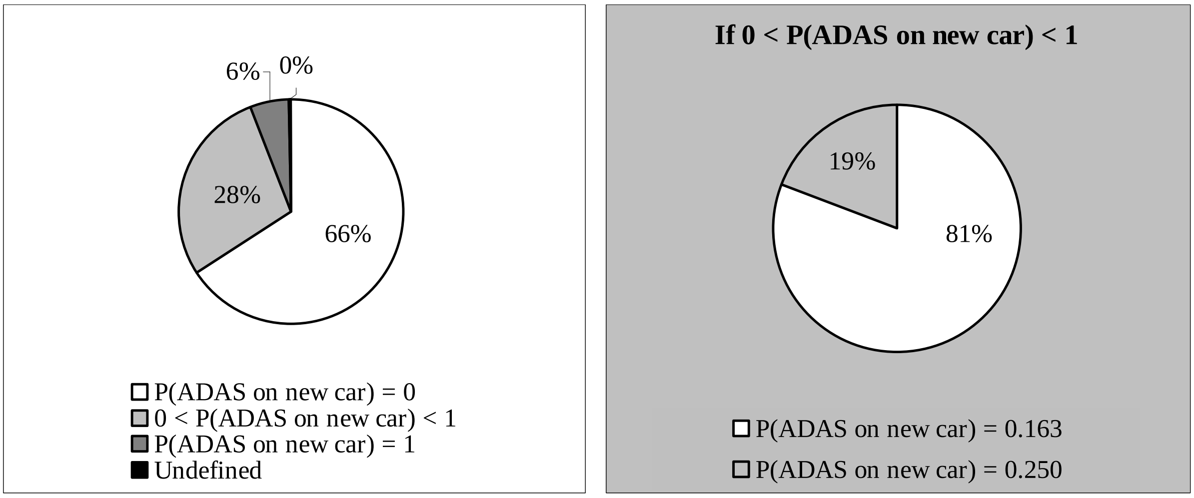


Figure 9.7: Distribution of probability of ADAS on a new car – public authorities do nothing, conservative strategies

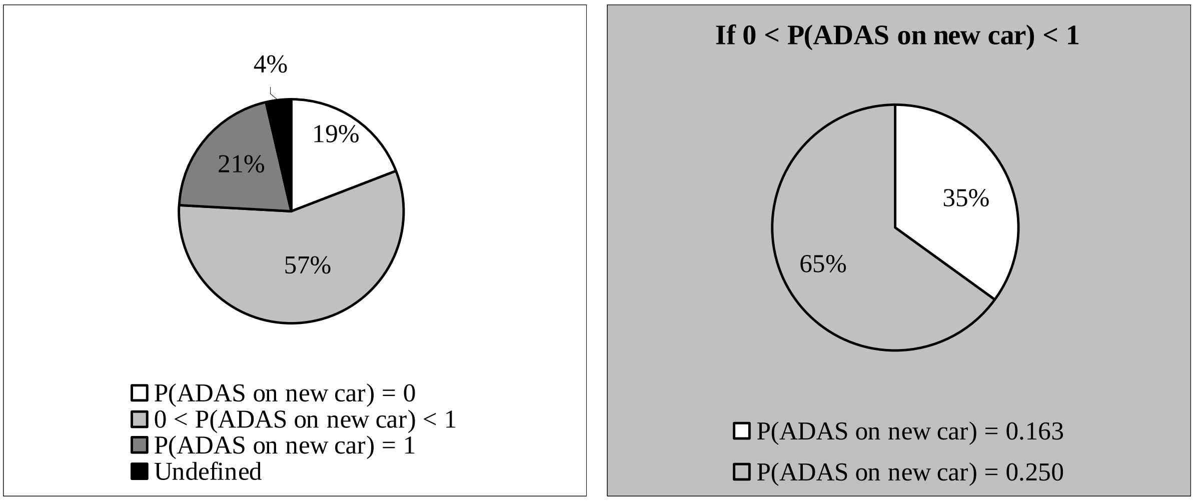


Figure 9.8: Distribution of probability of ADAS on a new car – public authorities do nothing, progressive strategies

9.4.4 Simulation 3: Public authorities provide 1,500 euros tax reduction

Figure 9.9 shows that, generally, the probability that ADAS are deployed increases some 12% when public authorities apply a 1,500 euros tax reduction, as opposed to no tax reduction (see Figure 9.6). This increase mainly affects the probability that user will buy an ADAS on their next new car. Furthermore, the probability that ADAS will be provided as an option by the automotive industry is also higher.

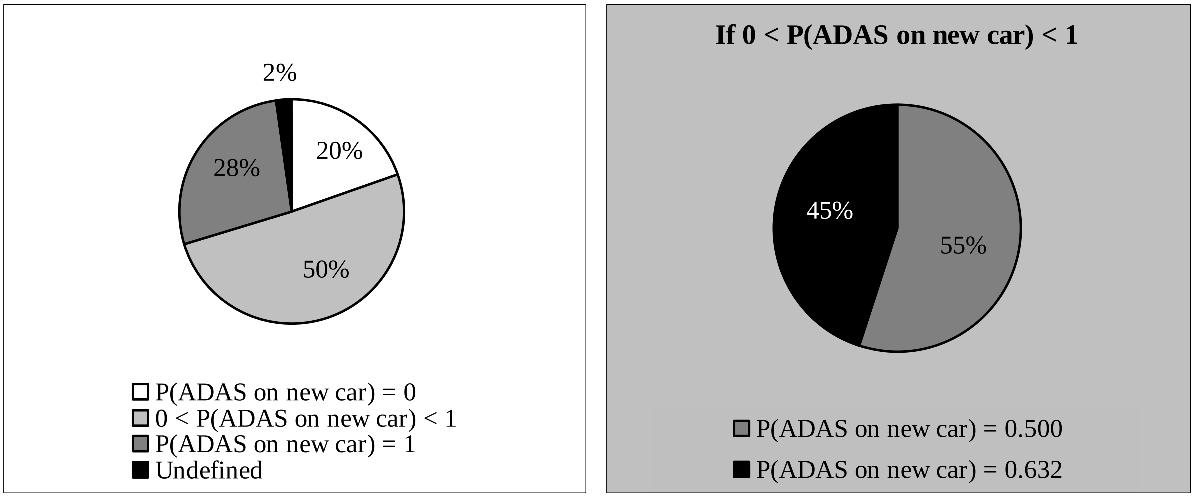


Figure 9.9: Distribution of probability of ADAS on a new car – public authorities apply tax reduction, all strategies

Figure 9.10 and Figure 9.11 show that the probability that ADAS will be provided as an option is stable across the different strategies (42% - 52%). The main difference with respect to doing nothing can be observed for conservative strategies. The result is that, in any case, the probability that ADAS will be deployed is more than 50%. In the case of progressive strategies, the probability that users will buy an ADAS on their next new car, when this ADAS is provided as an option, is also high, i.e. 0.5-0.632.

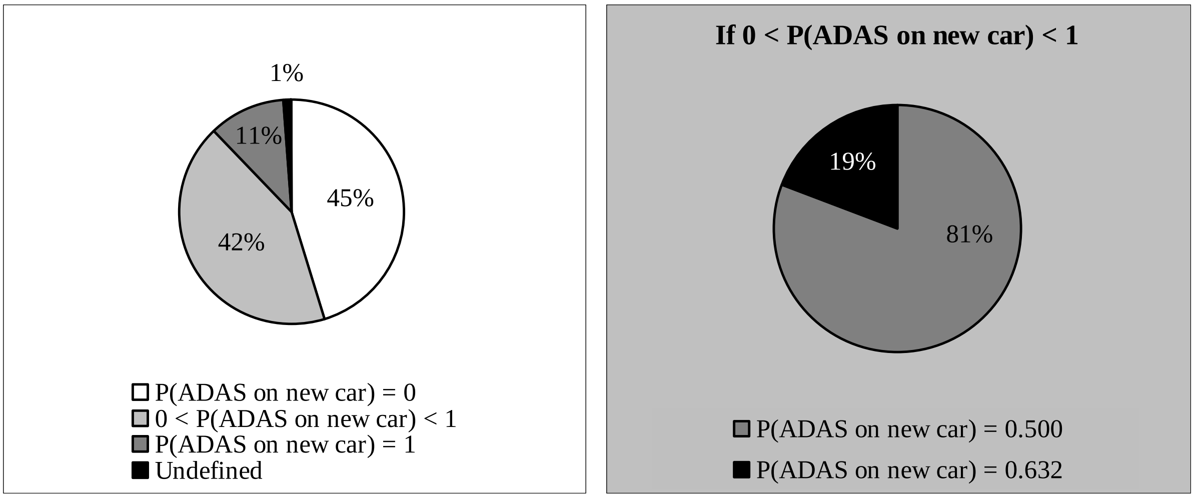


Figure 9.10: Distribution of probability of ADAS on a new car – public authorities apply tax reduction, conservative strategies

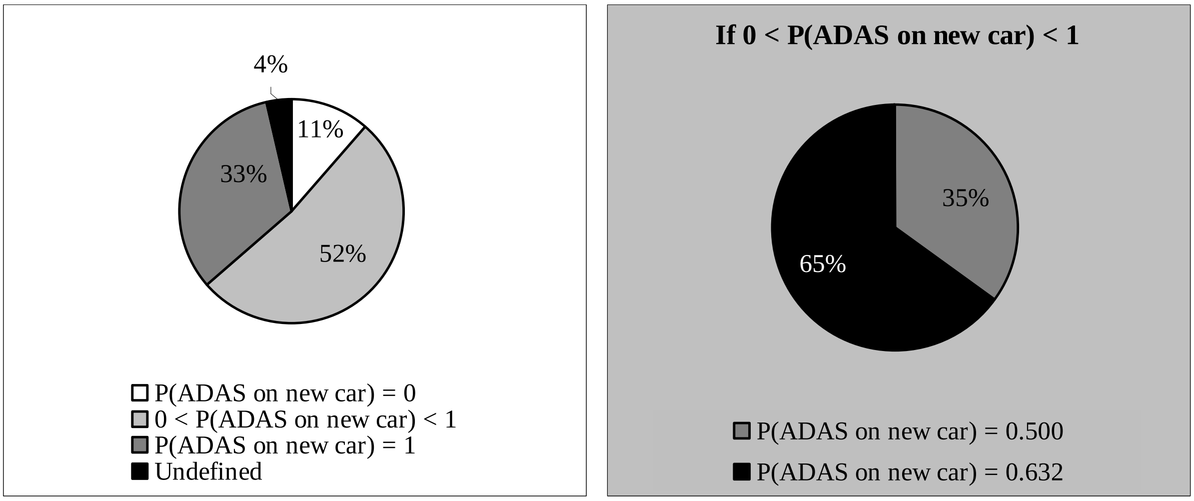


Figure 9.11: Distribution of probability of ADAS on a new car – public authorities apply tax reduction, progressive strategies

In summary, the results show a stable probability of deployment of ADAS as an option, when public authorities are applying a 1,500 euros tax reduction of 42% to 52% across strategies. Furthermore, the probability that users will buy an ADAS on their next new car, when provided as an option, is much larger than when public authorities are doing nothing.

These results can be interpreted that providing a tax reduction is an effective deployment action to stimulate other actors to take action in ADAS deployment, and for users to buy an ADAS on their next new car.

9.4.5 Simulation 4: Automotive industry offers ADAS as an option

Figures 9.12 – 9.14 present the distributions over probabilities that users will buy an ADAS on their next new car, if the automotive industry offers ADAS as an option. These data are eligible to be presented in one pie-chart for each strategy.

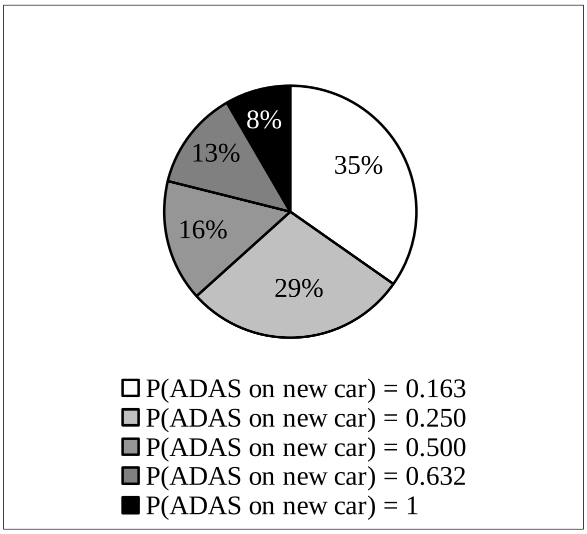


Figure 9.12: Distribution of probability of ADAS on a new car –the automotive industry offers optional ADAS, all strategies

Figure 9.12 shows that, on average, it is most likely that the probability that users will buy an ADAS on their next new car is 0.163 – 0.250. If a conservative strategy of insurance companies applies, this probability is most likely to be 0.163, and if a progressive strategy applies, it is most likely to be 0.250.

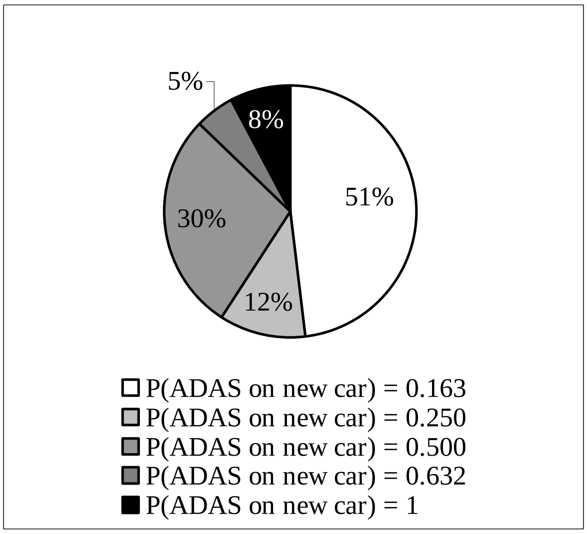


Figure 9.13: Distribution of probability of ADAS on a new car – the automotive industry offers optional ADAS, conservative strategies

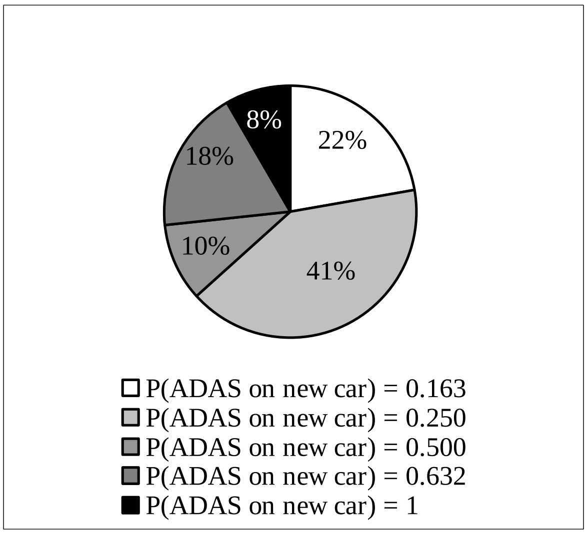


Figure 9.14: Distribution of probability of ADAS on a new car – the automotive industry offers optional ADAS, progressive strategies

In summary, the probability that users will buy an ADAS on their next new car, as a result of the automotive industry offering it as an option, is 0.163 – 0.250, depending on the strategy of insurance companies. Earlier findings suggested that the strategy of insurance companies is most likely to be conservative (see Chapter 7). It can therefore be argued that it is most likely that the probability that users will buy an ADAS on their next new car is around 0.163.

9.4.6 Simulation 5: Insurance Companies do nothing

Figures 9.15 – 9.17 show that, since insurance companies do not influence the deployment actions of other actors, the distribution over probabilities that users will buy an ADAS on their next new car is the same as in the reference case (see Figure 9.3 – 9.5). If ADAS is provided as an option, it was found to be most likely that the probability that users will buy an ADAS on their next new car is about 0.163, under any strategy.

In summary, the results of the simulation based on insurance companies doing nothing do not differ significantly from the reference case. If ADAS is provided as an option, the probability that users will buy an ADAS on their next new car is most likely about 0.163.

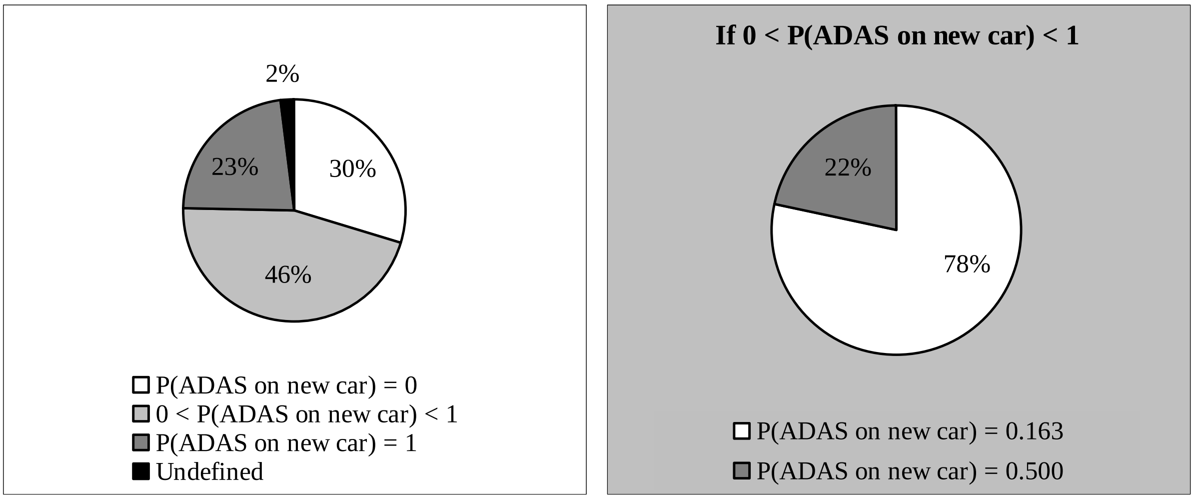


Figure 9.15: Distribution of probability of ADAS on a new car – insurance companies do nothing, all strategies

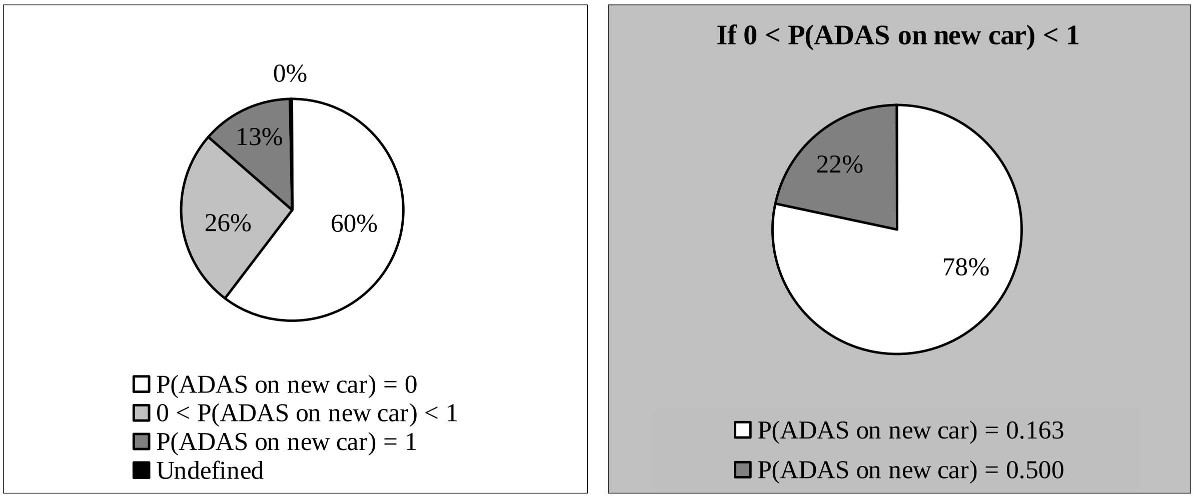


Figure 9.16: Distribution of probability of ADAS on a new car – insurance companies do nothing, conservative strategies

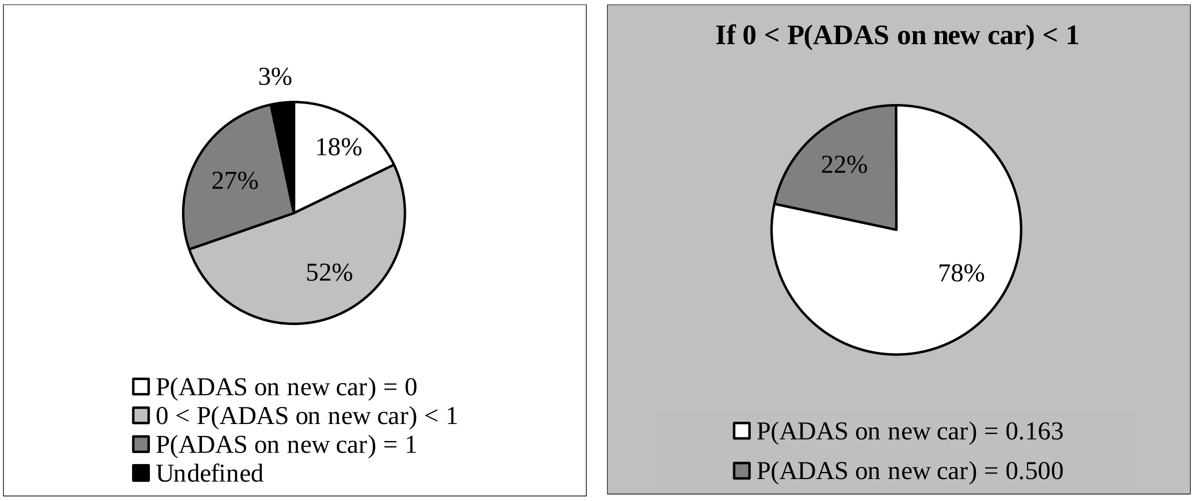


Figure 9.17: Distribution of probability of ADAS on a new car – insurance companies do nothing, progressive strategies

9.4.7 Simulation 6: Insurance Companies offer 25% premium reduction

Figures 9.18 – 9.20 generally show the same picture as Figures 9.15 – 9.17, in that there is no difference with respect to the reference case. The only difference is in the probability that users will buy an ADAS on their next new car, when provided as an option, which is most likely to be 0.250, when insurance companies offer a 25% premium reduction.

In summary, when insurance companies apply a 25% premium reduction, as opposed to doing nothing, the probability that users will buy an ADAS on their next new car, if this ADAS is provided as an option, increases from 0.163 to 0.250. This effect can be interpreted as relatively small, compared to that which public authorities can achieve with tax reductions.

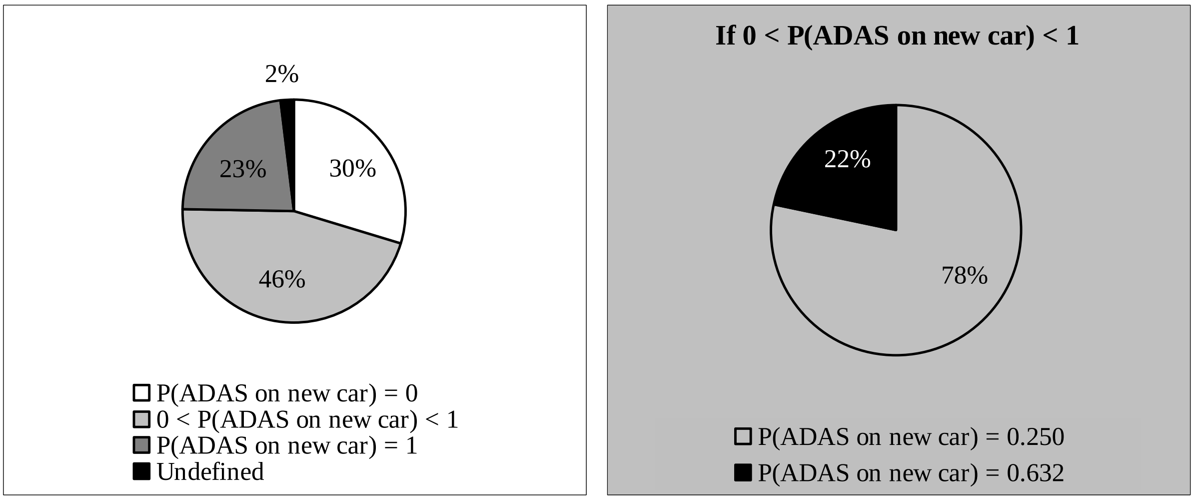


Figure 9.18: Distribution of probability of ADAS on a new car – insurance companies apply premium reduction, all strategies

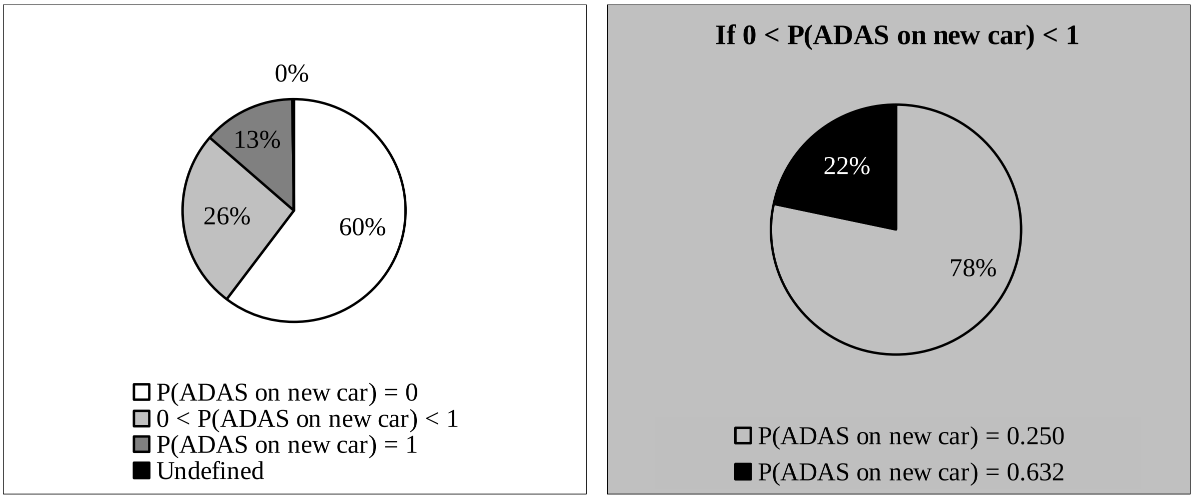


Figure 9.19: Distribution of probability of ADAS on a new car – insurance companies apply premium reduction, conservative strategies

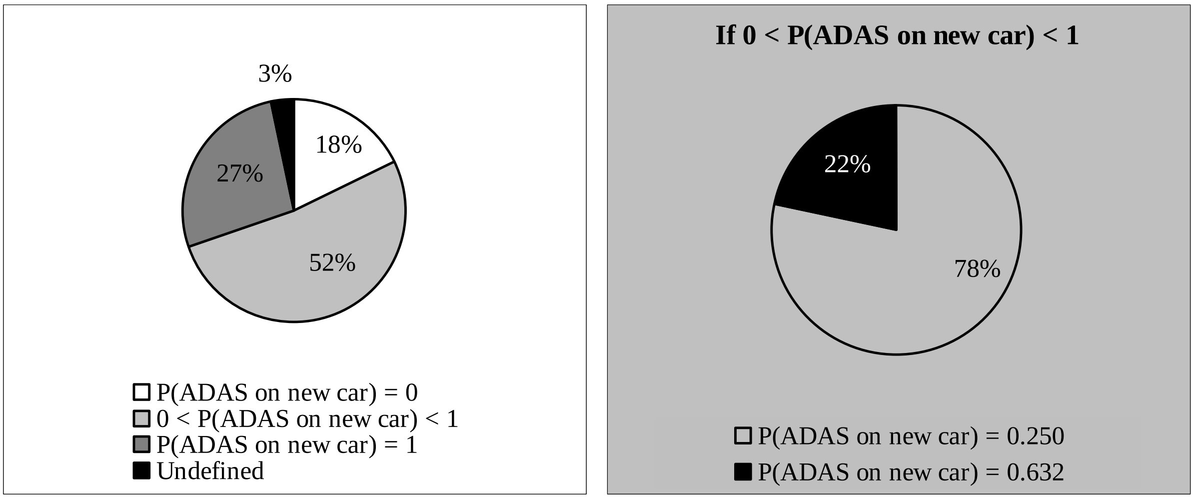


Figure 9.20: Distribution of probability of ADAS on a new car – insurance companies apply premium reduction, progressive strategies

9.4.8 Overall results

By means of simulations, based on models of actor and user decision-making regarding ADAS deployment, the probability of deployment scenarios based on actors' interactions, and the outcomes were explored of these deployment scenarios in terms of the probability that users will buy an ADAS.

In the reference case, in which the starting condition was that all actors do nothing, and no interaction between the actors takes place, it was found that different strategies of the automotive industry and insurance companies have a large effect on the probability that ADAS will be deployed, ranging between 39% and 79%. The actors expect that ADAS will be provided as an option, and if so, the probability that users will buy an ADAS on their next new car is about 0.163 – 0.250.

The effect of a 1,500 euros tax reduction applied by public authorities, as opposed to doing nothing, is expected to be large, and influences the deployment actions of both automotive industry and users. The probability that ADAS will be provided as an option as a result is stable across strategies, ranging between 42% and 52%. In addition, if provided as an option, the probability that users will buy an ADAS on their next new car is expected to increase from 0.163 when doing nothing, to 0.500 when applying a 1,500 euros tax reduction.

The effect of the automotive industry applying ADAS as an option, on the probability that users will buy an ADAS on their next new car, is expected to be about 0.163 – 0.250. It can be argued that a conservative strategy of insurance companies will prevail, and thus the expectation is that the probability is around 0.163.

The effect of a 25% premium reduction applied by insurance companies, as opposed to doing nothing, is expected to be relatively small. Other actors are not influenced by the actions of insurance companies, and if ADAS is provided as an option, it is expected that the probability that users will buy an ADAS on their next new car will increase from 0.163 when doing nothing, to 0.250 when applying a 25% insurance premium reduction.

9.5 Discussion

The outcomes of the simulations are influenced by known and unknown uncertainties, which were previously acknowledged in 9.2.3. This uncertainty was partly dealt with here by presenting the outcomes as probability distributions over possible outcomes, and by running simulations for extremely conservative, and extremely progressive, strategies of the automotive industry and insurance companies. Other uncertainties, related to the fact that stated preference data were used as an input to the model, were not straightforwardly dealt with in the simulations and the presentation of their results. However, the types of questions that were used to collect the data – in which the respondents had to make a trade-off between alternative deployment actions – were expected to limit the potential bias related to stated preference experiments (see Section 9.2.3). To increase confidence in the results, it may be recommended to perform a sensitivity analysis on these. This point is not addressed further in this dissertation.

9.6 Conclusions

9.6.1 Conclusions regarding the simulations

The results of the simulations show an average probability of 69% that ADAS are going to be deployed.

The results of the simulations show the probability that ADAS are going to be deployed is between 39% and 82%, depending on whether the automotive industry applies a conservative or a progressive strategy. Assuming that the sample of automotive industry respondents is representative with respect to strategies, the results show an average probability that ADAS are going to be deployed of 69%.

With a 1,500 euros tax reduction on purchasing ADAS equipment by public authorities, uncertainty regarding ADAS deployment as an option is decreased

The effect of a 1,500 euros tax reduction applied by public authorities, as opposed to doing nothing, influences the deployment actions of both the automotive industry and users. If public authorities are doing nothing, the results of the simulations show that the probability that the automotive industry deploys ADAS as an option is between 26% and 52%, depending on the strategy of the automotive industry. When public authorities apply a 1,500 euros tax reduction, this probability is more stable across strategies: between 42% and 52%.

If ADAS are going to be provided as an option, the results of the simulations show that the probability users will buy an ADAS on their next new car is about 0.163
The results of the simulations show that it is most likely that ADAS will be provided as an option, and if so, the probability that users will buy an ADAS on their next new car is 0.163 – 0.250 (and 0.255 – 0.371 for the Safe Driving Assistant). This probability is influenced by the strategy of insurance companies, and since a conservative strategy of insurance companies is likely to prevail (see Chapter 7), it is expected that the probability will be about 0.163.

With a 1,500 euros tax reduction by public authorities, this probability might increase to 0.500
As a result of the effect of a 1,500 euros tax reduction applied by public authorities, as opposed to doing nothing on users, the results of the simulations show that the probability that users will buy an ADAS on their next new car increases from 0.163 when doing nothing, to 0.500 when applying a 1,500 euros tax reduction, if ADAS are provided as an option.

With a 25% premium reduction by insurance companies, this probability might increase to 0.250
The effect of a 25% premium reduction applied by insurance companies, as opposed to doing nothing, is relatively small. Other actors are not influenced by the actions of insurance companies, and if ADAS is provided as an option, the results of the simulations show that the probability that users will buy an ADAS on their next new car increases from 0.163 when doing nothing, to 0.250 when applying a 25% insurance premium reduction.

9.6.2 Relevance of the results for ADAS deployment

Expectations regarding ADAS deployment
The findings once again underline the importance of the automotive industry as the main actor driving ADAS deployment. The results show it is expected that the probability that ADAS are going to be provided as an option, and eventually installed on about 15% of all new vehicles, is high, but there is still a lot of uncertainty involved.

Public authorities are not expected to play a big role, but if they should do so, applying a tax reduction on ADAS can have large effects on the probability that ADAS are going to be deployed, and on the probability that users will buy an ADAS on their next new car. Depending on the effects they want to achieve, and the contribution of ADAS to these effects, public authorities may want to reconsider their position regarding ADAS deployment. Here, a 1,500 euros tax reduction is considered; lower reductions will logically result in smaller probabilities.

The relatively small effects of insurance premium reductions add to the earlier conclusion, that insurance companies are not expected to play an important role in ADAS deployment. Their potential influence on, and interest in, the deployment rate of ADAS may be too small. That does not mean that they will not sell any insurance policies in combination with ADAS, but this may be limited to applications that are specifically interesting for insurance companies.

Remaining questions
The results ask some interesting questions relevant to future research about the development of the deployment rate, and the relation between the deployment rate and the effectiveness of ADAS.

From deriving insights into the probability that users will buy an ADAS on their next new car, the next question concerns what this probability means for the development of the deployment rate of the ADAS. While ADAS are expected to have positive effects for an individual driver, positive effects on traffic relate to the amount of vehicles equipped with an ADAS, represented by the deployment rate. In order for public authorities to potentially apply a tax reduction, it is necessary to have information on what deployment rate can be reached in which amount of time. The probabilities that users will buy an ADAS on their next new car can be used to make such calculations.

Next to the deployment rate, it is necessary to have knowledge about the relation between the deployment rate and the effects on traffic. For example, traffic simulations show that a Congestion Assistant is already effective on travel time at a deployment rate of 10%, but twice as effective at a deployment rate of 50% (Van Driel and Van Arem, 2008). With regard to the Speed Assistant, or Intelligent Speed Adaptation, the relationships between deployment rate and accidents were often assumed in studies, but apart from studies assuming a difference between a 0% and a 100% deployment rate (e.g. Carsten and Tate, 2005), studies on the effectiveness of intermediate deployment rates were not found.

Furthermore, given the heterogeneity found among users, the types of drivers that are among the first adopters of the ADAS, may influence the effectiveness of ADAS at lower deployment rates.

10 Conclusions and recommendations

What are the main findings of this dissertation, and what are its scientific and societal contributions? This chapter gives an overview of the research in this dissertation, and summarizes the main conclusions on actors' interactions in ADAS deployment. Furthermore, it discusses the scientific contributions, and the implications of the results for ADAS actors. We then reflect on the validity of the research outcomes, the methodology to investigate actors' interactions, and choices made in empirical research. Finally, some suggestions are made for further research.

10.1 Overview of research

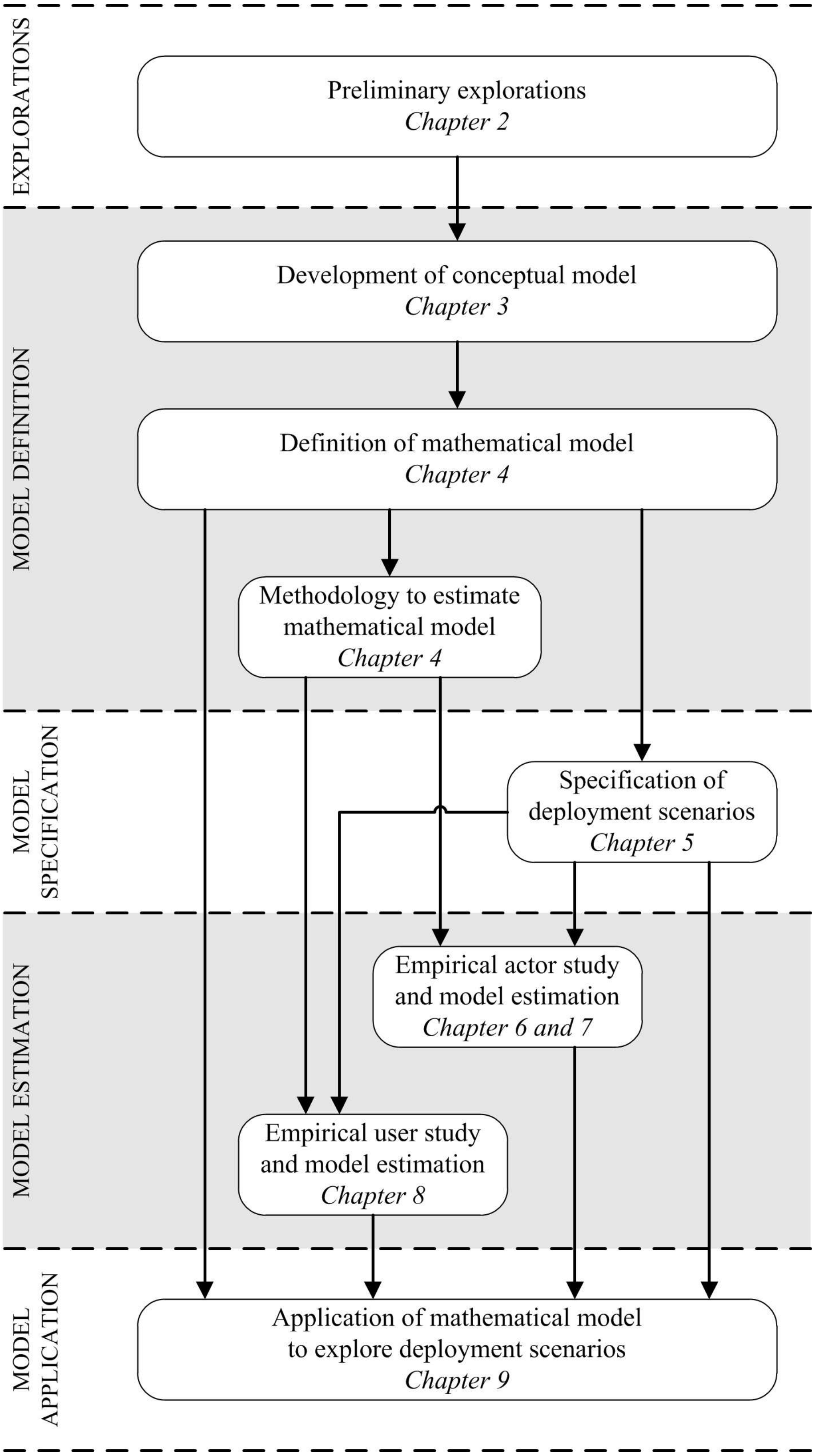


Figure 10.1: Research approach

10.1.1 Research approach

The approach used to answer the research questions of this dissertation is represented in Figure 10.1. It commences with some *preliminary explorations,* in order to increase knowledge on actor positions regarding ADAS deployment, their deployment options, and their decision criteria. The reflections on the results of these explorations led to insights about actors' interactions in ADAS deployment. These insights, literature on technological innovations, and several assumptions on actors' interactions, have been used to develop a *conceptual model* of actors' interactions in ADAS deployment. This conceptual model featured the interactions between public authorities, the automotive industry, insurance companies, and users. The conceptual model was translated into a *mathematical model*, consisting of an overall stochastic model of the interactions, and underlying mathematical models for individual actor and user decision-making. Alongside this, a *methodology* was developed to estimate the mathematical model, based on Stated Preference modeling. A number of *deployment scenarios* were then specified, that were to be explored by means of the mathematical model. The deployment scenarios acted as an input to an *actor study* and a *user study*. Empirical data were collected on actor and user decision-making regarding ADAS deployment, by means of questionnaires. Based on the data from the actor and user studies, the underlying mathematical models of actor and user decision-making were estimated. These models provide the necessary input to *explore deployment scenarios,* by means of application of the stochastic model of actors' interactions in ADAS deployment.

10.1.2 Model of the system of actors' interactions in ADAS deployment

Research question 1a: What conceptual model can describe the system of actors' interactions in ADAS deployment?

In this dissertation, ADAS deployment is conceptualized as a system of actors' interactions, in which the main actors are public authorities, the automotive industry, insurance companies and users. Supported by the relevant literature, and some preliminary explorations (see Chapter 2), a conceptual model of this system was developed (see Figure 10.2, left).

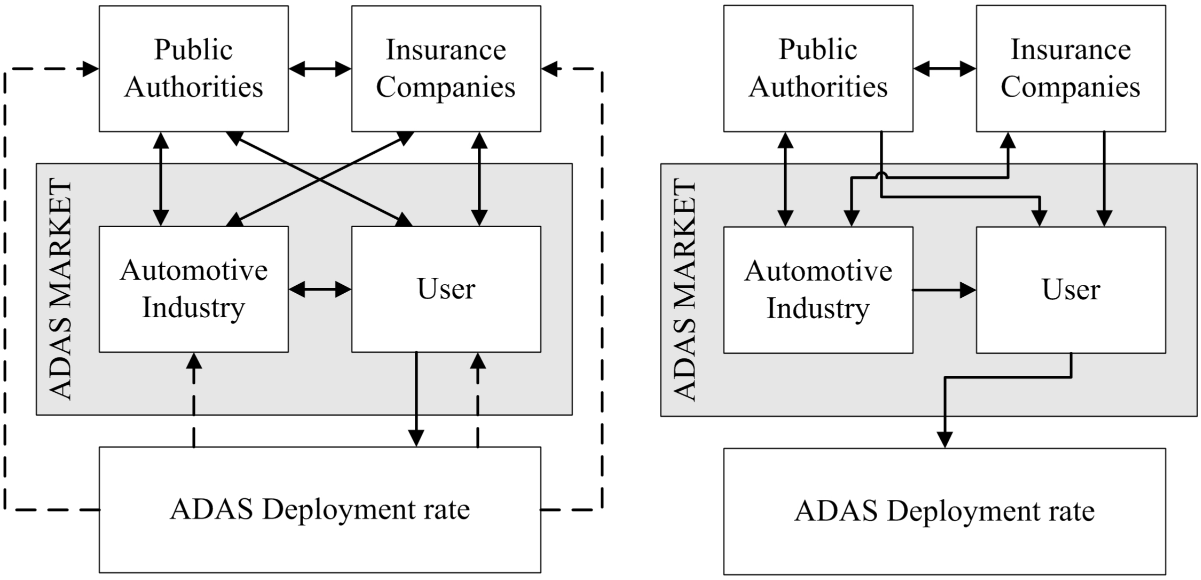


Figure 10.2: Theoretical conceptual model (left) and investigated conceptual model (right) of actors' interactions in ADAS deployment

For the empirical studies, the conceptual model was simplified by removing the feedback from the deployment rate, and the influence of user decisions on the actors (see Figure 10.2, right). With this conceptual model, initial deployment actions of the actors, and the reaction of the user – in terms of buying or not buying an ADAS – could be investigated, on the presumption that the current deployment rate of ADAS is very small.

In addition, underlying conceptual models of individual actor and user decision-making were defined. For actors, these conceptual models represent their choice for a deployment action, given the deployment actions already taken by other actors, and the ADAS to which they apply. Actor decision-making was conceptualized, based on bounded rationality, with respect to their beliefs of the impacts of their deployment actions. For users, the conceptual model represents their choice options to buy or not buy an ADAS, given the deployment actions taken by actors that apply to that ADAS. User decision-making was conceptualized as rational in terms of the decision process, but with attitude, affect, motives and choice influencing the outcomes of the decision process.

Research question 1b: How can this conceptual model be described in mathematical expressions?

The conceptual model of actors' interactions in ADAS deployment was mathematically represented by a stochastic model, in which the deployment scenario – consisting of the deployment actions of all actors – and the choice of the user to buy or not buy an ADAS, were included as stochastic variables. The underlying models of actor and user decision-making were translated in mathematical models that evaluate the utility or probability of a deployment action, as a function of the deployment scenario.

10.1.3 Methodology to estimate the model of actors' interactions in ADAS deployment

Research question 2: How can the mathematical model of actors' interactions in ADAS deployment be estimated?

In order to apply the model designed to explore deployment scenarios, and based on current expectations of actors and users, the probabilities of actors' deployment actions, and the probability that users will buy an ADAS on their next new car, need to be known. Since future actions are considered, there are no data available on current probabilities. Consequently, is was decided to collect empirical data by means of a Stated Preference survey on actors' expectations regarding potential ADAS deployment actions, and on users' reactions to these deployment actions.

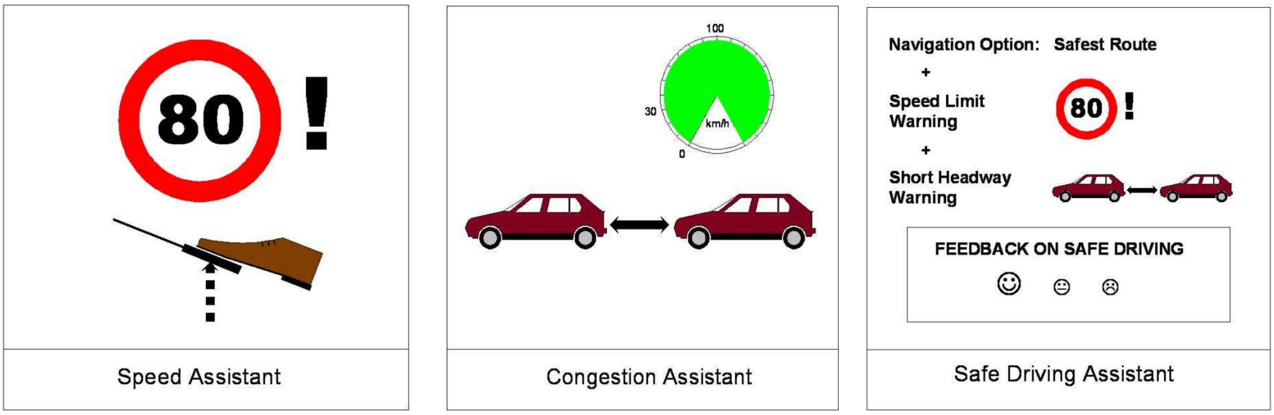
The actor survey included a conjoint measurement task for the respondents, in which they were asked to indicate the probability that a certain deployment option would be applied by their actor group, given the deployment actions of other actors, and the ADAS to which they would be applied. Consequently, the questions were different from those for respondents from public authorities, the automotive industry, and insurance companies. Based on the resulting data, additive probability models (based on additive utility models, using probabilities instead of utility ratings as data) were estimated for all actor groups, using multiple linear regression.

The user survey included a conjoint measurement task for the respondents, in which they were asked to indicate whether they would buy an ADAS or not, given the deployment actions of the actors, and the type of ADAS to which they are applied. Based on the resulting data, a binomial logit model was estimated, using logistic regression.

10.1.4 Empirical studies on actor and user decision-making regarding ADAS deployment

Research question 3a: Which potential actor deployment actions, and which ADAS, are relevant, given the current state of ADAS deployment?

In the empirical studies, three ADAS were included that are eligible for deployment in the near future, and for which it was expected that one of the actors would take the lead: public authorities for the Speed Assistant, the automotive industry for the Congestion Assistant, and insurance companies for the Safe Driving Assistant (see Figure 10.3).



Speed Assistant

Congestion Assistant

Safe Driving Assistant

Figure 10.3: ADAS included in investigation

For each of the actors, three potential deployment options were considered, one ‘do nothing’ option, one option stimulating users to buy ADAS, and one option forcing users to buy ADAS (see Table 10.1). In cases where the automotive industry does nothing, or forces the user to buy an ADAS by providing it as a standard option, the user has nothing to choose. The same holds true when public authorities or insurance companies force the user to buy an ADAS. Consequently, in the user survey, only the stimulating options were considered, specified to fit the user perspective (see Table 10.2).

Table 10.1: Actors’ deployment options included in actor survey and simulations

Type	Public authorities	Automotive industry	Insurance companies
Do nothing	Do nothing	Do nothing	Do nothing
Stimulating deployment	1,500 euros tax reduction	ADAS optional on new vehicles	Optional 25% premium reduction
Forcing deployment	Mandate ADAS on all vehicles	ADAS standard on new vehicles	Standard 25% premium reduction

Table 10.2: Actors’ deployment options as included in user survey

ADAS purchase cost	Insurance premium reduction
0 euros	0%
750 euros	25%
1,500 euros	50%

Research question 3b: What is the probability that an actor takes a certain ADAS deployment action, given the deployment actions of other actors?

Respondents from public authorities, the automotive industry, and insurance companies were invited to complete the actor survey, based on the networks of the researcher and colleagues. Of the invited respondents, 72 completed the questionnaire and were included in the analysis. The respondents from public authorities (20 respondents), and insurance companies (7), were mainly from the Netherlands, and the automotive industry (45) predominantly from other European countries. Furthermore, they had a varied background, and were quite familiar with ADAS.

The models estimated from the survey data generally show that the type of ADAS does not significantly influence the probability that actions will be taken to deploy it. Furthermore, they show that public authorities and the automotive industry are influenced by each others' deployment actions, but not by the deployment actions of insurance companies. The insurance companies are also not influenced by deployment actions of public authorities or the automotive industry. The average probability that the automotive industry is going to take action is high, as opposed to doing nothing. The average probability that public authorities and insurance companies will take action, as opposed to doing nothing, is small.

Based on certain patterns that were observed in the data, it was assumed that subgroups of respondents with different strategies exist. A strategy is defined here as a specific distribution of probability over the available deployment options. Subgroups were identified, based on a cluster analysis. For the automotive industry, three strategies were identified, which can be characterized by the extent to which they are expected to take action, and the extent to which they can be influenced by public authorities' deployment actions. The identified strategies for the automotive industry include the strategy of an *Active Deployer*, expected to take action without much influence of public authorities' deployment actions, the strategy of a *Reluctant Deployer*, not expected to take action until after deployment actions of public authorities, and the strategy of an *Adaptive Deployer*, expected to take action, and stimulated to do so even more by public authorities deployment actions. For insurance companies, two strategies were identified, characterized by the extent to which they are expected to take action. The identified strategies include that of an *Active Deployer*, expected to take action, and that of a *Non-Deployer*, not expected to take action. For public authorities, no distinct subgroups could be identified. Some explanations for the existence of the subgroups could be found in the familiarity of the respondents with ADAS, and their expectations regarding the impacts of the ADAS.

Research question 3c: What is the probability that users will buy an ADAS on their next new car, given the deployment actions of the actors?

Respondents of a traffic and transport panel were invited to complete the user survey, and 250 reactions were received. The model estimated from the survey data shows that the respondents prefer the Safe Driving Assistant to the other two ADAS, which is opposite to the expectation that they would prefer the Congestion Assistant. Possibly the Congestion Assistant and the Speed Assistant are less popular since they leave less freedom to the driver. Furthermore, the respondents' choice to buy an ADAS is substantially influenced by costs and premium reduction, which means that the financial incentives of public authorities, and to a lesser extent insurance companies, are potentially influential. In addition, it was shown that the respondents were more likely to buy an ADAS on a new car, than on their current car. The results showed a large amount of heterogeneity among the respondents to the survey, which could partly be explained by age, gender, mileage and car price. Since the respondents formed quite a representative group with respect to the Dutch society, the average probability that the respondents will buy an ADAS on their next new car could be used as the average for Dutch car buyers.

Application of the model: expectations regarding ADAS deployment
The results of the actor and the user survey were used to validate the structure of the model, i.e. either to confirm, or perhaps deny, the relations between the actors in the model. Since it was found that insurance companies and the other actors are not influencing each other, the relations between these actors were removed from the initial model (see Figure 10.4). The other relations in the model were confirmed by the results of the surveys.

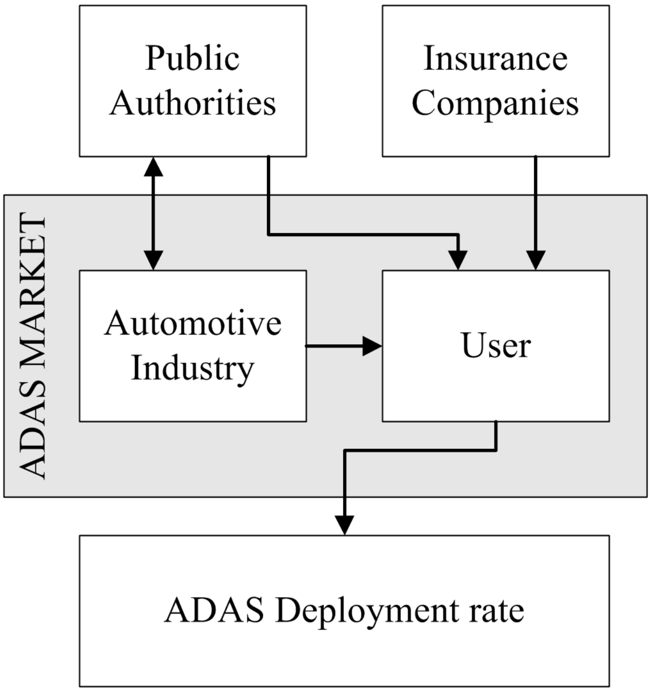


Figure 10.4: Updated model of actors' interactions in ADAS deployment

The stochastic model of actors' interactions in ADAS deployment was adjusted to these changes in the conceptual model. It was applied to explore various deployment scenarios under a number of specific starting conditions, and relate these to the reaction of the user. The starting conditions included initial deployment scenarios in which all actors do nothing, and in which one actor is taking action. Given each of these starting conditions, the probabilities that certain deployment scenarios will occur were determined, while using the actor models as input. The reaction of the users to these deployment scenarios was determined in terms of the probability that they will buy an ADAS on their next new car, using the user models as input.

For each of the starting conditions, the outcomes were presented as distributions over potential outcomes, with respect to the probability that users will buy an ADAS on their next new car. Furthermore, separate simulations were made in which the most extreme strategies of the automotive industry and insurance companies were combined, in order to get an overview of the range of possible outcomes, depending on the strategies. The main findings were that it is expected that the automotive industry is taking the lead in ADAS deployment. However, subgroups with different strategies were identified among the automotive industry respondents, one of which is not expected to take the lead. Furthermore, the influence of public authorities in terms of tax reductions can be substantial, since the automotive industry and users are expected to react in a positive way for ADAS deployment.

10.2 Main findings

The automotive industry is expected to take the lead in ADAS deployment
Of the three actors that were considered – public authorities, the automotive industry, and insurance companies – the automotive industry is expected to be the first to apply deployment options that will stimulate, or even force, users to buy an ADAS. These findings apply to the types of ADAS that were considered in this dissertation, which typically need to be integrated in vehicles when they are built, and are supporting the driver, but not completely taking over the driving task. There is as yet no evidence on whether the findings also apply to other types of ADAS.

Public authorities have a large potential influence on ADAS deployment
While public authorities are not expected to take initial action, their potential influence on ADAS deployment is expected to be large. Not only could they mandate the equipment of cars with ADAS, the results also show that tax reductions can have a large positive influence on the expectations that the automotive industry is going to take action, and that users will buy an ADAS on their next new car. This expected effect of tax reductions is comparable with experiences in Denmark with a tax reduction on Electronic Stability Control (ESC). A tax reduction made the rate of new cars being equipped with ESC increase from 30% to 90% between 2003 and 2008 (ETSC, 2009b). However, since ESC has less impact on normal driving than ADAS, these figures are not likely to be matched by ADAS. Nevertheless, they do support the apparent validity of the influence of a tax reduction.

Insurance companies are not expected to become a main actor in ADAS deployment
Although insurance companies were expected to take action by the respondents, additional analysis emphasized that these expectations needed to be given nuances. The subgroup of respondents that expected insurance companies to take action was found not to be very familiar with ADAS, but expecting very positive impacts. On the other hand, the subgroup of respondents who expected insurance companies not to take action was found to be familiar with ADAS, but not expecting positive impacts. Consequently, it is assumed that insurance companies can be expected not to take action over time, at least not with respect to the type of ADAS considered in this dissertation. However, since insurance premium reductions do increase the probability that users will buy an ADAS, insurance companies may be interested in promoting the use of ADAS types that fit the specific company interests.

Different opinions on ADAS deployment strategies exist among actors
Subgroups of respondents with different strategies were identified among the automotive industry and insurance companies’ respondents. These subgroups differ in the probability that they are expected to take action, and in their reaction to public authorities’ actions. An explanation for the existence of different subgroups among the automotive industry respondents is that different networks exist within the automotive industry, with a different attitude towards ADAS deployment. An explanation for the existence of different subgroups for insurance companies is that they have different levels of experience with ADAS (see the finding above). Apart from this finding, the differences between the subgroups could, generally, not be explained by the respondent characteristics collected by the survey. No subgroups were identified among public authorities’ respondents. This may be due to the fact

that the respondents were mainly from the Netherlands. Public authorities from different countries may have different strategies, due to differences in the transport problems these countries are facing, and differences in the general role of public authorities in these countries.

There is a large heterogeneity among users regarding the choice to buy an ADAS
The utility that users derive from choosing to buy an ADAS is significantly influenced by the price of the ADAS and insurance premium reductions. There is a large heterogeneity among these results that can be partly attributed to age, gender, mileage, price of the car, and whether ADAS are purchased on a new or on a current car. Yet other aspects that were not included could explain this heterogeneity, such as general attitudes towards innovations.

The results of the analyses in this dissertation correspond with general observations
Many of the results in this dissertation show a picture of ADAS deployment that largely corresponds to what is generally expected. The results in this study provide added value in that they clearly outline to what extent actors will take action or not, and whether and how they can be influenced to do so. This finding indicates that the model is producing realistic results, and can therefore be considered for further, perhaps more detailed, research. However, the input information might have been optimistic.

10.3 Scientific contribution

The main scientific contributions of this dissertation include the development of a conceptual model of actors' interactions in ADAS deployment, the development of a mathematical model of these interactions, the methodology to investigate actors' interactions, the findings regarding the role of insurance companies, and the identification of different strategies.

The focus on ADAS deployment actions contributes, since prior research has mainly focused on ADAS technology options, which is a necessary first step, but the combination with deployment actions gives more detailed knowledge on the expectations regarding ADAS deployment. The development of a mathematical model of actors' interactions in ADAS deployment contributes, since prior research has used different conceptual models of decision-making, which were found not to fit the specific case of ADAS deployment. In addition, a mathematical model of the type of conceptual model of actors' interactions in ADAS deployment assumed in this dissertation, was not yet available. The methodology to investigate actors' interactions contributes by showing how these interactions can be empirically studied using Stated Preference modeling, and what types of results can be expected. The findings about the role of insurance companies contribute, since their role has not yet been investigated with respect to ADAS deployment. While they have an influence on user adoption of ADAS, their influence on public authorities and the automotive industry is negligible. Finally, the identification of different strategies contributes to science by showing how these strategies can be revealed using quantitative data on actor actions and interactions in ADAS deployment.

10.4 Societal contribution: implications for actors

Electronic driving aids for road vehicles, also called "Advanced Driver Assistance Systems," or ADAS, are a promising means to contribute to an increase in traffic safety and traffic flow efficiency, and a decrease in environmental pollution. To fulfill this promise, many vehicles need to be equipped with these ADAS, since the deployment rate determines success for a large part. The research project described in this dissertation studied the expected deployment actions of public authorities, the automotive industry, insurance companies, and car users, which could influence the rate of vehicles equipped with ADAS. The implications of the outcomes of this research project for public policymaking are discussed below.

The automotive industry is expected to take the lead in ADAS deployment
It was found that the automotive industry is expected to take the lead by providing ADAS as an option for new cars. Public authorities and insurance companies are, generally, expected not to be the first to take action. This means that ADAS will probably be deployed without further interference of public authorities, and that improvement of traffic safety and traffic flow efficiency could be achieved by means of the market. However, it has to be taken into account that the types of ADAS that will be brought to the market by the automotive industry will principally be increasing comfort, and only secondly safety, for individual users. It is uncertain whether these types of ADAS all have the same positive effect on traffic safety and traffic flow efficiency as systems that may be less marketable. Furthermore, the automotive industry usually starts deployment of ADAS on luxury models, while cheaper cars could in some circumstances benefit even more from ADAS (compare, for example, with the case of electronic stability control). In conclusion, while the automotive industry will probably take the lead, public authorities might monitor the market, and possibly take action, when the market deployment of those ADAS that are particularly effective on traffic safety, or traffic flow efficiency, are not developing at the desired speed.

Influence of public authorities is potentially large
It was found that although public authorities are not expected to take the lead, the influence of their deployment actions is potentially large. Not only do they possess the potential to mandate equipment of cars with ADAS, but also to apply reductions on car purchase taxes. These can have a substantial effect on ADAS deployment. The analysis in this dissertation shows, for instance, that when a tax reduction of 1,500 euros is applied by public authorities, the probability that the automotive industry is going to sell a certain ADAS increases from approximately **0.7** to **0.8**, and the probability that users will buy this ADAS on their next new car increases from **0.15** to **0.5**. In conclusion, applying tax reductions to stimulate ADAS deployment can be a very effective means in terms of an increase in ADAS deployment rate. It has to be ascertained, however, that such an increase in ADAS deployment has a substantially positive impact on traffic safety and/or traffic flow efficiency, in order to justify investments in tax reductions.

The automotive industry consists of subgroups with different strategies regarding ADAS deployment
It was found that within the automotive industry, subgroups with different strategies may be present. These strategies differ with respect to the probability that they will take action, and the extent to which they are influenced by public authorities’ deployment actions. They can be characterized as the strategies of *Active Deployers*, *Reluctant Deployers*, and *Adaptive Deployers*. This finding confirms that the automotive industry (here: car manufacturers) cannot be considered as a single actor in ADAS deployment. No specific characteristics that could explain the different strategies were identified by the data collected. An explanation might be the existence of different networks within the automotive industry, with different opinions or philosophies towards car driving in general (e.g. regarding safety or freedom of driving).

Users are very heterogeneous with respect to buying an ADAS on their next new car
The probability that users will buy an ADAS on their next new car was found to be strongly influenced by factors such as age, gender, mileage, and price of the car. In addition, it is expected that further factors, such as attitudes towards technology, play a role. As a result, ADAS deployment actions will not have the same influence on all users, and different actions may be necessary to stimulate different target groups to adopt ADAS.

10.5 Reflection

10.5.1 Validity

Does the model of actors' interactions in ADAS deployment produce valid outcomes, in the sense that they correspond with reality? That question cannot be answered by validating the results with actual reported data, since these data are not yet available. Instead, the external validity of the overall outcomes of the research is considered by a reflection on the validity of the conceptual model, and the validity of the methodology that was applied. The validity of the conceptual model depends on the selection of its elements, and the relations between them. In addition, the validity of the methodology depends on the definition of the Stated Preference models and the stochastic model (see Figure 10.5).

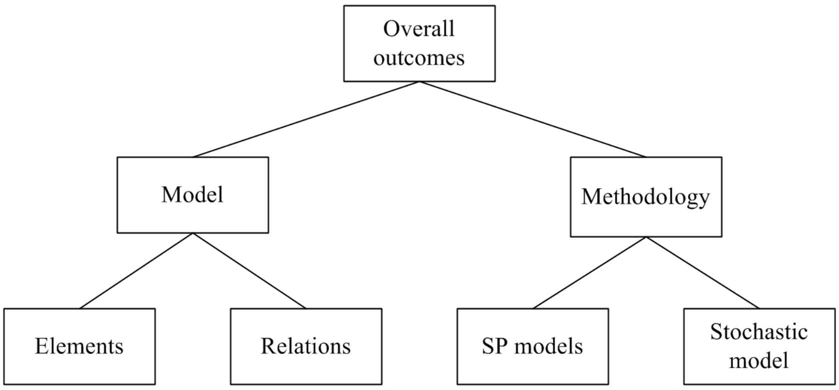


Figure 10.5: Research components that influence the external validity of overall outcomes

Validity of the conceptual model
The *elements* of the conceptual model – public authorities, the automotive industry, insurance companies, users, and the deployment rate – were chosen as the set of most relevant elements, i.e. the most important elements in influencing ADAS deployment. Some elements were deliberately not included in the conceptual model, such as external forces (e.g. economic and demographic developments, crucial events), and other actors, such as interest groups. This implies that the model is at least valid in situations in which these elements are not subject to major changes.

A number of *relationships* between the elements were explicitly considered. The data from the empirical actor and user studies were used to estimate the magnitude of these relationships, and also to confirm the existence of these relationships. Consequently, the mutual influence was confirmed between public authorities and the automotive industry, and also the influence on users of public authorities, the automotive industry, and insurance companies. However, the mutual influence was denied of insurance companies on the one side, and public authorities and the automotive industry on the other side. As a result of the empirical validation, there is confidence in the structure of the conceptual model.

Validity of the methodology
The *stated preference models* were estimated, based on data collected from respondents representing real actors, and a representative sample of Dutch car users. This is a prerequisite for optimal applicability of the models used. However, the bias related to stated preference data (i.e. people are found to overstate the economic value of alternatives) might have caused too optimistic expectations regarding ADAS deployment. On the other hand, the method of questioning might have limited this bias. The actors were asked to give a probability distribution over possible deployment actions, and thus were forced to make a trade-off between alternatives. This may have discouraged overstating certain alternatives. The users were not asked for a stated value but for a choice, which is found to be less prone to optimism bias (Murphy et al., 2005).

The number of respondents from which data were collected was limited. This is partly due to the limited number of potential respondents, and the difficulty to find them, but also to the difficulty to find respondents with a certain amount of knowledge about ADAS, which was particularly the case for insurance companies. A larger number of respondents would have been desirable, especially from insurance companies, in order to increase confidence in the results. However, these are difficult to find, and as a result, research like this will have to manage with low numbers of respondents.

The *stochastic model* is fully based on the conceptual model, and so the same considerations regarding validity apply to the model. Furthermore, the considerations regarding the applicability of the input data from the stated preference models apply.

In conclusion
The overall outcomes of the research were found to point in a direction that is intuitively likely, i.e. they have high apparent validity. There is also confidence in the conceptual model, of which the assumed relationships were validated with empirical data. However, the results may to a certain extent be relatively optimistic about ADAS deployment, given that they are valid in situations where there are no major changes in factors that are external to the model. The results can also be biased by the inevitably low number of respondents. In addition, the data collected were a ‘snapshot’ in a limited time window, and opinions of respondents may change over time.

10.5.2 Methodology

The main methodological challenge was in collecting the empirical data on actor decision-making, regarding ADAS deployment actions. The methodology used was aimed at collecting data to estimate a probability model, by means of conjoint analysis. The questions that were asked as a result of this approach were experienced as difficult, as reported by some colleagues and respondents who completed a pilot questionnaire. The key question is whether the questionnaire was the main reason for this difficulty, or if ADAS deployment, and particularly interacting with the other actors, also explains part of the difficulty. The fact that many of the comments were made by respondents from insurance companies, supports the latter conclusion. Consequently, if interactions in ADAS deployment are difficult matters in themselves, answering questions about these matters cannot be expected to be easy.

In summary, the methodology used to investigate the actors has succeeded in deriving the necessary data on their interactions with the other actors, but brings along substantial difficulties for the respondents in completing the related questionnaire. For future research with this model, the questionnaire set-up should not be more complicated than the one used here, and may need some redesign. If a substantially larger number of respondents per actor group is available, a choice-based questionnaire can be set up, which is assumed to be less difficult to answer.

10.5.3 Influence of choices made in the empirical studies

How have the choices made in the empirical studies of this dissertation influenced the results, and how does this influence the extent to which the results can be generalized? In this section, the choices are reflected upon for type of ADAS, actors, deployment options, and the Netherlands as a case study.

One of the findings was that, particularly for the actors, the influence of the ADAS-type on the probability that they would apply a deployment option is small, and not statistically significant. Both choices made regarding the types of questioning, and the types of ADAS included, could have been of influence. In the questionnaire, it was deliberately decided not to present the respondents with the impacts of the ADAS, but to ask the respondents for their expectations regarding the impacts, assuming bounded rationality. Their expected impacts of the ADAS on safety, throughput, environment, and user acceptance, were comparable and quite positive. However, in not presenting the ADAS impacts to the respondents, this may have led to underestimation of the influence of ADAS on utilities and probabilities. The reasons for this underestimation could be that the attention of the respondents was predominantly being drawn to the deployment options of other actors. Furthermore, the respondents’ expectations regarding the ADAS impacts were very similar across the ADAS. The choice for the specific ADAS in this dissertation was mainly driven by the idea they should be comparable in terms of interference with normal driving, and should contain certain aspects regarding impacts and acceptance that make them specifically of interest to each one of the actors. Since it is expected that ADAS have different impacts on traffic, the findings of this dissertation cannot be generalized to all ADAS, but may apply only to ADAS that have positive effects on traffic, and are still acceptable for car users. In future surveys, information on the impacts of ADAS could be given to respondents, in order to further explore the influence of ADAS on the choice for deployment actions.

In the choice for actors to be included in the model, it was decided to focus on individual car buyers who own the majority of the cars on the road, and exclude commercial fleet owners from the empirical research. The latter can still influence a substantial proportion of cars on the road (approx. 30% in the Netherlands; CBS, 2010). Since fleet owners probably have different objectives, it is expected that they make different choices than individual users when buying cars. As a result, the finding with respect to the probability that users will buy an ADAS on their next new car, is not representative for all decision-makers that can adopt ADAS on their vehicles. In future surveys, fleet owners could be included, in order to obtain the complete picture with respect to the expected deployment rate of ADAS.

As a result of the methodology chosen, the set of deployment options included in this dissertation was quite basic (i.e. only three per actor group). Particularly in the case of the stimulation options, there are many more options available than were included in the questionnaire. The question is whether the particular choice of stimulation options has very much influenced the analysis results. It could be argued that the stimulation option selected for the automotive industry – offering ADAS as an option – is not so much a stimulation option, but rather a required option for all other options to take effect. This may explain the finding that the probability that the automotive industry is taking action is relatively high, i.e. the threshold for the other actors to stimulate deployment is probably higher. The distribution over the deployment options selected in this dissertation could give an indication of the distribution over ‘do nothing’, ‘stimulation’, and ‘forcing’ options in general. At the same time, the results can certainly not be generalized for all possible stimulation options. Thus future surveys should further refine the picture by studying different stimulation options.

The empirical studies in this dissertation were focused on the Netherlands, including respondents from Dutch public authorities and insurance companies, and a panel of Dutch car drivers. The question is whether these results can be generalized to other countries. First of all, the respondents from the automotive industry represented different countries, and were not asked to specifically confine their answers to the Dutch situation. Consequently, their results can be generalized for other (European) countries. With respect to public authorities, differences with regard to culture, society, and transport problems experienced, may influence their decisions. This means that the results could only be generalized to countries that are similar to the Netherlands in these aspects. The same holds for car users, and possibly also for insurance companies. For other countries, empirical data needs to be collected.

10.6 Further research

10.6.1 Exploring further applications of the model

Since it was found that the current model structure leads to plausible results with respect to the expected deployment actions of actors, it can be used for further explorations. These could include estimation of the model based on empirical data from other countries, integration of other important actors like fleet owners, and application of the model for more consecutive deployment scenarios, based on a more extensive data sets. Furthermore, the study described in this dissertation could be repeated, in order to observe dynamics in actor expectations over time.

10.6.2 Increasing knowledge on actor decision-making to take ADAS deployment actions

Based on several findings in this dissertation it is recommended to increase knowledge on the following issues:

Firstly, to increase the knowledge about possible dynamics in actor strategies, it is recommended to further investigate the assumed relation between familiarity with ADAS, expected ADAS impacts, and expected deployment actions. This could be achieved by, for instance, longitudinal research in which these factors are monitored over time. Knowledge about these dynamics can be used to obtain more detailed forecasts of ADAS deployment.

Secondly, to increase knowledge on further development of ADAS deployment, following the initial deployment actions, the influence could be investigated of the current deployment rate on actor deployment actions. This could be achieved by including the deployment rate, as an attribute of the deployment scenarios.

10.6.3 Increasing knowledge with regard to the effects of ADAS deployment actions

In order to increase knowledge on actor decision-making to take ADAS deployment actions, further knowledge on the effects of ADAS deployment actions is essential.

It was found that there is limited knowledge about the effects of ADAS at different deployment rates. Most of the available knowledge is on Adaptive Cruise Control and the Congestion Assistant (e.g. Van Driel and Van Arem, 2008; VanderWerf et al., 2002;

Hoogendoorn and Minderhoud, 2001). Studies of the effects of Intelligent Speed Adaptation usually consider the difference between 0% and 100% penetration, in order to assess the potential (e.g. Carsten and Tate, 2005). Knowledge of the relation between the deployment rate of ADAS, and its effects, are important for actors to consider, so that deployment actions can be aimed at attaining a certain deployment rate. In addition to increasing the number of simulation studies on this aspect, it is also recommended to proceed with field studies, in order to collect evidence on the effects of different deployment rates of ADAS.

In addition, knowledge is needed on how deployment rates develop based upon, amongst others, the initial probability that users will buy an ADAS on their new car, which was one of the outcomes of this research project. Existing models on user adoption of (technological) innovations may be applied to answer this question, using the initial probabilities as input.

Finally, the effectiveness of ADAS may depend on the type of car drivers who use it, and as such it is worth investigating what types of drivers are amongst the people that are the early adopters of ADAS, since this may influence the relationship between the deployment rate and effectiveness. For example, if the first adopters are among people who have a relatively low annual vehicle mileage (see Chapter 8), the effectiveness may be lower than average, and higher penetration rates may be necessary to attain the objectives. This could be investigated by developing a user survey that includes specific variables that characterize the stage in deployment in which a user is likely to adopt an innovation, and analyze the relation between these characteristics, and variables such as annual vehicle mileage.

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Appendix A: Revised models of utilities and probabilities of actors’ deployment actions

Table A.1: Public authorities' overall utilities to take ADAS deployment actions (statistically significant attributes only)

PUBLIC AUTHORITIES	**Do nothing**		**Tax reduction**		**Mandate**	
Overall utilities	coeff	*sig*	coeff	*sig*	coeff	*sig*
Constant	4.783	*0.000*	4.406	*0.000*	2.850	*0.000*
ADAS						
Speed Assistant	-0.283	*0.055*	0.000	-	0.350	*0.007*
Congestion Assistant	0.000	-	0.000	-	0.000	-
Safe Driving Assistant	0.283		0.000		-0.350	
Industry action						
Do nothing	-0.567	*0.008*	0.644	*0.015*	0.650	*0.001*
Option	-0.400	*0.028*	0.744	*0.008*	0.350	*0.013*
Standard	0.967		-1.389		-1.000	
R Square	0.924		0.959		0.966	

Table A.2: Public authorities' overall probabilities in (%) to take ADAS deployment actions (statistically significant attributes only)

PUBLIC AUTHORITIES	**Do nothing**		**Tax reduction**		**Mandate**		**Other**	
Overall probabilities	coeff	*sig*	coeff	*sig*	coeff	*sig*	coeff	*sig*
Constant	62.333	*0.000*	20.000	*0.000*	8.161	-	9.506	-
Industry action								
Do nothing	0.000		0.000		0.000	-	0.000	-
Option	-10.208	*0.002*	7.542	*0.002*	0.000	-	0.000	-
Standard	10.208		-7.542		0.000		0.000	
R Square	0.769		0.777		-		-	

Table A.3: The automotive industry's overall utilities to take ADAS deployment actions (statistically significant attributes only)

AUTOMOTIVE INDUSTRY	Do nothing		Option		Standard	
Overall utilities	coeff	*sig*	coeff	*sig*	coeff	*sig*
Constant	1.926	*0.000*	5.704	*0.000*	5.442	*0.000*
Authorities' action						
Do nothing	1.055	*0.001*	0.000	-	-1.897	*0.009*
Tax reduction	0.000	-	1.370	*0.000*	0.000	-
Mandate	-1.055		-1.370		1.897	
Insurance action						
Do nothing	0.475	*0.037*	-0.403	*0.056*	0.000	-
Option	0.000	-	0.000	-	0.000	-
Standard	-0.475		0.403		0.000	
R Square	0.876		0.921		0.957	

Table A.4: The automotive industry's overall probabilities in (%) to take ADAS deployment actions (statistically significant attributes only)

AUTOMOTIVE INDUSTRY	Do nothing		Option		Standard		Other	
Overall probabilities	coeff	*sig*	coeff	*sig*	coeff	*sig*	coeff	*sig*
Constant	19.576	*0.000*	43.543	*0.000*	34.004	*0.000*	2.877	-
Authorities' action								
Do nothing	12.622	*0.001*	5.010	*0.042*	-18.138	*0.000*	0.000	-
Tax reduction	0.000	-	10.680	*0.002*	-8.044	*0.000*	0.000	-
Mandate	-12.622		-15.690		26.182		0.000	
R Square	0.793		0.919		0.993		-	

Table A.5: Insurance companies' overall utilities to take ADAS deployment actions (statistically significant attributes only)

INSURANCE COMPANIES	Do nothing		Option		Standard	
Overall utilities	coeff	*sig*	coeff	*sig*	coeff	*sig*
Constant	3.016	*0.000*	5.032	-	4.447	-
ADAS						
Speed Assistant	0.358	*0.014*	0.000	-	0.000	-
Congestion Assistant	0.000		0.000	-	0.000	-
Safe Driving Assistant	-0.358		0.000		0.000	
Authorities' action						
Do nothing	0.794	*0.001*	0.000	-	0.000	-
Tax reduction	-0.496	*0.007*	0.000	-	0.000	-
Mandate	-0.299		0.000		0.000	
R Square	0.928		-		-	

Table A.6: Insurance companies' overall probabilities in (%) to take ADAS deployment actions (statistically significant attributes only)

INSURANCE COMPANIES	Do nothing		Option		Standard		Other	
Overall probabilities	coeff	*sig*	coeff	*sig*	coeff	*sig*	coeff	*sig*
Constant	47.302	-	28.572	-	16.668	-	7.462	-
R Square	.-		-		-		-	

Appendix B: Revised models of utilities and probabilities of actors' deployment actions by subgroup

Public authorities

Table B.1: Public authorities' utilities to take ADAS deployment actions – Passive Deployers (statistically significant attributes only)

PUBLIC AUTHORITIES	**Do nothing**		**Tax reduction**		**Mandate**	
Utilities Cluster 1	coeff	*sig*	coeff	*sig*	coeff	*sig*
Constant	5.463	*0.000*	3.426	*0.004*	1.414	*0.000*
ADAS						
Speed Assistant	-0.193	*0.035*	0.000	-	0.350	*0.040*
Congestion Assistant	0.293	*0.016*	0.000	-	0.000	-
Safe Driving Assistant	-0.100		0.000		-0.350	
Industry action						
Do nothing	-0.253	*0.021*	0.000	-	0.438	*0.017*
Option	-0.280	*0.017*	0.000	-	0.000	-
Standard	0.533		0.000		-0.438	
Insurance action						
Do nothing	0.293	*0.016*	0.000	-	0.000	-
Option	-0.403	*0.008*	0.000	-	0.000	-
Standard	0.110		0.000		0.000	
R Square	0.995		-		0.744	

Table B.2: Public authorities' utilities to take ADAS deployment actions – Deployment Champions (statistically significant attributes only)

PUBLIC AUTHORITIES	**Do nothing**		**Tax reduction**		**Mandate**	
Utilities Cluster 2	coeff	*sig*	coeff	*sig*	coeff	*sig*
Constant	3.950	*0.000*	5.606	-	4.606	*0.000*
ADAS						
Speed Assistant	0.000	-	0.000	-	0.350	*0.001*
Congestion Assistant	0.000	-	0.000	-	0.000	-
Safe Driving Assistant	0.000		0.000		-0.350	
Industry action						
Do nothing	-1.222	*0.007*	0.000	-	0.988	*0.000*
Option	0.000	-	0.000	-	0.618	*0.000*
Standard	1.222		0.000		-1.606	
Insurance action						
Do nothing	0.000	-	0.000	-	0.000	-
Option	0.000	-	0.000	-	-0.223	*0.003*
Standard	0.000		0.000		0.223	
R Square	0.673		-		0.998	

Automotive industry

Table B.3: The automotive industry’s utilities to take ADAS deployment actions – Active Deployers (statistically significant attributes only)

AUTOMOTIVE INDUSTRY	**Do nothing**		**Option**		**Standard**	
Utilities Cluster 1	coeff	*sig*	coeff	*sig*	coeff	*sig*
Constant	1.656	*0.000*	6.711	*0.001*	6.128	*0.000*
Authorities' action						
Do nothing	0.861	*0.000*	0.000	-	-1.728	*0.000*
Tax reduction	-0.356	*0.002*	0.000	-	0.306	*0.017*
Mandate	-0.506		0.000		1.422	
Insurance action						
Do nothing	0.500	*0.000*	0.000	-	-0.308	*0.010*
Option	0.000	-	0.000	-	0.000	-
Standard	-0.500		0.000		0.308	
R Square	0.985		-		0.989	

Table B.4: The automotive industry’s utilities to take ADAS deployment actions – Restrained Deployers (statistically significant attributes only)

AUTOMOTIVE INDUSTRY	**Do nothing**		**Option**		**Standard**	
Utilities Cluster 2	coeff	*sig*	coeff	*sig*	coeff	*sig*
Constant	4.222	*0.000*	3.222	*0.000*	3.978	*0.004*
Authorities' action						
Do nothing	3.167	*0.000*	0.000	-	-3.044	*0.000*
Tax reduction	0.000	-	1.967	*0.000*	-2.311	*0.000*
Mandate	-3.167		-1.967		5.356	
R Square	0.958		0.857		0.980	

Table B.5: The automotive industry's utilities to take ADAS deployment actions – Adaptive Deployers (statistically significant attributes only)

AUTOMOTIVE INDUSTRY	**Do nothing**		**Option**		**Standard**	
Utilities Cluster 3	coeff	*sig*	coeff	*sig*	coeff	*sig*
Constant	1.933	*0.002*	5.311	*0.000*	4.256	*0.000*
Authorities' action						
Do nothing	1.767	*0.023*	1.022	*0.007*	-2.883	*0.000*
Tax reduction	-0.900	*0.061*	2.822	*0.000*	0.000	-
Mandate	-0.867		-3.844		2.883	
Insurance action						
Do nothing	0.817	*0.053*	0.000	-	0.000	-
Option	0.000	-	0.000	-	0.000	-
Standard	-0.817		0.000		0.000	
R Square	0.852		0.976		0.932	

Table B.6: The automotive industry's utilities to take ADAS deployment actions – Option-prone Deployers (statistically significant attributes only)

AUTOMOTIVE INDUSTRY	**Do nothing**		**Option**		**Standard**	
Utilities Cluster 4	coeff	*sig*	coeff	*sig*	coeff	*sig*
Constant	0.000	-	7.056	-	0.000	-
R Square	-		-		-	

Table B.7 The automotive industry's utilities to take ADAS deployment actions – Standard-prone Deployers (statistically significant attributes only)

AUTOMOTIVE INDUSTRY	**Do nothing**		**Option**		**Standard**	
Utilities Cluster 5	coeff	*sig*	coeff	*sig*	coeff	*sig*
Constant	1.601	-	4.891	*0.000*	7.488	*0.000*
ADAS						
Speed Assistant	0.000	-	-0.353	*0.024*	-0.667	*0.041*
Congestion Assistant	0.000	-	0.000	-	0.000	-
Safe Driving Assistant	0.000		0.353		0.667	
Authorities' action						
Do nothing	0.000	-	0.362	*0.036*	-0.500	*0.100*
Tax reduction	0.000	-	0.819	*0.001*	0.000	-
Mandate	0.000		-1.181		0.500	
R Square	-		0.952		0.636	

Table B.8: The automotive industry’s probabilities in (%) to take ADAS deployment actions – Active Deployer (statistically significant attributes only)

AUTOMOTIVE INDUSTRY	Do nothing		Option		Standard		Other	
Probabilities Cluster 1	coeff	*sig*	coeff	*sig*	coeff	*sig*	coeff	*sig*
Constant	11.356	*0.002*	52.422	*0.000*	32.756	*0.000*	3.467	*0.000*
Authorities' action								
Do nothing	6.600	*0.056*	0.000	-	-13.733	*0.000*	0.000	-
Tax reduction	0.000	-	0.000	-	0.000	-	0.000	-
Mandate	-6.600		0.000		13.733		0.000	
Insurance action								
Do nothing	0.000	-	0.000	-	0.000	-	-1.133	*0.000*
Option	0.000	-	0.000	-	0.000	-	0.800	*0.002*
Standard	0.000		0.000		0.000		0.333	
R Square	0.428		-		0.932		0.909	

Table B.9: The automotive industry’s probabilities in (%) to take ADAS deployment actions – Reluctant Deployer (statistically significant attributes only)

AUTOMOTIVE INDUSTRY	Do nothing		Option		Standard		Other	
Probabilities Cluster 2	coeff	*sig*	coeff	*sig*	coeff	*sig*	coeff	*sig*
Constant	44.089	*0.000*	29.500	*0.000*	22.800	*0.000*	3.611	*0.002*
ADAS								
Speed Assistant	0.000	-	0.000	-	0.000	-	-0.917	*0.033*
Congestion Assistant	0.000	-	0.000	-	0.000	-	0.000	*0.000*
Safe Driving Assistant	0.000		0.000		0.000		0.917	
Authorities' action								
Do nothing	24.800	*0.000*	0.000	-	-16.900	*0.000*	-3.278	*0.001*
Tax reduction	0.000	-	11.667	*0.002*	-11.967	*0.000*	-2.444	*0.003*
Mandate	-24.800		-11.667		28.867		5.722	
Insurance action								
Do nothing	0.000	-	0.000	-	0.000	-	0.722	*0.083*
Option	0.000	-	0.000	-	0.000	-	-0.944	*0.044*
Standard	0.000		0.000		0.000		0.222	
R Square	0.920		0.754		0.987		0.993	

Table B.10: The automotive industry's probabilities in (%) to take ADAS deployment actions – Adaptive Deployer (statistically significant attributes only)

AUTOMOTIVE INDUSTRY	Do nothing		Option		Standard		Other	
Probabilities Cluster 3	coeff	*sig*	coeff	*sig*	coeff	*sig*	coeff	*sig*
Constant	15.611	*0.000*	35.389	*0.000*	48.333	*0.000*	0.000	-
Authorities' action								
Do nothing	15.500	*0.000*	17.611	*0.000*	-34.000	*0.000*	0.000	-
Tax reduction	0.000	-	17.778	*0.000*	-17.000	*0.000*	0.000	-
Mandate	-15.500		-35.389		51.000		0.000	
R Square	0.899		0.982		0.995		-	

Insurance companies

Table B.11: Insurance companies' utilities to take ADAS deployment actions – Active Deployers (statistically significant attributes only)

INSURANCE COMPANIES	**Do nothing**		**Option**		**Standard**	
Utilities Cluster 1	coeff	*sig*	coeff	*sig*	coeff	*sig*
Constant	1.733	-	6.067	-	5.511	-
R Square	-		-		-	

Table B.12: Insurance companies' utilities to take ADAS deployment actions – Non-Deployers (statistically significant attributes only)

INSURANCE COMPANIES	**Do nothing**		**Option**		**Standard**	
Utilities Cluster 2	coeff	*sig*	coeff	*sig*	coeff	*sig*
Constant	6.222	-	2.444	-	1.778	-
R Square	-		-		-	

Table B.13: Insurance companies' probabilities in (%) to take ADAS deployment actions – Active Deployer (statistically significant attributes only)

INSURANCE COMPANIES	**Do nothing**		**Option**		**Standard**		**Other**	
Probabilities Cluster 1	coeff	*sig*	coeff	*sig*	coeff	*sig*	coeff	*sig*
Constant	23.333	-	40.694	*0.000*	24.167	-	11.806	-
Authorities' action								
Do nothing	0.000	-	-6.528	*0.002*	0.000	-	0.000	-
Tax reduction	0.000	-	7.222	*0.001*	0.000	-	0.000	-
Mandate	0.000		-0.694		0.000		0.000	
R Square	-		0.862		-		-	

Table B.14: Insurance companies' probabilities in (%) to take ADAS deployment actions – Non-Deployer (statistically significant attributes only)

INSURANCE COMPANIES	**Do nothing**		**Option**		**Standard**		**Other**	
Probabilities Cluster 2	coeff	*sig*	coeff	*sig*	coeff	*sig*	coeff	*sig*
Constant	79.258	-	12.407	-	6.667	-	1.669	-
R Square	-		-		-		-	

Getting ADAS on the Road – Summary

The current level of traffic demand is exceeding the infrastructure supply in densely populated areas, such as the Randstad area in the Netherlands. This leads to problems in terms of traffic safety, traffic flow and the environment. New technologies, such as Advanced Driver Assistance Systems (ADAS), are promising means to help overcome these problems. To be effective, ADAS need to be installed in a substantial number of vehicles. The speed at which this will be achieved depends on the deployment actions of relevant actors with respect to ADAS – public authorities, the automotive industry, insurance companies, and users. Current knowledge about actors with respect to ADAS deployment is predominantly focused on public authorities and users. This knowledge is mainly limited to the preferences of these actors for alternative ADAS technologies; preferences for alternative deployment options for ADAS have rarely been studied. The positions of public authorities, automotive industry and users regarding ADAS are fairly well known, but it is uncertain what is the relation between these positions and the deployment actions these actors can be expected to take. As a consequence, the potential interactions between the actors' deployment actions have also yet to be studied.

Conceptual model

In this dissertation, ADAS deployment is conceptualized as a system of actors' interactions. A conceptual model of this system was developed, describing the relations between public

authorities, the automotive industry and insurance companies, and between these actors and the user. These relations represent the actions they can take that could influence the other actors' actions, and that eventually could influence the deployment rate of ADAS (see Figure 1). This conceptual model was developed to explore different deployment scenarios (i.e. combinations of deployment actions of public authorities, the automotive industry, and insurance companies), and the outcome of these deployment scenarios in terms of the users' choice to buy an ADAS in their next new car. Underlying models of actor and user decision-making, based on existing theories of human decision-making, serve as building blocks for this conceptual model.

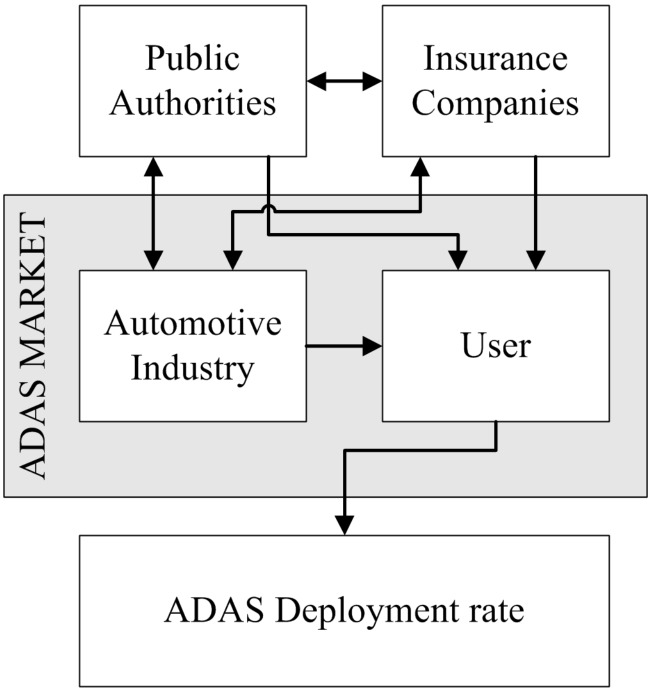


Figure 1: Conceptual model of actors' interactions in ADAS deployment

Methodology

The conceptual model adopted in this dissertation is at some points different from models that are assumed in common methodologies to study multi-actor decisions. The main difference is the explicit inclusion of the user reaction in the model. As a result, a customized methodology needed to be developed to study the system of actors' interactions in ADAS deployment. The conceptual model was translated into a stochastic model, in order to explore the probabilities of different deployment scenarios. The underlying models of actor and user decision-making were translated in mathematical models to evaluate the utility or probability of a deployment action, as a function of the deployment scenario. The mathematical models of actor and user decision-making were to be estimated based on stated preference data, collected by means of questionnaires. These estimated actor and users models were then to be integrated in the stochastic model.

Deployment scenarios

The deployment scenarios to be addressed were first specified. For each of the actors, three different options for taking deployment actions were defined, which include *doing nothing*, an option to *stimulate adoption of ADAS*, and an option to *force adoption of ADAS*. For users, the deployment scenarios were reflected by their influence on *ADAS purchase costs* and *insurance premium reduction*. The deployment scenarios were considered for a number of

ADAS, a *Speed Assistant*, a *Congestion Assistant*, and a *Safe Driving Assistant*. These ADAS were expected to be particularly interesting to be deployed for, respectively, public authorities, the automotive industry, and insurance companies.

Actor study and estimation of actor models
A questionnaire among actors to collect data to estimate the underlying actor models resulted in 45 respondents from the automotive industry, 20 from public authorities, and 7 from insurance companies. In this questionnaire, the respondents were asked to evaluate the utility they derive from each of their three deployment options, given the current deployment scenario and a certain ADAS. They were also asked to evaluate the probability that each of the deployment options will be applied by the actor group of which they are a member. From the resulting data, utility and probability models were estimated for each of the actors. In these models, the dependent variable is the utility or probability of a certain deployment option, and the independent variables are the current deployment scenario (i.e. deployment actions taken by other actors), and the ADAS.

The main conclusion that can be drawn from the resulting models is that the automotive industry and public authorities are the most important actors in ADAS deployment, and that the deployment actions of other actors have more influence on the utilities and probabilities of deployment actions than the ADAS types, which proved to be insignificant. The automotive industry is expected to take action first; which specific action depends on the action of public authorities. The probability that public authorities will take action is expected to be low, and relatively insensitive to what the automotive industry is doing. Insurance companies prove to be relatively insensitive to the actions of other actors, and the other actors are also insensitive with regard to the insurance companies' actions. The probability that they will take action is fairly low. All of these conclusions were drawn based upon the average utilities and probabilities over all respondents for the three actor groups. However, it was found that subgroups of respondents with different strategies regarding ADAS deployment are present within these actor groups.

Subgroups of respondents with different strategies
Subgroups of respondents with different strategies were identified by means of a cluster analysis, applied to the utility and probability data collected by means of the questionnaire. The results showed that the automotive industry is most heterogeneous with respect to taking ADAS deployment actions. This heterogeneity manifests itself in different preferences for deployment actions, and different susceptibility to influence of public authorities. This means that it can be expected that different parts of the automotive industry will show different strategies with regard to ADAS deployment. For public authorities, different subgroups were only identified based on the utility data. These subgroups differed mainly in their preference of deployment actions: one group preferred doing nothing, and another to take action. The same was found for insurance companies, based on the utility data as well as the probability data. Examining the background characteristics of the different respondents in the subgroups, it was found that insurance company respondents who expected an inactive role of insurance companies were relatively more familiar with ADAS than the subgroup that expected an active role. They also perceived the impacts of the ADAS as less positive. This could mean that when familiarity with ADAS increases in the future, insurance companies are not likely to play a part in ADAS deployment. Similar results were found for public authorities, but the effect was less strong than for insurance companies.

User study and estimation of user models

A questionnaire among potential users to collect data to estimate the underlying user models resulted in 250 respondents from a car users' panel. In this questionnaire, the respondents were asked to indicate whether or not they would buy an ADAS, given the deployment scenario and type of ADAS. From the resulting data, a choice model (logit) was estimated. In this model the dependent variable is the probability that users will buy an ADAS, and the main independent variables are the ADAS type, its costs, and its related insurance premium reduction. Further variables included in the model were age, gender, mileage, price of car, and whether the ADAS is purchased on a new car, or for the respondent's current car.

The results showed that the probability that users choose to buy a Safe Driving Assistant is higher than the probability that they would choose to buy a Speed Assistant or a Congestion Assistant. Possibly, users are more interested in informing systems than more intervening systems. The results of the user survey show that, if actors want to stimulate users' choice to buy an ADAS, applying a reduction on the purchase costs may prove to be more effective than a reduction on the monthly insurance premium. Finally, there is a large heterogeneity among users with respect to the utility they derive from buying an ADAS, which could only be partly explained by the respondents' age, gender, mileage, the price of their car, and whether the ADAS is purchased for a new car or their current car.

Application of the model

Based on the results of the actor and user studies, the conceptual model of actors' interactions in ADAS deployment was updated (see Figure 2). The relations initially assumed to exist between the insurance companies on the one hand, and public authorities and automotive industry on the other hand, were removed from the model, since they did not prove to be relevant from the research results. The stochastic model was simplified accordingly, and was applied to explore different deployment scenarios. The probability of different deployment scenarios was determined for several starting conditions (i.e. initial deployment scenarios), based on the results of the actor survey. The outcome of the deployment scenarios – the probability that users will buy an ADAS – was determined based on the results of the user survey.

The results show a probability of about 69% that ADAS are going to be deployed by some action of the automotive industry. If they provide ADAS as an option, for which the probability is about 45%, the probability that users will buy an ADAS is likely to be about 16%. Not all subgroups of automotive industry expect such a high probability that ADAS will be provided as an option, their expectations vary between 26% and 52%. Public authorities are not expected to play a big role, but if they would, applying a 1500 euros tax reduction on ADAS can have large effects on the deployment of ADAS. The expectations of the automotive industry subgroups converge; if a tax reduction is applied the probability that ADAS will be provided as an option vary between 42% and 52%. Furthermore, the probability that users are will buy an ADAS is likely to increase to 50% as a result of the tax reduction. The relatively small effects of insurance premium reductions add to the earlier conclusion that insurance companies are not expected to play an important role in ADAS deployment. That does not mean they will not introduce any insurance policies in combination with ADAS, but the types of ADAS for which these policies are developed are expected to be limited to applications that are specifically of interest for insurance companies.

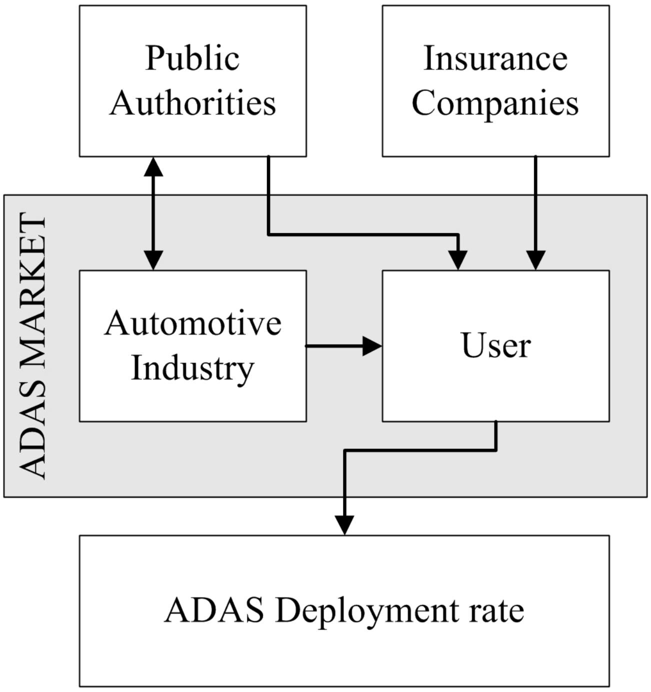


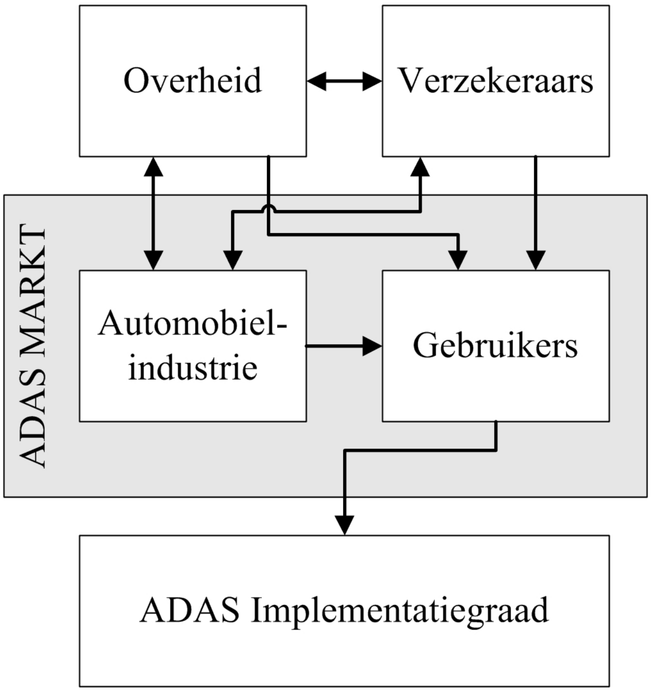
Figure 2: Updated conceptual model of actors' interactions in ADAS deployment

Op weg naar wegen met ADAS – Samenvatting

Het huidige niveau van de verkeersvraag overstijgt in dichtbevolkte gebieden, zoals de Randstad, het aanbod van de infrastructuur. Dit leidt tot problemen op het gebied van de verkeersveiligheid, de doorstroming van het verkeersnetwerk en het milieu. Nieuwe technologieën, zoals Advanced Driver Assistance Systems (ADAS), zijn veelbelovende middelen om deze problemen te helpen voorkomen. Om effectief te zijn moeten ADAS worden geïnstalleerd in een substantieel aantal voertuigen. De snelheid waarmee dit zal worden bereikt hangt af van de implementatie-acties van relevante actoren – de overheid, de automobielindustrie, verzekeringsmaatschappijen en gebruikers. De huidige kennis over actoren met betrekking tot de implementatie van ADAS is voornamelijk gefocust op de overheid en gebruikers. Deze kennis is grotendeels beperkt tot de preferenties van deze actoren met betrekking tot alternatieve ADAS technologieën. Preferenties met betrekking tot alternatieve implementatie-opties voor ADAS zijn zelden onderzocht. Over de standpunten van de overheid, de automobielindustrie en gebruikers ten opzichte van ADAS is betrekkelijk veel bekend, maar het is onzeker wat de relatie tussen die standpunten en welke implementatie-acties we van deze actoren kunnen verwachten. Logischerwijze zijn de interacties tussen de implementatie-acties van deze actoren ook nog niet onderzocht.

Conceptueel model

In dit proefschrift is de implementatie van ADAS geconceptualiseerd als een system van interacties tussen actoren. Een conceptueel model van dit systeem is ontwikkeld, en beschrijft de relaties tussen de overheid, de automobielindustrie en de verzekeringsmaatschappijen, en tussen deze actoren en de gebruiker. Deze relaties vertegenwoordigen de acties die de actoren kunnen ondernemen die invloed kunnen uitoefenen op de acties van andere actoren, en die uiteindelijk invloed kunnen uitoefenen op de implementatiegraad van ADAS (zie Figuur 1). Dit conceptuele model is ontwikkeld om verschillende implementatiescenario’s (i.e. combinatie van implementatie acties van de overheid, de automobielindustrie en de verzekeringsmaatschappijen) en de uitkomst van deze implementatiescenario’s, in de vorm van de keuze van de gebruiker om een ADAS op een nieuwe auto aan te schaffen, te kunnen verkennen. Onderliggende modellen van besluitvorming door actoren en gebruikers, gebaseerd op theorie over besluitvorming door mensen, dienen als bouwstenen voor dit conceptueel model.



Figuur 1: Conceptueel model van de interacties tussen actoren m.b.t. de implementatie van ADAS

Methodologie

Het conceptueel model dat is gebruikt in dit proefschrift verschilt op enkele punten van modellen die zijn aangenomen in gebruikelijke methodes om multi-actor beslissingen te bestuderen. Het belangrijkste verschil is dat de reactie van de gebruiker expliciet in het model is opgenomen. Als gevolg daarvan moest een passende methodologie worden ontwikkeld om het systeem van actor interacties met betrekking tot de implementatie van ADAS te kunnen bestuderen. Het conceptuele model is vertaald in een stochastisch model zodat de kansen van verschillende implementatiescenario's kunnen worden verkend. De onderliggende besluitvormingsmodellen voor actoren en gebruikers zijn vertaald in wiskundige modellen die het nut van of de kans op een implementatie-actie evalueren als functie van het implementatiescenario. Deze wiskundige modellen moesten worden geschat op basis van zogenaamde ‘stated preference’ data, verzameld door middel van vragenlijsten. De geschatte modellen moesten vervolgens worden geïntegreerd in het stochastische model.

Implementatiescenario's

De implementatiescenario's die moesten worden meegenomen in het onderzoek zijn vooraf gedefinieerd. Implementatiescenario's bestaan uit de implementatie-acties die door de actoren (de overheid, de automobielindustrie en de verzekeringsmaatschappijen) zijn ondernomen. Voor elk van de actoren zijn drie verschillende opties voor implementatie-acties gedefinieerd: *niets doen*, een optie voor het *stimuleren van ADAS adoptie*, en een optie voor het *forceren van ADAS adoptie*. Voor gebruikers zijn de implementatiescenario's weergegeven door middel van de *aanschafkosten voor ADAS* en *reductie op verzekeringspremie*. De implementatiescenario's zijn beschouwd voor een drietal verschillende ADAS: een *Snelheidsassistent*, een *Fileassistent* en een *Veilig Rijden Assistent*. Van deze ADAS werd verwacht dat ze met name interessant waren om te implementeren voor respectievelijk de overheid, de automobielindustrie en de verzekeringsmaatschappijen.

Actoronderzoek en schatten van actormodellen

Een vragenlijst uitgezet onder actoren om data te verzamelen voor het schatten van de onderliggende actormodellen resulteerde in 45 respondenten vanuit de automobielindustrie, 20 vanuit de overheid, en 7 vanuit verzekeringsmaatschappijen. In de vragenlijst werd de respondenten gevraagd om het nut dat zij ontlenen aan hun drie verschillende implementatie-acties, gegeven het huidige implementatiescenario en een zekere ADAS. Ze werden ook gevraagd om de kans aan te geven dat elk van de implementatie-acties zou worden ondernomen door de actor groep waar ze deel van uitmaken. Op basis van de resulterende data zijn nutsmodellen en kansmodellen geschat voor elk van de actoren. In deze modellen is de afhankelijke variabele het nut of de kans van een zekere implementatie-actie, en zijn de onafhankelijke variabelen het huidige implementatiescenario (bestaand uit de implementatie-acties die andere actoren hebben ondernomen) en de ADAS.

De hoofdconclusie die uit de resulterende modellen kan worden getrokken is dat de automobielindustrie en de overheid de belangrijkste actoren zijn, en dat de implementatie-acties van andere actoren meer invloed op de nutten en de kansen van implementatie-acties hebben dan de verschillende ADAS, die niet significant bleken te zijn. Van de automobielindustrie kan worden verwacht dat deze het eerst tot actie overgaat; het hangt af van wat de overheid doet welke specifieke actie zij zullen ondernemen. De kans dat de overheid daadwerkelijk actie onderneemt wordt verwacht laag te zijn, en relatief ongevoelig voor wat de automobielindustrie doet. Verzekeringsmaatschappijen blijken relatief ongevoelig te zijn voor de acties van de andere actoren, en de andere actoren zijn ook ongevoelig met betrekking tot hun acties. De kans dat verzekeringsmaatschappijen actie ondernemen is voorts betrekkelijk laag. Al deze conclusies zijn getrokken op basis van de gemiddelde nutten en kansen van de respondenten voor de drie actorgroepen. Het is echter vastgesteld dat er subgroepen van respondenten met verschillende strategieën ten aanzien van ADAS implementatie bestaan binnen de actorgroepen.

Subgroepen van respondenten met verschillende strategieën

De subgroepen van respondenten met verschillende strategieën zijn geïdentificeerd door middel van een clusteranalyse, toegepast op de nuts- en kansdata die verzameld was door middel van de vragenlijst. Op basis hiervan werd gevonden dat de automobielindustrie het meest heterogeen is met betrekking tot het ondernemen van implementatie-acties voor ADAS. Deze heterogeniteit manifesteert zich in de verschillende preferenties voor implementatie-acties, en de verschillende ontvankelijkheid voor de invloed van de overheid. Dit betekent dat kan worden verwacht dat, in eerste instantie, verschillende delen van de automobielindustrie verschillende strategieën zullen laten zien met betrekking tot ADAS implementatie. Voor de overheid konden alleen subgroepen worden geïdentificeerd op basis van de nutsdata. Deze subgroepen verschilden met name op hun preferenties voor implementatie-acties: een groep prefereerde niets doen, terwijl een andere groep prefereerde om actie te ondernemen. Hetzelfde werd gevonden voor verzekeringsmaatschappijen op basis van zowel de nuts als de kansdata. Uit het onderzoeken van enkele achtergrondkarakteristieken van de respondenten in de subgroepen bleek dat respondenten van verzekeringsmaatschappijen die een inactieve rol voor verzekeringsmaatschappijen verwachtten beter bekend waren met ADAS dan de subgroep die een actieve rol verwachtte. Ook schatten zij de effecten van ADAS minder positief in. Dit zou kunnen betekenen dat als de bekendheid met ADAS onder de verzekeringsmaatschappijen in de toekomst toeneemt, het niet waarschijnlijk is dat de verzekeringsmaatschappijen een rol spelen in de implementatie van ADAS. Vergelijkbare resultaten werden gevonden voor de overheid, maar het effect was hier minder sterk.

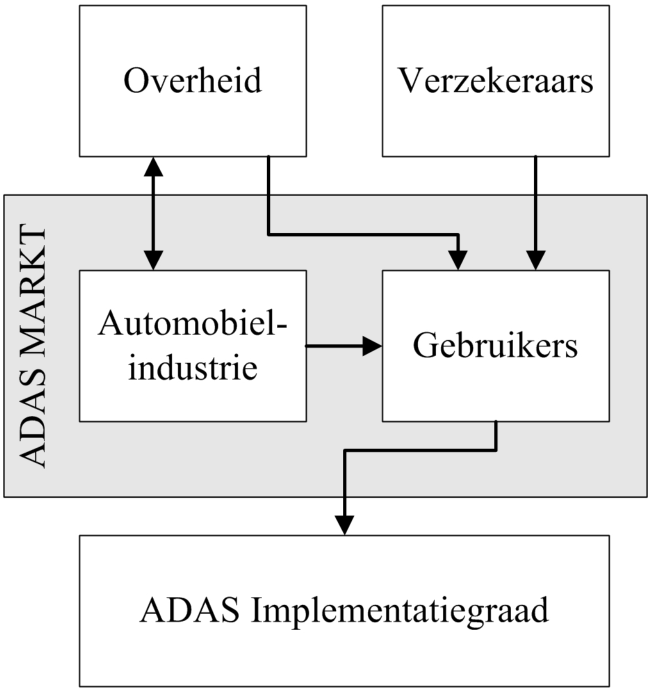
Gebruikersonderzoek en schatten van gebruikersmodellen

Een vragenlijst uitgezet onder potentiële gebruikers om data te verzamelen om de onderliggende gebruikersmodellen te schatten resulteerde in 250 respondenten uit een panel van autogebruikers. In deze vragenlijst werden de respondenten gevraagd aan te geven of zij wel of niet een ADAS zouden kopen, gegeven het implementatiescenario en het type ADAS. Op basis van de resulterende data werd een keuzemodel (logit) geschat. In dit model is de afhankelijke variabele de kans dat gebruikers een ADAS aanschaffen, en de belangrijkste onafhankelijke variabelen het type ADAS, de aanschafkosten en de gerelateerde reductie op de verzekeringspremie. Verdere variabelen die in het model zijn opgenomen zijn leeftijd, geslacht, het aantal kilometers dat jaarlijks wordt gereden, de aanschafkosten van de auto, en of de ADAS wordt aangeschaft voor een bestaande of op een nieuwe auto.

De resultaten laten zien dat de kans dat gebruikers een Veilig Rijden Assistent zullen aanschaffen hoger is dan de kans dat zij een Snelheidsassistent of een Fileassistent zullen aanschaffen. Mogelijk zijn gebruikers meer geïnteresseerd in informerende dan in interveniërende systemen. De resultaten van het gebruikersonderzoek laten zien dat, als actoren de keuze van gebruikers voor een ADAS willen beïnvloeden, het toepassen van een korting op de aanschafkosten wel eens effectiever kan zijn dan een reductie op de maandelijkse verzekeringspremie. Tenslotte is er een grote heterogeniteit wat betreft het nut dat gebruikers ontlenen aan het aanschaffen van een ADAS. Deze heterogeniteit kan slechts deels worden verklaard door de leeftijd en het geslacht van de respondenten, hun jaarlijks aantal kilometers, aanschafkosten van de auto, en of de ADAS wordt aangeschaft voor een bestaande of op een nieuwe auto.

Toepassing van het model

Gebaseerd op de resultaten van het actorenonderzoek en het gebruikersonderzoek is het conceptueel model van interacties tussen actoren met betrekking tot ADAS implementatie aangepast (Figuur 2). De relaties waarvan aanvankelijk werd aangenomen dat ze bestonden tussen de verzekeringsmaatschappijen aan de ene kant, en de overheid en de automobielindustrie aan de andere kant, zijn uit het model verwijderd omdat uit de onderzoeksresultaten bleek dat ze niet relevant waren.



Figuur 2: Aangepast conceptueel model van interacties tussen actoren m.b.t. de implementatie van ADAS

Het stochastisch model is op vergelijkbare wijze vereenvoudigd, en is toegepast om verschillende implementatiescenario's te verkennen. De kans op verschillende implementatiescenario's is bepaald voor een aantal verschillende startcondities (initiële implementatiescenario's), gebaseerd op de resultaten van het actorenonderzoek. De uitkomst van de implementatiescenarios's – de kans dat gebruikers een ADAS zullen aanschaffen – is bepaald op basis van de resultaten van het gebruikersonderzoek.

De resultaten laten zien dat wordt verwacht dat de kans rond de 69% is dat ADAS zullen worden geïmplementeerd door een implementatie-actie van de automobielindustrie. Als ze ADAS als optie aanbieden, waarop de kans 45%, is de kans dat gebruikers een ADAS aanschaffen waarschijnlijk rond de 16%. Niet alle subgroepen van de automobielindustrie verwachten een dergelijke hoge kans dat ADAS als optie zal worden aangeboden, hun verwachtingen variëren tussen de 26% en 52%. Van de overheid wordt niet verwacht dat ze een grote rol zal spelen, maar als ze dat wel doen kan het toepassen van een reductie van 1500 euro op de BPM grote effecten hebben op de implementatie van ADAS. De verwachtingen van de subgroepen van de automobielindustrie convergeren: als een belastingreductie wordt toegepast varieert de kans dat ADAS als optie zal worden aangeboden tussen de 42% en de 52%. Voorts is het waarschijnlijk dat de kans dat gebruikers een ADAS zullen aanschaffen toeneemt tot 50% als gevolg van de belastingreductie. De relatief kleine effecten van de reductie van de verzekeringspremie dragen bij aan de eerdere conclusie dat van de verzekeringsmaatschappijen niet worden verwacht dat ze een belangrijke rol spelen in de implementatie van ADAS. Hun potentiële invloed op, en belang bij de implementatie van ADAS zal daarvoor waarschijnlijk te klein zijn. Dat betekent niet dat ze in het geheel geen verzekeringspolissen in combinatie met ADAS zullen aanbieden, maar het type ADAS waarvoor deze polissen zullen worden ontwikkeld zullen naar verwachtingen beperkt zijn tot toepassingen die specifiek interessant zijn voor verzekeringsmaatschappijen.

About the author

Leonie Walta was born in Amsterdam on 10 September 1975. She followed the Dutch Preparatory Scientific Education at the Fons Vitae Lyceum in Amsterdam. After graduating in 1993, she studied for a bachelor degree in Civil Engineering at the Hogeschool Alkmaar. Her graduation project in construction engineering took place combined with an internship at BV Articon in Amersfoort, a company that became part of ARCADIS in 1998. After graduating in 1997 she was offered a job there as a Junior Designer, and worked for four years on the design and calculation of concrete structures as part of railway infrastructure. Driven by experiences and curiosity, she decided to quit this job in 2001 to do a master in Civil Engineering at the University of Twente, from which she graduated in 2004 on the deployment of cooperative vehicle-roadside systems. After a short break, she embarked on a PhD on the deployment of Advanced Driver Assistance Systems at the Transport and Logistics section of Delft University of Technology in 2005, of which this dissertation is the final result. Since 2009 she is appointed as a researcher at the Transport and Logistics section. Her current research interest is in the success and failure of transport innovations. Furthermore, she is involved in education as a teaching assistant and coordinator. In 2010 she was a visiting scholar at the Centre for Transport and Society at the University of the West of England for eight months, which broadened her scope as a transport researcher. Leonie likes outdoor endurance sports, such as running, skating, and rowing, and plays several musical instruments.

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