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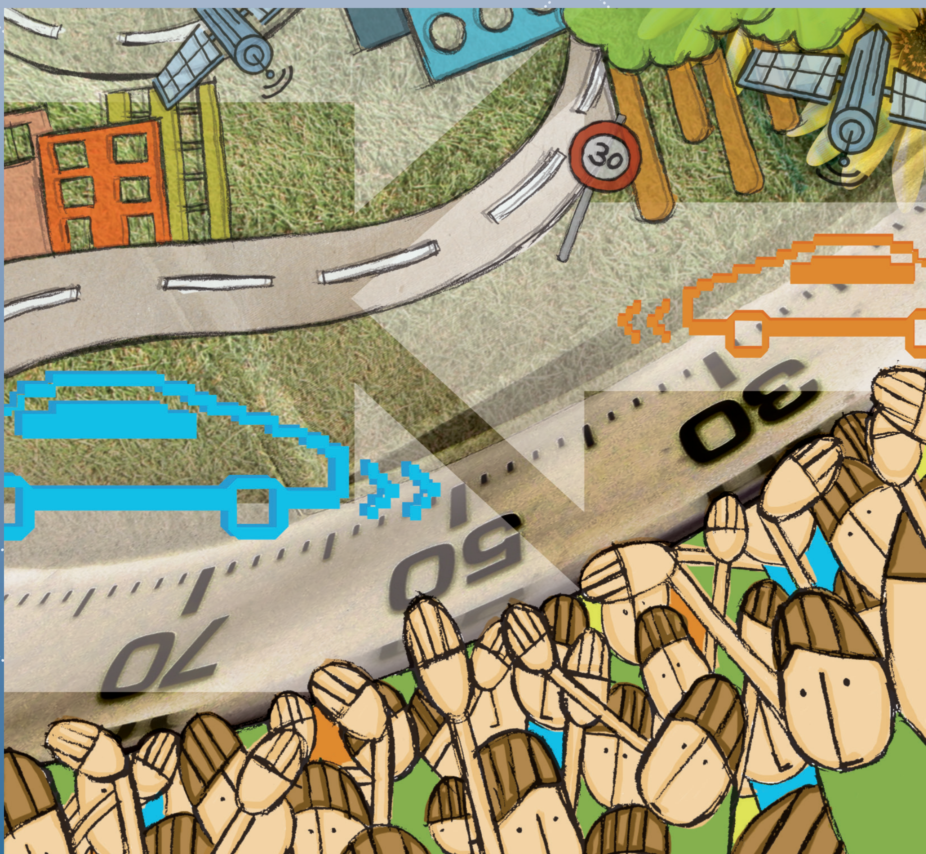
Sven Vlassenroot



The Acceptability of In-vehicle Intelligent Speed Assistance (ISA) Systems:

from Trial Support to Public Support

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Sven Vlassenroot

This PhD research project is a co-operation between Delft University of Technology, the Netherlands and Ghent University, Belgium.

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The Acceptability of In-vehicle Intelligent Speed Assistance (ISA) Systems: from Trial Support to Public Support

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ter verkrijging van de graad van doctor
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op gezag van de Rector Magnificus prof.ir. K.C.A.M. Luyben,
voorzitter van het College voor Promoties,
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door

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Voorwoord

In 2002 startte het eerste demonstratieproject rond het gebruik van intelligente snelheidsassistentie (ISA) in België. De start van deze trial betekende ook het begin voor mij in de wereld van mobiliteits- en verkeersveiligheidsonderzoek aan de Universiteit Gent. Ik had nog geen rijbewijs en zeer weinig ervaring in onderzoek, maar toch kreeg ik de opdracht om deze trial mee te organiseren, te coördineren en de analyse van het rijgedrag uit te voeren. Mijn eerste stap was dan ook eigen rijgedrag creëren en dus mijn rijbewijs behalen. Dit project bracht mij ook naar Zweden waar ik bij de 'uitvinder' van het actieve gaspedaal een tijdje in de leer kon. Geloof me, ISA systemen ontwikkelen en installeren was een echte ambacht. Daar groeide ook mijn interesse naar digitale (snelheids)kaartontwikkeling; een issue dat vandaag nog steeds brandend actueel is. Einde 2005 kregen we dan ook de opdracht om te onderzoeken of een snelheidskaart in Vlaanderen haalbaar was. In hetzelfde jaar begon ik ook mogelijkheden te zoeken om te kunnen promoveren omtrent het draagvlak voor ISA bij (potentiële) gebruikers. Dit bracht me naar Hasselt waarbij een samenwerking om te doctoreren tussen Universiteit Gent en Universiteit Hasselt werd opgezet. Dit werd echter na anderhalf jaar stopgezet. In 2007 kon ik mijn promotietraject verder afleggen aan de Technische Universiteit Delft (TUDelft) in samenwerking met de Universiteit Gent (UGent). Na ongeveer 10 jaar onderzoek naar diverse aspecten over ISA gebruik en implementatie is met dit proefschrift één hoofdstuk voor mij afgesloten. Het verhaal zelf is nog niet ten einde; de fascinatie en interesse voor intelligente transportsystemen, en in het bijzonder ISA, zijn er nog steeds.

ISA heb ik leren kennen via Johan De Mol. Bij hem is dan ook mijn academische loopbaan begonnen. Zijn expertise maar ook zij enthousiasme, vastberadenheid – soms tot het koppige toe – werkten inspirerend voor het maken van dit proefschrift. Ik dank hem voor zijn steun, medewerking en vriendschap tijdens de voorbije jaren. Mijn promotor Karel Brookhuis wil ik bedanken voor zijn kijk op het onderzoek met een gezonde dosis Groningse nuchterheid. Ooit stelde Karel dat hij enkel promotor wou zijn indien ik hem kon voorzien van het beste bier ter

wereld (uiteraard Belgisch). Deze voorwaarde werd dan ook voldaan en zo geschiede. Ik dank mijn 'Gentse' (in werkelijkheid Antwerpse) promotor Frank Witlox voor het steeds weer wetenschappelijk verfijnen van de papers en de vrijheid die hij mij gaf in het uitwerken van verschillende onderzoeksideeën (al dan niet relevant voor het proefschrift). Vincent Marchau dank ik voor de kans die hij mij gaf om aan de TUDelft te kunnen promoveren. Bij één van zijn bezoeken in Gent overhaalde hij mij om mijn promotietraject verder af te leggen aan de TUDelft. Hij stond ook steeds klaar om zowel zinnige en onzinnige commentaar en levenswijsheden mee te geven. Georges Allaert en Bert van Wee wil ik bedanken voor de mogelijkheden die zij gaven om deze interuniversitaire samenwerking te realiseren. Steven Broekx dank ik voor het analyse-klaar krijgen van de rijdata tijdens de trial. Enid Zwerts, Dimo Kavadias en Eric Molin dank ik voor de nodige statistische reflectie en ondersteuning. Jan-Willem van der Pas dank ik voor zijn kritische inbreng, leuke discussies tijdens conferenties en zijn kijk op ISA. Verder wil ik al mijn collega's bij beide universiteiten bedanken voor de fijne werk- en ontspanningsmomenten tijdens de voorbije jaren. Ik dank Sidharta Guatama voor de tijd die ik mocht vrijmaken om mijn proefschrift verder af te werken.

De stad Gent dank ik voor de mogelijkheden die ze boden om een ISA-proefproject op te zetten en te realiseren. Tijdens de ISA-trial in Gent, heb ik ook Sven Gustafsson, bezieler van het actieve gaspedaal, leren kennen. Ik wil hem graag bedanken voor de kennis die hij doorgaf en zijn gastvrijheid bij elk bezoek in Zweden. Maarten Matienko van de automobielvereniging VAB en Ton Hendriks van ANWB dank ik voor de hulp om de verspreiding van de survey op zo een grote schaal mogelijk te maken. Bijzondere aandacht vraag ik voor Eddy Wouters. Dankzij zijn geloof in nieuwe technologie voor het verbeteren van verkeersveiligheid werd ISA naar België gehaald. Helaas overleed Eddy enkele jaren geleden.

Naast de professionele loopbaan is er uiteraard nog een ander leven. Dankzij de steun van vrienden en familie was dit proefschrift niet mogelijk geweest. Ik wil mij alvast excuseren bij al mijn vrienden voor de 'verwaarlozing' van jullie tijdens de voorbije jaren. Ik hoop dit zo snel mogelijk recht te zetten.

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Freija dank ik voor het ontwerp van de coverillustratie. Als laatste wil ik mijn paranimfen Koen en Jan-Willem bedanken.

Sven Vlassenroot
Gent, mei 2011

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1 Introduction

In 2007, around 40 000 road fatalities were recorded across the European Union (EU). On average, more than 100 persons die every day on the EU road network. Also, in 2007 for the first time in years there was no reduction in the number of road fatalities in the EU (ETSC, 2008). In their white paper "European Transport Policies for 2010: Time to Decide", the European Commission stated that road fatalities should be reduced by 50% in 2010, compared with 2001. This target was not achieved.

One third of all road accidents are caused by speeding, inappropriate or excessive speed. Besides safety, speed also has effects on the environment (pollution, emissions, etc.) and the quality of life (insecurity, injuries, etc.). Therefore, tackling speeding is beneficial for our society.

Transport policymakers implement a variety of measures in order to tackle the problem of speeding, such as infrastructural solutions, enforcement (police controls, speed cameras, etc.), road signs, information and education, and the use of vehicle technology. Since too many people still die on the European roads, the question arises whether traditional measures are good enough to secure the safety of road users.

The European Commission (EC) stated in 2001 that the use of certain transport technologies (known as Intelligent Transport Systems (ITS)) can play a significant role in achieving a reduction of congestion, an increase in traffic safety, an increase in energy efficiency, and a reduction of dependence on fossil fuels (European Commission, 2001). Already, many ITS applications in the field of traffic management and travel information that are on the market have proven their effectiveness. These systems support transport system users, traffic managers, and fleet operators with traffic and travel information.

In December 2008, the EC took a major step towards the deployment and use of ITS. In the Action Plan on ITS, the EC (2008) suggested a number of targeted ITS measures and a proposal for a Directive laying down the framework for their implementation. The Action Plan stated that better use should be made of the newest active safety systems and Advanced Driver Assistance Systems (ADAS) with proven benefits in terms of in-vehicle safety for the vehicle occupants and other road users (including vulnerable road users). Advanced Driving Assistance Systems (ADAS) are systems that partially take over driving tasks such as distance keeping, lane keeping, overtaking, etc. Many research initiatives on a variety of ADAS technologies are currently being conducted at international, national, and regional levels. ADAS vary from relatively simple systems that provide drivers with basic information to relatively complex systems that take over parts of the drivers' tasks to achieve 'good' driving behaviour (Brookhuis & De Waard, 1999).

One of the most promising ADAS, aimed at reducing inappropriate speed, is Intelligent Speed Assistance (ISA). ISA is an intelligent in-vehicle device that warns the driver about speeding, discourages the driver from speeding, and/or prevents the driver from exceeding the speed limit (Brookhuis & De Waard, 1999; Morsink et al., 2006). Most ISA uses the Global Positioning System (GPS) and a digital speed limit database; the position of the vehicle is determined using a GPS receiver. The position is used to retrieve the speed limit or other information from a database. The information is then reported to the driver. ISA can use three types of limits: static speed limits (posted speed signs), variable speed limits (information about speed limits depending on the location), and dynamic speed limits (information based on actual road and traffic conditions). ISA devices can be divided depending on how intervening they are. An informative or advisory system displays the speed to remind the driver of the changes in speed levels. A warning or open system cautions the driver if the posted speed limit at a given location is exceeded; the driver then decides whether to use or ignore this information. An intervening, supportive, or half-open system gives a force feedback through the gas pedal if the driver tries to exceed the speed limit (like the active accelerator pedal). It is however still possible for the driver to overrule the counter-pressure initiated by the accelerator pedal. A mandatory, automatic control, restricted, or closed system will fully prevent the driver from exceeding the limit; hence, the driver cannot overrule the system.

Many research initiatives on different ADAS and ISA technologies have been conducted at the international, national, and regional levels. While most studies focus on the technological feasibility of ADAS and its expected impacts, the important question as to whether these new technologies will be accepted and used remains unanswered.

In this dissertation, the focus will be on the use of ISA as a possible speed management solution and under which conditions potential users would accept this technology. This should lead to better implementation strategies for policymakers.

1.1 The importance of support

This section describes the problem of conceptualizing the notion of acceptance and acceptability: how can acceptance and acceptability of ISA be defined and measured in relation to its policy goal (increasing road safety) and transport system framework (speed management).

To increase the chances of their policies being successful, policymakers will try to obtain widespread public support. Acceptance, acceptability, social acceptance, public support, social support, etc. are all terms frequently used to describe a similar phenomenon: how will (potential) users act and react if a certain measure or device is implemented? The interest in defining support can be seen in the light of a growing awareness that policymaking has to be considered as a two-way direction between the authorities and the public, in which interaction, transaction and communication are the key-elements (Nelissen & Bartels, 1998). This leads, in terms of road safety policy, to the assumption that the chance of succes of a measure will increase if there is public support. Public support for road safety will be reflected in positive valuation of road safety and support for measures that evidently increase road safety.

Van Meegeren et al. (2001) identified different components that would have an influence on public support (Figure 1-1). A positive valuation leads, under favourable conditions, to an increased willingness to accept a measure and even to support it actively. On the other hand, when a measure attracts opposition from a large group, there is the chance that this group will organize itself and will instigate a movement against the measure. So, the effect of the measure can be undermined.

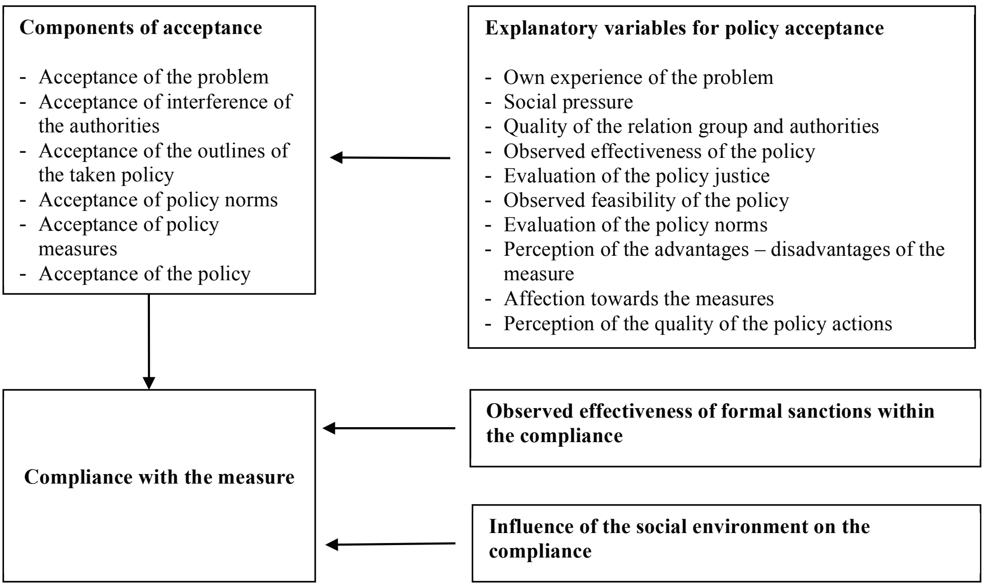

Figure 1-1. Components and explanatory variables of policy support

There is no good definition of what the term ‘public support’ means. In most cases ‘public support’ has been related to acceptability, commitment, legitimacy and participation (Goldenbeld, 2002). An important distinction that has been made is between political, policy, and social ‘support.’ To a certain extent, the terms acceptance and support are strongly related. Goldenbeld (2002), however, describes a nuance between support and acceptance. Acceptance can be available, but would not necessarily lead to the support of a measure. For example: it is possible for an individual to accept paying taxes, but (s)he would not necessarily support it. In this way, acceptance can be seen as a precondition for support.

In order to determine the support for a particular policy, or how the support is developing, measuring instruments are necessary. Via support measurement the underlying, determining opinions about the severity and magnitude of a problem, the expected effectiveness of the measures and opinions about the measure and possible alternatives can be made visible. In most research, the term 'support' is not used because of its vagueness. The terms 'acceptance' and 'acceptability' are mostly used in the context of defining, getting or creating support for a policy measure (Hedge & Teachout, 2000; Molin & Brookhuis, 2007).

Some authors (e.g. Molin & Brookhuis, 2007) state that there seem to be as many questionnaires as methods to measure acceptance and acceptability. In addition to the problems in finding the right approach for measuring acceptance or acceptability, the terms acceptance and acceptability are defined in different ways by different researches. In the field of ITS, Ausserer and Risser (2005) define acceptance as a phenomenon that reflects the extent to which potential users are willing to use a certain system. Hence, acceptance is closely linked to usage, and the acceptance will then depend on how user needs are integrated into the development of the system. Nielsen (cited in Young et al., 2003) described acceptability as the question of whether the system is good enough to satisfy all the needs and requirements of the users and other potential stakeholders. More generally, in Rogers' diffusion of innovations (2003), acceptability research is defined as the investigation of the perceived attributes of an ideal innovation in order to guide the research and development (R&D), to create such an innovation. Schade and Schlag (2003) make a clear distinction between acceptance and acceptability. They describe acceptance as the respondents' attitudes, including their behavioural responses after the introduction of a measure, and acceptability as the prospective judgement of something that should be introduced in the future. In the last case, the respondents will not have experienced any of the measures or devices in practice, which makes acceptability an attitude construct. Acceptance is then more related to user acceptance of a device. Van der Laan et al. (1997) distinguished user acceptance and social acceptance. User acceptance is more directed towards evaluation of the ergonomics of the system, while social acceptance is a more indirect evaluation of the consequences of the system. Related to the previous definition, social acceptance will be part of acceptability but user acceptance cannot be evaluated by ex-ante acceptability research.

1.2 Objectives and research method

The main objective of this dissertation can be describes as follows:

To define, analyse, and understand the acceptability of Intelligent Transport Systems (ITS) within the context of speed management in order to achieve an implementation of in-vehicle speed controlling technologies that has better public acceptability.

This overall objective has been translated into the following four research questions:

Q1. How can the use of ITS be beneficial for speed management?

The benefits of ITS for speed management is studied by conducting a literature review of the reported effects of speed and speeding on road safety, the environment, and the quality of life, and how the negative effects of speed can be tackled by the use of environmental, behavioural and technological measures. Based on this study, Intelligent Speed Assistance (ISA) stands out as being beneficial. A meta-analysis is then performed to describe the research on ISA; the development of ISA related technologies; the actors involved in the deployment of ISA and the status of the implementation of ISA. We then identify the users and potential users of ISA behavioural outcomes and users point of view. Research question Q1 is described in Chapter 2 and 3.

Q2. When ISA is used, what are the behavioural and attitudinal outcomes with respect to acceptance and adoption?

The behavioural and attitudinal outcomes with respect to acceptance and adoption are studied through a field operational test in which drivers used one type of ISA (supportive system). Data logging was used to analyse the driving behaviour, and a survey was held to gather the test drivers' attitudes and opinions on supportive ISA. This field trial led to the main question of this dissertation on what potential users would think about ISA. The results of this trial are presented in Chapter 4.

Q3. How can acceptability be defined and which factors influence acceptability?

Different theories, methods and studies are analysed to define acceptability and to identify the factors that could influence the degree of acceptability. A conceptual framework is described and tested by the use of a large-scale survey. This leads to a model that can be used for policymaking actions. The theoretical concept is given in Chapter 5. The descriptive results are presented in chapter 6 and the model is described in chapter 7.

Q4. How can the constructed acceptability framework contribute to the design of a better plan in the context of an integrated speed management policy?

The constructed and validated model provides indications of the aspects that will influence the acceptability of ISA by individuals the most. From a policy point of view these results would be useful to policymakers for constructing an acceptable and supported ISA implementation strategy. Implementation must always be seen within the speed management context. This is discussed in the final chapter.

1.3 Research scope

The focus of this research is on the acceptability of in-vehicle technology as a speed management policy, especially Intelligent Speed Assistance (ISA). The research includes a field trial and a large-scale survey. In the trial (held in 2003) only one type of ISA was used. The vehicles were equipped with the Active Accelerator Pedal (AAP). In the large-scale survey (2009), four types of ISA were explained and presented to the respondents: informative, warning, supportive and restrictive.

Only drivers (mainly drivers of passenger cars) were the target group of both the field trial and the survey. In the ISA-trial, drivers were only from Belgium (Ghent area), while the large-scale survey was held in Belgium (Flanders region) and the Netherlands. Passenger car-users were the main target group, because they are the largest group of drivers on the Belgian and Dutch network. Also car-owner organizations in Belgium and the Netherlands were used to distribute the survey.

Although the results are given from the ISA-trial in Ghent, the main focus of this research is on the acceptability of ISA by drivers who did not experienced driving with ISA. The results of the Ghent trial led to a discussion about the measurement and theory development with respect to acceptance and acceptability. Also the results of the Ghent trial need to be understood in their context and time frame: in 2002-2003 the use of navigation and computer technology in vehicles was at their starting point; in Belgium, not that much investments had been made on road safety and speed management; the ISA system that was used was still a prototype. Therefore a comparison between the trial and the large-scale survey is not made and cannot be made.

The main focus of this research is obtaining a better understanding of the different factors that would influence acceptability. Based on a variety of researches and methods a survey was developed. This survey represents the opinions, attitudes, and findings of drivers, who were members of the car owner organisations. This framework and method could be useful on other ITS topics, cross-cultural studies, method development, etc. These potentials are discussed in the last section of this dissertation.

1.4 Scientific and social relevance

1.4.1 Scientific relevance

From scientific point of view, it is important to develop and validate new tools that can help to understand why individuals accept or do not accept a certain device or measure. The first part of this research focuses on defining acceptance and acceptability. The second part is devoted to developing and specifying an acceptability framework and model that links factors affecting acceptability to the acceptance of a policy measure. The third part uses the model to estimate the influence of the different factors. The final part shows how certain elements in the framework can be influenced to get higher acceptability. This research contributes to the body of knowledge regarding policymaking actions: a better understanding of the road safety desires of the public that can help to create realistic and transparent measures. For ISA, this tool can contribute to the development of better implementation strategies.

1.4.2 Social relevance

It is widely accepted that ISA can help to increase road safety. Therefore, it is useful to understand the full potential of ISA and to understand how people will react if ISA is implemented. The use and concept of ISA is related to other road safety measures, such as speed signs, mobility use, vehicle development, etc. ISA must be seen as a part of future speed management policies. ISA is not just a device; implementation needs a full-scale system approach that takes into account many different factors. Large-scale implementation of ISA needs an integrated view on technical issues, behavioural aspects, and awareness of the ISA's potential. Large-scale implementation will require large investments; therefore, a better understanding of all aspects that can influence the success of ISA is needed. This research can help in understanding how potential ISA users think about the technology and how they might react to its implementation. It also provides new insights in today's problems in speed management.

1.5 Dissertation outline

The next seven chapters of this dissertation address the four research questions presented in section 1.2. Chapter 2 explains the problem of speed and speeding as well as how excessive and inappropriate speed can be tackled. Chapter 3 focuses on the potential of ISA and the actors involved to deploy the use of ISA. These two chapters form the base to answer Research Question 1. Chapter 4 investigates the use of one type of ISA-type more intensively. In this chapter the first results of the ISA-trial on acceptance and adoption are described, which provide an answer on Research Question 2. This research was the trigger to develop a better method for acceptance and acceptability measurement. The development of the theory and the conceptual model is explained in Chapter 5. Based on this concept, a large-scale survey was carried out. The descriptive statistics from the survey are described in Chapter 6. The model that was developed is described in Chapter 7. In the final chapter, some conclusions are drawn and the model is used to identify promising implementation strategies for ISA (Research Question 4) to use ISA in a speed management context. Figure 1-2 provides a visual overview of the relationships among the chapters of this dissertation. Shading is used to group the chapters according tot the research question (Q) addressed.

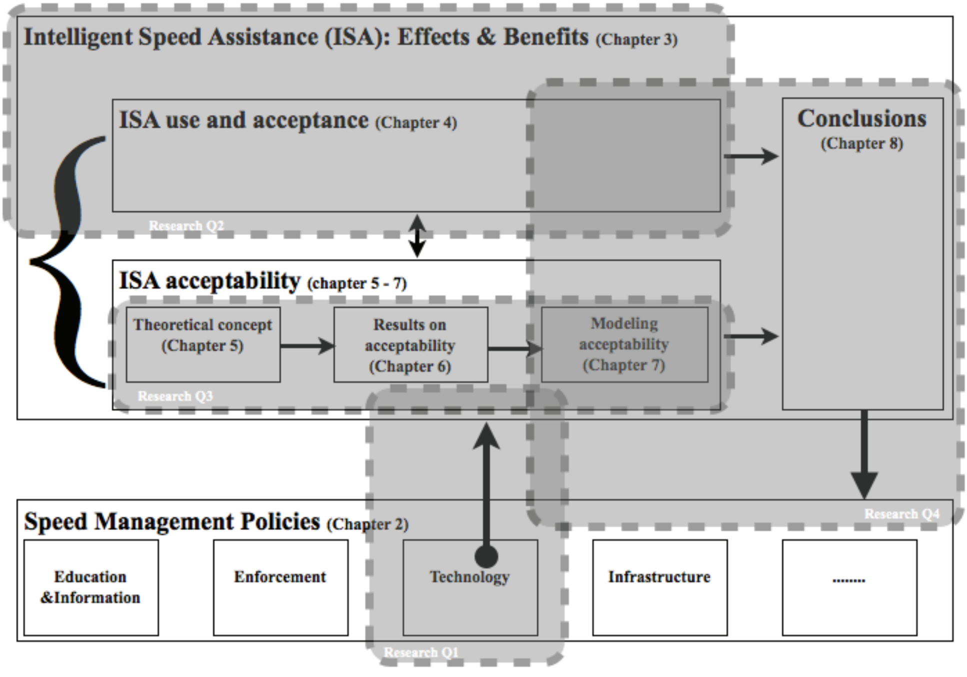

Figure 1-2. Overview of relationships among the chapters and between the chapters and research questions

We would like to inform the reader that in some chapters the term Intelligent Speed Adaptation is used, while in other chapters the term Intelligent Speed Assistance is used. These two terms are used to refer to the same set of devices that assist drivers in choosing appropriate speeds and complying with speed limits. The last couple of years the term Intelligent Speed Assistance is more likely preferred than Intelligent Speed Adaptation.

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2 Speed and Speed Management

Higher speed in transport and mobility has contributed to the economic development and the quality of life in a lot of countries. High-speed trains, planes, fast transport of goods, etc., have positive impacts such as reduction in journey time, and create opportunities in our economic, social, and cultural life.

However, to have and maintain high-speed levels in transport and mobility, society has to pay a price: higher speed levels imply by more noise, higher emissions and decrease of safety and urban liveability.

2.1 The problem of speed

2.1.1 Effects of speed on road safety

The number and severity of road traffic accidents increases as speed increases. High speed reduces the time people have to process the relevant information, to decide whether or not to react and to execute an action. Higher speed also leads to longer braking distances and the ability to avoid collisions decreases as speed increases (OECD, 2006).

The role that speed plays related to accidents is difficult to determine. Generally, speed plays a role; but other factors such as the road infrastructure, the road surface, the condition of the driver, etc., will also have an influence. Speed can cause an accident because it may be higher than the posted speed limit or it may be too high to drive safely (Van Schagen, 2007). Also, it is often difficult to determine whether inappropriate speed is the main cause of an accident. It is assumed that one out of three accidents are caused by excessive or inappropriate speed (OECD, 2006).

Every 1 kph (kilometres per hour) reduction in average speed leads to a 2-3% reduction in injury accidents (ETSC, 1995, Finch et al., 1994), although this varies according to the situation: the largest decrease in accidents is found on urban roads and the smallest on motorways (OECD, 2006). Nilsson (2004) has modelled the relationships between speed, serious injury accidents and fatal accidents and speed in his “Power Model” (see Figure 2-1).

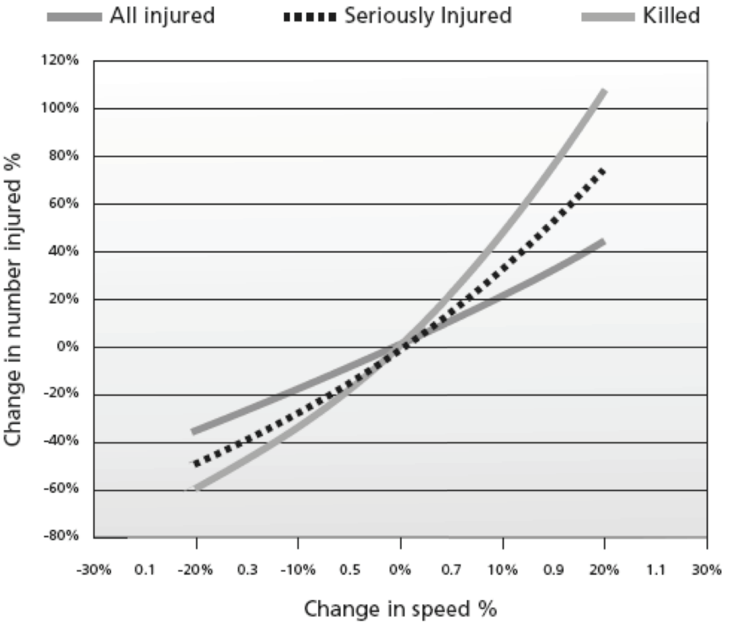

Figure 2-1. The Power model: relationship between change in mean speed and accidents (Nilsson, 2004)

In Nilsson’s model (2004), a 10% increase in mean speed leads to a 21% increase in all injury accidents, a 33% increase in fatal and severe injury accidents, and a 46% increase in fatal accidents. With a 10% decrease in mean speed, there are 19% fewer injury accidents, 27% fewer severe accidents and 34% fewer fatal accidents. Aarts and Van Schagen (2006) used this model to estimate the impact of a 1 kph change in speed on the severity of accidents given several reference speeds (original speed driven on road before a change). The results show that a change in speed will have a higher impact in lower speed zones (see table 2-1).

The consequences of an accident also depend on the type of accident and the type of road user involved. The most vulnerable are pedestrians and cyclists; they will have a high risk of severe injury when hit by a motor vehicle. The probability of a pedestrian being killed in a car accident increases with the impact speed: 90% of pedestrians would survive being hit by a car at a speed of 30 kph; only 20% would survive at speed of 50 kph (OECD, 2006).

Table 2-1. Application of the Power Model for different reference speeds (Aarts & Van Schagen, 2006)

Percentage change in accidents for 1 kph change in average speed						
Type of accidents	**Reference speed**					
	50	**70**	**80**	**90**	**100**	**120**
Injury accidents (%)	4.0	2.9	2.5	2.2	2.0	1.7
Injury and fatal accidents (%)	6.1	4.3	3.8	3.4	3.0	2.5
Fatal accidents (%)	8.2	5.9	5.1	4.5	4.1	3.3

2.1.2 Environmental effects

Vehicles emit various gases and substances in different amounts depending upon the speed. The emissions consist principally of carbon monoxide (CO), hydrocarbons (HC), nitrogen oxide (NO_x), and fine particulate matter (PM).

The emission of these gases is quite complex and varies from vehicle to vehicle, depending on the vehicle class and the specifications of the engine. NO_x is primarily produced at high engine temperatures, so a reduction in speed will decrease NO_x emissions. The effect of speed reduction on HC, CO, and PM emissions is less clear: HC emissions are reduced at low speeds; CO and PM emissions are reduced at moderate speed. Carbon dioxide (CO_2) is a greenhouse gas; the amount of CO_2 emissions is primarily related to the fuel. The optimum speed (the speed at which the emission is minimised) depends on the type of emission. The emission of harmful gases is lowest at a constant speed between 40-90 kph. CO and CO_2 emissions are highest at a low speed (15 kph or less) (Collier et al., 2005).

Another important factor influencing emissions is the driving style: changing of gears, accelerating, cold or warm starts (De Vlieger, 1997).

Better engine and new vehicle technologies could potentially lead to lower emissions of harmful substances. Therefore, new vehicles would be (theoretically) more environmentally friendly than old vehicles.

How fast you drive will also affect fuel consumption: driving at a constant speed of 90 kph instead of 110 kph could lead to a reduction of 23% in fuel consumption.

Speed has an effect on noise as well. At a lower speed there will be less noise. But other factors, such as changing gears may have more impact on noise than the average speed (Brenac et al., 2003).

2.1.3 Effects on quality of life

The effects of speed on quality of life are difficult to quantify. Injuries, pollution and noise are relatively easy to identify and measure, but it is harder to quantify what the effects that fear of fast moving vehicles have in discouraging people from walking and cycling, or in limiting their joy or preventing them from reducing facilities and services (OECD, 2006).

In 2003 test-drivers in the Belgian ISA-trial were asked whether they had feelings of insecurity when others were driving to fast (Vlassenroot, 2004). The drivers were asked whether they feel safe or unsafe when they see other cars driving too fast in different speed areas. They were asked about these feelings as pedestrians, bicyclists or drivers. Some of these results are presented in figure 2-2).

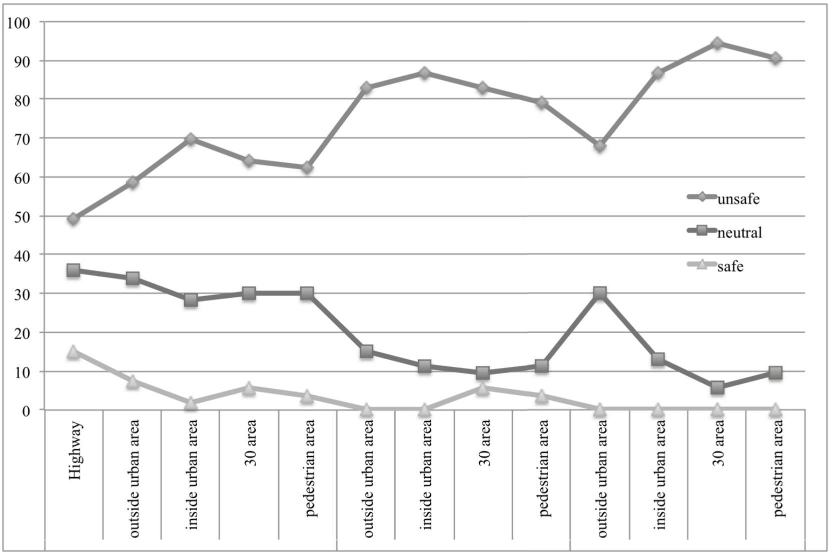

Figure 2-2. Frequencies of respondents feeling insecure in different roles and speed areas

The respondents would practically never feel safe in the role of pedestrian in any speed area when other cars are driving to fast. The test-drivers feel most insecure as pedestrians in a 30kph area (94%) and pedestrian area (90%). As drivers, 49% feel unsafe on highways and 70% feel unsafe in urban areas when they see other cars driving too fast. As bicyclists 87% feel unsafe in urban areas, 83% outside urban areas and 30kph area, and 79% in pedestrian areas. In general we could say, that the respondents feel insecure when other vehicles are driving too fast.

2.1.4 Speeding behaviour and attitudes about speed

Many factors can influence speeding behaviour, such as personality, road and traffic conditions, weather, etc. (ETSC, 1995).

Table 2-2. Factors that affect drivers' choice of speed (WHO, 2004)

Road and vehicle factors	Traffic & environment factors	Driver related factors
Road	**Traffic**	Age
Width	Density	Sex
Gradient	Composition	Reaction time
Alignment	Prevailing speed	Attitudes
Surrounding	**Environment**	Thrill-seeking
Layout	Weather	Risk acceptance
Markings	Surface condition	Hazard perception
Surface quality	Natural light	Alcohol level
Vehicle	Road lighting	Ownership of vehicle
Type	Signs	Circumstances of journey
Power/weight ratio	Speed limit	Occupancy of vehicle
Maximum speed	Enforcement	
Comfort		

The World Health Organisation (2004) listed a total of 32 variables that affect drivers' speed choice. This list includes road-related factors, vehicle related factors, traffic factors, and environmental factors (Table 2-2).

Shinar (2007) distinguishes two main driver-related variables that affect speed choice: individual differences (who we are) and motivating factors (what we want). The most common individual differences are age and gender.

Most studies have concluded that male drivers are more likely to speed than female drivers. Shinar et al. (2001) found male drivers reported themselves less likely to drive within the speed limit. Male drivers are more likely than female drivers to be involved in crashes linked to traffic violations including speeding (Parker et al., 1995). Based on analysis of the speeding behaviours and attitudes of female and male drivers, Meadows and Stradling (2000) found that a greater proportion of male drivers indicated a preference for high speed, reported speeding behaviour, and had pro-speeding attitudes, but that a greater proportions of female drivers thought the possible adverse consequences of speeding more likely to occur. Although male drivers are more likely to speed, Stradling et al., (2003) found that some studies were unable to find a difference between the sexes. Parker and Stradling (2001) found female drivers under the age of 20, reported speeding behaviour that was similar to that of male drivers in the same age group.

Speeding is also more related to the age of the drivers. Most studies noted that the age group between 21 to 25 years was the group most likely to speed (Stradling et al., 2000; Ingram et al., 2001; Shinar et al., 2001). The number of speeders drops as the age increases.

Stradling et al. (2000) studied the demographic and driving characteristics of speeding, violating, and thrill-seeking English drivers. Stradling et al. (2000) found two population groups whose driving behaviour put themselves and other road users at risk. The first group was young and mostly, but not exclusively, male drivers. The second group was drivers from high-income households, living outside the town, driving larger engine cars for high annual mileage as part of their work. They concluded that English drivers who speed, who violate other rules of the road, and who seek thrill when driving, pose greater risks to themselves and to other road users.

Besides these personal characteristics Silcock et al. (2000) produced a list of the eight most prevalent reasons drivers give to justify their speeding behaviour:

- Unintentional
- In a hurry (e.g. to collect a child at school)
- Being 'forced' to speed (by someone tailgating me)
- The limit is wrongly set for this location (based on experience of similar roads with higher limits)
- My modern car can stop more quickly than those on the roads at the time the limit was set, therefore my speeding is safe
- The same limit should not apply at all times (the empty road, late at night)
- The limit does not apply to me because I am an above-average driver
- My speeding is acceptable because it is not a lot over the limit and others abuse it more flagrantly.

Additionally, speeding is mostly not recognized as a ‘real crime’ by most drivers (Corbett, 2001). In the SARTRE research project (2004), it was noted that drivers are significantly more likely to report that they drive faster than other drivers rather than that they drive dangerously. While nearly one-fifth (18%) of drivers in European Union countries responded that they drove faster than average, less than one in twenty (5%) reported that they were more dangerous than other drivers. This shows that, in general, drivers do not appreciate that speed is associated with risk as far as their own driving is concerned. 28% of the drivers in European Union countries reported that they drive faster than the speed limit (either ‘often’, ‘very often’, or ‘always’) on ‘Motorways,’ only 19% did so on ‘Main roads between towns,’ and 13% reported doing so on ‘Country Roads’. There appears to be a widespread recognition that driving speed should be low in built-up (residential) areas since ‘only’ 7% of drivers in the European Union countries reported exceeding speed limits in such areas, in contrast to 28% who reported exceeding the speed limit on motorways. On average, 84% of the European drivers think that other drivers frequently exceed speed limits (either ‘often’, ‘very often’ or ‘always’). In fact, even in those countries with a low score on speeding, nearly three-quarters of the drivers thought that other drivers were guilty of frequently speeding. In SARTRE it was also noted that ‘driving too fast’ is very widely recognised as being a contributory factor in accidents. Even in those countries with a relatively low score for this question (such as Sweden, France, and the Netherlands), nearly three quarters of the drivers recognised it as being a major cause of accidents. However, the results obtained for other questions suggest that drivers do not think the risks associated with speed apply to them.

Since 2003, the Belgian Institute for Road Safety (BIVV/IBSR) has been measuring the driven speed in different speed areas (Riguelle, 2009). Each year, a speed measurement takes place at 150 locations along Belgian roads, spread over three provinces and four speed regimes: 30, 50, 70, and 90 kph. To ensure the representativeness of the sample, the measurement points are randomly selected. Only vehicles moving in smooth traffic conditions are taken into account, so the focus is on the behaviour of drivers and not on the traffic conditions on the roads.

Table 2-3. Average measured speed in Belgium period 2003 – 2007 (kph) (Riguelle, 2009)

Speed limit	2003	2004	2005	2006	2007
30 kph	38	36	35	-	52
50 kph	54	51	50	50	55
70 kph	77	78	75	77	74
90 kph	94	88	89	83	87

Table 2-3 shows a slight downward trend on 70 and 90-kph roads, while the average speed on 50-kph roads shows little change over time. In 30-kph areas driving too fast seems to be common, with a very high peak of 52 kph on average in 2007. In 2007, the average speed of the vehicles on the 50-kph and 70-kph roads was 4 to 5 kph above the speed limit. On the 90-kph roads, the average speed was 3 kph under the posted speed limit. Riguelle (2009) also noted that more than half of the vehicles were driving too fast (66% on 50 kph and 60% on 70 kph). The speed in 30-kph areas in 2007 is with an average of 52 kph very high and only 4% of the vehicles are driving slower than the posted speed limit. The main reason for this is that the measurements were made around school areas, where the posted speed limit is 30 kph. These 30-kph areas were generally roads that have a ‘transit’-function or where no infrastructure measures were made related to the posted 30-kph speed limits.

Table 2-3 shows some alarming figures about the average driven speed in the different areas. The V85 speed in Table 2-4 indicates even higher speeds in the different area. The V85-speed is the speed that is driven by 85% of the vehicles. In 50-kph and 70-kph areas, the V85 speed is 15 kph higher than the posted speed limit. Only in 2006 was the speed lower than 100 kph in 90-kph areas, but it was still higher than the posted speed limit.

Table 2-4. V85 speed in Belgium period 2003 – 2007 (in kph) (Riguelle, 2009)

Speed limit	V 2003	V 2004	V 2005	V 2006	V 2007
50 kph	65	62	61	61	64
70 kph	89	91	86	89	85
90 kph	109	102	102	96	101

Riguelle (2009) also noted that night speeds were 5 to 10 kph higher than the daytime speeds in almost every speed zone. During the day and the peak hours, the speed is lower, but it is still higher than the legal speed limit (e.g. 46.8 kph in 30 kph-areas).

These figures indicate that speeding is still a major problem. One of the main questions that arises is how excessive speed can be tackled. In other words, how speed can be managed. In section 2.2, some visions on safety and speed will be given. In section 2.3, some further details will be given about speed management.

2.2 Background and visions on safety and speed

As noted before, excessive speed is a serious problem for society. Some countries have developed a vision or action plan to improve road safety and to reduce casualties. In what follows, a brief summary is given of some national safety visions. We mainly focus on how the country would tackle excessive speed. The national visions are from Sweden, the United Kingdom and the Netherlands (the 'SUN'countries). These 3 countries have very good road safety records.

2.2.1 Vision Zero (Sweden)

Vision Zero (SRA, 2002) is the foundation for road safety initiatives in Sweden. It was established by a parliamentary resolution in 1997. Vision Zero is a road safety philosophy that envisions a future in which no one is killed or seriously injured. An important objective of Vision Zero is to get people interested in traffic safety matters and to create discussions and motivation. Vision Zero was led to changes in road safety policy and in methods and actions to come to improve road safety.

The resolution on Vision Zero (SRA, 2002) states:

> "The Swedish Parliament supports the Government's proposal for a new direction in road traffic safety based on 'Vision Zero'. The long-term goal for road traffic safety is that nobody is to be killed or seriously injured as a result of traffic accidents in the road transport system. To achieve this goal, the design and performance of the road transport system is to be adapted to the requirements of Vision Zero. Responsibility for road safety should be shared between road users and system designers, including road managers, vehicle manufacturers and people responsible for commercial road transport."

Basically, Vision Zero is an ethical approach to road safety. An important element of Vision Zero is that people should be able to use the road transport system without putting their lives or health at risk. According to Vision Zero, road safety assumes that everything possible is done to prevent serious injuries and deaths in road traffic.

With respect to speed, Vision Zero has led to an increased deployment and use of 30 kph zones in urban areas. In the Vision Zero Philosophy, 30 kph speed limits in built-up areas are the maximum permissible speed if pedestrians and cyclists are to survive a collision. Another example is the choice between traffic lights and roundabouts at an intersection (OECD, 2006). If the goal is to reduce the number of accidents, then traffic lights are the best solution: the number of accidents will be reduced. But those accidents that still occur will often result in serious injury or death. If the goal is to avoid serious injuries, as it is in Vision Zero, then a roundabout offers the best results: it is possible that more accidents will happen, but the resulting injuries will be minor, since the accidents will occur at different collision angles and at lower speeds. As a result, roundabouts have become a more common traffic solution at intersections in Sweden, particularly in built-up areas.

2.2.2 Tomorrow's roads – safer for everyone (United Kingdom)

In March 2000, the Prime Minister of the UK set out a new framework for delivering further improvements in road safety over the next decade (DETR, 2000). Based upon previous research and statistical evidence, the strategy intends to produce a 40% reduction in the number of people killed or seriously injured in road accidents and a 50% reduction in the number of children killed or seriously injured in road accidents (compared with the baseline average for the calendar years 1994 to 1998).

The inclusion of 'Safer speeds' is one of the ten key themes in the Road Safety Strategy (DETR, 2004). Speed Management has been considered as an important way to reduce the number of casualties in 2010. 'Safer speeds' recognizes that a sensible balance must be achieved between the need to travel and the improvement of the quality of life. Great Britain's speed management strategy seeks to take better account of the contribution of appropriate speeds to environmental and social objectives, as well as to road safety. One of the key issues is increasing the public acceptance of speed limits and speed management strategies.

The strategy that speed limits were more effective when introduced as part of a wider speed management package, including other measures, such as engineering and landscaping changes, to raise the driver's awareness of their environment, education, driver information, training, and publicity (DETR, 2004). The Government is also highly supportive of the use of safety camera technology as one of the options available for addressing road safety concerns.

2.2.3 Sustainable safety (the Netherlands)

The aim of the Netherlands' sustainable safety approach is to create a traffic system and traffic conditions in which the probability of an accident is limited by means of an inherently safe road environment (OECD, 2006; Wegman et al., 2006).

In a sustainable safe traffic environment, the road users and their fallibility and vulnerability are the starting point. All elements of the traffic system are tuned to the capabilities and limitations of its users. The number of required actions and operations per time unit should be limited, so that the chance of errors is reduced. Hence, the road network and road infrastructure must be easy to understand and predictable, and more or less automatically elicit the required, safe behaviour. Vehicles must be made and equipped in such a way that the human task is simplified, human errors less probable, and the consequences of errors less disastrous. Furthermore, road users must be adequately educated, informed and, where still necessary, controlled. The role of new technologies in the vehicle and along the road will become more important as a mean to support road users with their tasks in traffic.

Sustainable safety (Wegman et al., 2006) is based on five key safety principles: functionality, homogeneity, predictability, forgivingness, and state awareness.

Functionality refers to the use of the road network. The road network should consist of a small number of road types or road categories, with each category having its own exclusive function with its own exclusive requirements regarding use and behaviour.

Homogeneity refers to the elimination of large differences in speed, mass, and direction. This principle results in speed related measures. The main idea is that in situations in which motorised traffic and vulnerable non-motorised traffic use the same space, the speed of motorised traffic has to be very low. Also, 60 kph zones in rural areas were introduced, mainly around rural settlements and recreational areas where there is mixed traffic. At intersections, speed reduction measures were taken by constructing roundabouts and using raised areas and speed bumps.

Predictability is directly related to the road user. The layout and design of the road network and the individual roads in the network should be clear and unambiguous and prevent uncertainties among road users.

The principle of forgivingness has a physical component and a social component. The physical component is directly related to the vulnerability of the human body. If a crash is inevitable, the injury consequences should be kept to a minimum. The social component of forgivingness refers to the interaction between road users. Road users need to be made aware of the fact that other road users may not always behave as expected because they make an error or violate a rule intentionally.

State awareness refers to peoples' awareness of task capability. For example, inexperienced road users and the elderly have poorly developed or declining competences and thus a reduced task capability, but they are not always sufficiently aware of that.

2.2.4 Intergovernmental visions and policies

The European road safety policy (European Union)
The European Union stated in its White Paper on transport policy for 2010 (EC, 2001) and its Road Safety Action Program (EC, 2003) the goal of reducing the number of road fatalities by 50% (reference year 2001). Related to this objective is the creation of e-safety expert groups. E-safety is the use of information and communication (ICT) to tackle insecurity, to provide support for users in their driving-related tasks and in to reduce potential human errors in car use. As a result, the EU has funded many studies and tests on the use of ICT. First applications have already appeared on the market, such as the speed limiters in curbs, and Intelligent Speed Adaptation (ISA), which has been tested in different countries around Europe.

Others applications are being studied, both for active safety to prevent accidents (systems for improved dynamic characteristics of vehicles, improved braking performance, obstacle detection, information on the state of the road, lane departure warning, etc.), as well as for passive safety to limit consequences of an accident (airbags, safety belts, emergency calling systems, etc). In Europe, current research focuses on particular technical elements of new technology systems, such as sensors, telematics, and in-vehicle architecture.

Speed Management Policy (OECD/CEMT)
In 2006, a report was published about speed management programs, that was based on various studies and cooperation with 23 states within the OECD (Organization for Economic Co-operation and Development) and ECMT (European Conference of Ministers of Transport). The purpose of this report was to support national authorities in the further development of speed management programs. This report focuses on trends regarding speed in relation to road safety, environmental and economic aspects. It describes the needed policy and operational improvements to develop a better speed management policy framework.

2.3 Speed management and speed management components

Speed management can be defined as a set of measures to limit the negative effects of excessive and inappropriate speed in a transport system (OECD, 2006). The purpose of speed management is to produce an integrated and comprehensive approach for improving the current situation with respect to speeding. In this section, the components of speed management are described in three categories: road infrastructure, human behaviour and the vehicle technology. We conclude that an integrated use of these components could lead to better and more sustainable traffic policies.

2.3.1 Road infrastructure

Infrastructure measures
In most countries, roads have three main functions (OECD, 2006): flow, distribution, and access. Roads with a flow function allow efficient throughput of long distance traffic. Motorways and express roads, as well as some urban arterials, have a flow function. Roads with a distribution function allow drivers to enter and exit all kinds of urban or rural areas at intervals along the road. Roads with an access function allow access to properties alongside the road or street.

Related to these functions, roads are frequently classified according to their location and type. Table 2-5 presents the categories in each of these three classifications: location, type, and function.

Table 2-5. Road categories and functions (OECD, 2006)

Location	Type	Function
Outside built-up areas	Motorway (interurban)	Flow
	Main highways (principal inter urban roads)	Flow
	Rural main roads	Flow/distribution
	Rural minor roads	Access
Built-up areas	Motorways (urban)	Flow
	Urban arterial roads and main roads	Flow/distribution
	Urban residential roads	Access

The intention is also that the safety measures for roads are self-explaining and can be related to its location, type and function. In the Netherlands, one of the principles in Sustainable Safety is predictability (Wegman & Aarts, 2005). The principle of predictability is based on the idea that human errors and crashes can be prevented by the use of predictable and recognizable roads. The road characteristics should tell the road user immediately on what road type he/she is driving, what driving behaviour is expected of him/her and other road users, and what other types of road user he/she can expect (Aarts et al., 2007).

Aarts et al. (2007) developed a theory of recognizable layouts based on the process of mental categorization. They stated that people recognize things by placing them in a certain category. Categorization, and consequently recognition, is easier the more roads in the same category resemble each other. The differences between categories should be as large as possible. This improves the distinctiveness of road categories. In other words, roads should be distinguishable; they should evoke and support correct expectations. In Figure 2-3 this chain of thinking is presented graphically.

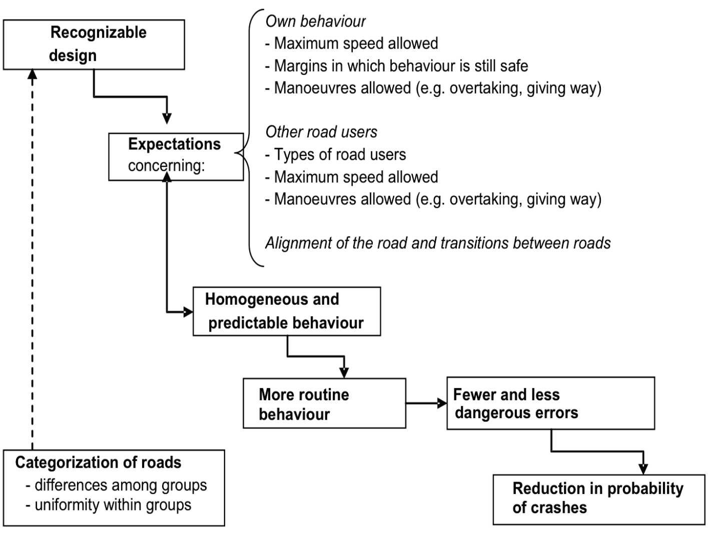

Figure 2-3. Chain of recognizable layout and predictable behaviour as suggested in Sustainable Safety (Aarts et al. 2007)

In principle the speed limit should depend on the desired function of the road, its type and its location (built/non-built). To have safe roads, the roads should have a recognizable layout. A frequently used approach to define the speed limits is to use the design speed. The design speed of a road is defined as the highest speed that can be maintained safely and comfortably when traffic is light (ETSC, 1995). In principle, the required design speed depends on the function of the road and, hence, on the desired speed level. If high speeds are desired, road quality and roadside protection need to be of an appropriate standard. The alternative to improving road standard is to reduce the speed limit and actual speeds, consistent with the standard and risk of the road (ETSC, 1995). The OECD (2006) stated that the design speed must never be lower than the speed limit. On the other hand, it is not wise to have a speed limit that is much lower than the design speed of a road. This may damage the credibility of the speed limit. In Table 2-6 the safety characteristics, risks and infrastructural adjustments (in relation to the risks) are described for roads in different locations.

Table 2-6. Desired speed design in relation to safety characteristics, risks, and infrastructure (ETSC, 1995; Elvik, 2004; Webster & Mackie, 1994: OECD, 2006; Aarts et al., 2006)

Location	Safety Characteristics	Safety Risks	Infrastructural adjustments
Non built up areas			
Highways	Safest road environment for fast moving traffic.	- Risks on ramps and exits - Risks when there is congestion - Risks when there is a lot of variation in vehicle speeds - Risks during road works	- Narrowing and good communication (message signs) are a must if certain risks can occur. - Not always subject to additional infrastructure measures for speed management purposes. - Reduced speeds are required for workforce protection and vehicle occupant safety.
Rural roads	Carry the greatest risk of death and injury. Around 60% of traffic fatalities in most industrialised countries.	- Collisions with roadside objects - Head-to-head collisions - High level of inappropriate speed - Vehicles of different mass and vehicles travelling at different speeds can create high-risk stretches of road, especially where light vehicles overtake slow, heavy ones. - Bicyclists are vulnerable on these roads	- It is not always possible to take away all the risks on these roads (this would be too expensive and impractable). - Removing obstacles at dangerous locations. - Separate traffic travelling in opposite directions. - Separate lanes for slow moving vehicles, such as heavy vehicles and agricultural vehicles. - Use bicycle lanes and paths (lanes are only visually separated from the road by longitudinal markings; paths are physically separated from the driving lane).
Transition zones	Entering a lower speed zone, in particular after a period of driving at a high speed, drivers will generally underestimate their speed and consequently not reduce their speed enough to comply with the lower speed limit.	- Risks when transitioning from motorways to main roads - Risks when transitioning from main roads to an urban environment and at intersections with e.g. residential roads.	- Complementary measures along the through-route within the urban area are required. - Measures at the transition zone should be such that they achieve a cumulative effect, finishing at the actual gateway to the town or village.
Urban area	High variation in road users	- Risks around shopping areas - Risks around schools - Risks at intersections - Risks in residential areas	- Ring roads around cities - Pedestrian areas - Physical speed-reducing measures - Creation of home zones and 30 kph areas to reduce traffic.

In addition to the road design, engineering measures can be used to increase safety. Some of these were mentioned in Table 2-6. Gates, as an engineering measure, can help to indicate the change from one traffic environment to another. Gates can improve a drivers' understanding of the change in traffic behaviour required. Central traffic islands are often used at the entrances to urban areas, especially on the roads that pass through smaller cities or villages. Differences in function and shape are evident between one-sided central islands dedicated to decreasing the speed on entry only, and two-sided central islands, which are intended to prevent the speed of vehicles increasing as they exit the urban area, or even inside the urban area (OECD, 2006). Narrowing the width of a two-lane road is another change to the infrastructure that can calm down traffic. Such narrowing can be made either from the middle of the road or from the sides, and can be done by introducing middle islands. Roundabouts are another solution to reduce speeding. Elvik and Vaa (2004) report an injury accident reduction of 10-40%, depending on the number of arms and the previous form of the traffic situation. The effect on pedestrian accidents is similar to that of other accident types; the effects for cyclists are somewhat smaller (10-20%). The meta-analysis showed an increase in the number of damage-only accidents at roundabouts.

Besides infrastructure, road markings can also play a role in a drivers' choice of speed. There are four main functions of markings are described (OECD, 2006): to guide the driver, to inform the driver of regulations (overtaking, no parking, etc.), visualising speed zones and to warn the drivers of road alignment ahead.

In addition to infrastructure and markings, another important speed management measure is the use of speed limits. In the next section, the use of speed limits will be explained in more detail.

Speed limit measures

The OECD (2006) stated that appropriate speed limits are only one element of a speed management approach, but for the foreseeable future speed limits will continue to form the backbone of speed management strategies and policies.

Several aspects have to be taken into consideration to set an appropriate speed limit, such as safety, mobility, and environmental considerations, and the impact of a speed limit on the quality of life for those living alongside the stretch of road.

Table 2-7 presents the OECD's suggestion (2006) on how appropriate speed limits can be defined for the different types of road.

Table 2-7. How to define the appropriate speed for different types of roads (OECD, 2006)

Road type and function	Appropriate range of speed to meet specified objectives			
	Safety	**Environment**	**Economy and mobility**	**Quality of residential life**
Motorways and principal inter-urban roads High quality network designed for high-speed range for long distance movement of people, goods and services.	**90 to 130 kph** Reduced speed may be appropriate in poor weather.	**70 – 90 kph** Higher speeds lead to high emissions and noise. Reduced speeds needed where air quality or noise issues are important.	**High end of speed range** This is of high importance for commercial and private movements alike.	**Low end of speed range** Little adjacent development but, where there is, speeds should reflect this to improve noise, air quality and safety
Urban arterial roads and main roads High quality urban network designed to cater to through traffic.	**50-60-70 kph** Reduced to 30 kph where there are many vulnerable road users.	**30 – 60 kph** Within optimum range for vehicle emissions.	**High end of speed range** Local traffic as well as through traffic. Often commercial and residential development. Need to balance safety and mobility.	**Low end of speed range** Important where adjacent land use is residential. Need to manage speeds for air quality, noise, and safety effect.
Urban residential roads Network designed for living and access only for local traffic.	**30 kph** Traffic calmed where necessary to achieve lower speeds.	**(Speed not given)** Below optimal range for emissions; vertical traffic calming elements can cause increase in noise.	Takes second place to safety and quality of life.	Very important on all residential roads.
Rural main roads (Not principal inter- urban) Designed for local through traffic.	**70 to 90 kph** Depending on quality. Reduce for curves and junctions.	**60 to 90 kph** Lower speeds within optimum range for emissions but higher speeds lead to more emissions and noise.	Important.	
Minor rural roads Designed for local access traffic with presence of vulnerable road users.	**40 to 60 kph** Depending on quality and presence of vulnerable road users.	Within range of optimum speeds.	Takes second place to quality of life.	

Table 2-8. Speed limit categories and definitions (Van Mulken et al., 2004)

Speed limit category	Definition
General (implicit) speed limits	**Speed limits in accordance with national speed legislation.**
G.1 – Infrastructure	Speed limits depending on road category (motorway, other road, built up area, etc.).
G.2 – Environment/weather	Speed limits that are subject to prevailing environmental or weather conditions. E.g. Rain and snow dependent speed limits in France, and dependant on visibility in Germany. Day and night dependent speed limits would also fall under this category.
G.3 – Vehicle	Vehicle (and equipment) dependent speed limits. E.g., trucks, buses, and use of studded winter-tires.
G.4 – Driver	Driver dependant speed limits. E.g. young drivers.
Specific (explicit) speed limits	**Speed limits in accordance with speed legislation by governmental agencies, regional authorities, and/ or municipalities. These speed limits differ from general rules. They are site dependent and posted by fixed or variable road signs.**
S.1 – Fixed speed limit, signposted	Speed limits, permanently posted by means of static road signs. E.g. curves, bridges, built-up areas.
S.2 – Variable speed limit, fixed signposted	Speed limits, fixed signposted indicating a variable speed limit. E.g. at road works, incidents, or during school hours when the regulation is not limited to a certain time period.
S.3 – Variable speed limit, variable message sign	Speed limits, posted on variable road signs, which may be of a permanent or mobile nature, indicating a variable speed limit. E.g., road works, rescue operations, traffic conditions and weather conditions.
S.4 – Temporary speed limit, fixed signposted.	Speed limits, fixed signposted indicating a speed limit restricted to a defined time period. These speed limits can vary depending on the regulation. E.g.: During road works, police traffic control, accidents, or during school hours, all for a specified period.
S.5 – Temporary speed limit, variable message sign.	Speed limits, posted on variable road signs, in case of a temporarily situation. E.g. road works, rescue operations, traffic conditions and weather conditions.
S.6 –Recommended maximum speed	These maximum speed recommendations are not enacted but are a recommendation to enhance road safety.
S.7 Pre-announcement of speed limits (e.g. towards end of motorways)	Announcing an upcoming speed limit, usually by a fixed signpost, with additional text indicating the distance to the actual speed limit.

As there is a classification for roads, the European SpeedAlert-project made a classification of speed limits (Van Mulken et al. 2004). In Table 2-8 an overview of this classification of speed limits is given. A distinction is made between general (implicit) and specific (explicit) speed limits. The general speed limits dependent, besides differences between countries, on infrastructure, environmental conditions, and type of vehicle and drivers age. These speed limits are generally not signposted along the roadside. The specific speed limits are deviations from general speed limit rules and are always required to be explicitly signposted along the roadside. Specific speed limits may be of fixed, variable, or temporary nature.

If a speed limit is chosen related to road categories and functions, it is also necessary that the road users will accept the limit. Van Schagen et al. (2004) described the Dutch concept of ‘credible speed limits.’ Safe, credible speed limits are expected to result in motorists complying better with the speed limits. A credible speed limit is defined as a speed limit that matches the image that is evoked by the road and the traffic situation. A distinction is made between ‘the road image’ and ‘the situation image.’ The static features of the road and its environment form the ‘road image’ (e.g. the lining and markings, bends, buildings, and vegetation); the dynamic features of the traffic situation, such as weather conditions and the amount of traffic, create the ‘situation image’. The dynamic features are particularly relevant for dynamic speed limits. In a photograph study (Goldenbeld, 2006) it was demonstrated that the credibility of 80 kph roads depend on the road width, the presence or absence of a bend, the view ahead, the view to the right, the clarity of the situation, the presence or absence of buildings and the presence or absence of trees on the right hand side.

Van Nes et al. (2007) studied how well drivers comply with credible speed limits in a simulator study. It was noted that more credible limits resulted in an average driving speed that was closer to the limit. When the limit was experienced as being too low, the average speed was considerably higher than the limit; for limits that were experienced as being too high, the average speed was lower than the limit. There were indications that drivers older than 50 were more influenced by the credibility of limits than younger ones; gender and thrill seeking had no influence.

Drivers have to be aware of the speed limits, the meaning of signals, and the limits that infrastructure imposes. Generally this is communicated to drivers during the training and licensing, and afterwards it is reinforced by enforcement and campaigns. In the next section, the aspects to guide the driver are explained, from informative via preventive speed management to reinforcement.

2.3.2 Human behaviour

Education and information

The OECD (2006) indicated education, training and information as essential elements of a comprehensive speed management program.

Most road safety education and training occurs informally, provided by the family and outside the school. Parents and other adults in a child’s surrounding have a responsibility to set a good example. They need to be aware that their behaviour, opinions, and remarks play an important role in a child’s way of looking at the world in the future.

The OECD (2006) stated that there is only a limited role for education of primary school children in the framework of speed management, because they are not in a position to influence the speed of motorized vehicles. However, children at a young age are directly affected by the risk that speeding vehicles represent for them. Therefore, it is important to focus on the importance of young children not becoming victims themselves. Most European countries provide lessons in traffic and safety during elementary school.

At secondary school, children will participate in traffic more intensively, like on a bicycle and later with motorized vehicles (mopeds, scooters, cars, etc.). The school can fulfil an important role in the preparation of the transition from low to high speed and risky transport modes by including some road safety education. However, it must be stated that, for instance in Belgium, specific road safety education is poor or even absent in secondary school. It might be possible to integrate the effects of speed of motorized vehicles into the topics of the school curriculum, such as physics (impact of speed, impact of mass, braking distance, etc.), chemistry (emissions), and human sciences (resistance of the human body, health consequences).

At a young age, people learn to drive. Learning to drive is a complex and long-term process. It involves acquiring knowledge, developing skills, and correctly assessing risks and one’s own ability. Driver training should also be based on the characteristics of young people. Parker et al. (1992) indicated that three main problems for young drivers are the tendency to overestimate their abilities and to underestimate the risks, lack of motivation to take sufficiently wide safety margins, and lack of experience. Engström et al. (2003) also stated that young drivers have been found to drive faster and with shorter following distances when they have young passengers in the car. This was the case for both male and female young drivers, but the largest effect was found for young male drivers with young male passengers.
Driving instructors should also make the young drivers more aware of the consequences of speed and speeding. However, this is not an easy task, because if the learning driver is doing the practical training, he/she will be regularly confronted with overtaking and speeding drivers.

Even if the individual has a driving license, information and training should still be given on speed and speeding. Despite their popularity in use by the governments, the effects of information campaigns as a means of changing attitudes and behaviour are hard to prove, especially if they are applied as a stand-alone measure (OECD, 2006).

In addition to the license training, driver improvement and safe driving courses may be useful. Driver improvement or rehabilitation courses do not focus on the driving population at large; they focus on drivers who have committed serious traffic violations or reached a particular level of demerit points (Elvik & Vaa, 2004). These courses can be compulsory or voluntary, for instance in combination with a reduction in punishment. Most driver improvement courses are related to drink-driving offences, while some focus on safe driving in general. Companies will mainly apply safe driving courses, as part of a corporate safety strategy (ETSC, 2008). Typically, a specific group of employees is assigned to go through this kind of training. Safe driving courses should include both theoretical and practical elements like information on accident causation, risk awareness, techniques for choice of safe speed, eco-driving, etc.

Besides training and information, incentives or rewards can be used to convince people to behave correctly and safely. While there are some who are sceptical about the benefits of using incentives, or feel that it is unjustified to give rewards for something that is 'normal', the effects can be very positive. In 2004, a trial was carried out in the Netherlands by giving credit points, which can be exchanged for gifts, when the drivers showed good behaviour

(Belonitor, 2005). During the trial, a clear improvement could be observed, with less speeding and larger following distances and, as a consequence, less fuel consumption. Once the trial had finished, however, a substantial part of the effects disappeared, although some of the participants persisted in their improved behaviour.

Enforcement

The OECD (2006) stated that in an ideal world, with logical and credible speed limits, self-explaining roads, consistent speed limit signing, as well as good information to road users about the consequences of inappropriate speeds and the rationale for speed limits, there would hardly be a need for enforcement.

However, speeding remains the single most important factor in traffic deaths and injuries across Europe (ETSC, 2006). Improved compliance through either increased enforcement or suitable incentives make a major contribution to reducing traffic deaths and injuries in Europe. In particular the case of speeding, 5800 deaths could be prevented per year (ETSC, 2008). Figure 2-4 shows the mechanism of policy enforcement (Goldenbeld, 2005).

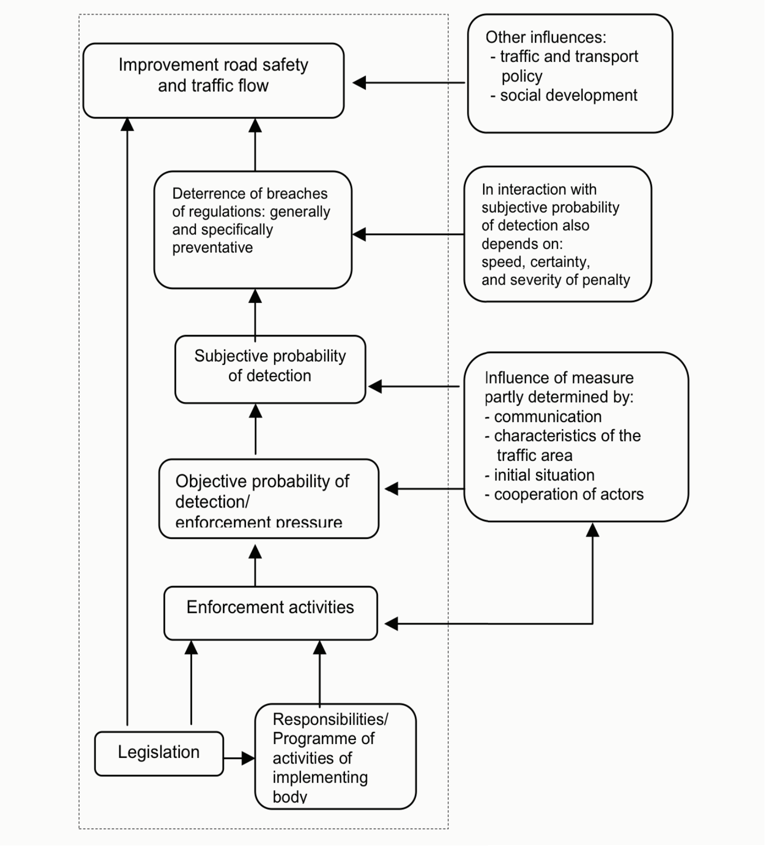

Figure 2-4. Diagram of the mechanism of police enforcement (inside dotted line), and the influence of external factors (outside dotted line) (Goldenbeld, 2005)

Goldenbeld (2005) described the chain as follows:

> "The first step is traffic legislation. The legislation defines the rules for traffic participation and determines the possibilities for tracking down and punishing violations. The actual enforcement of the rules leads to an enforcement pressure or objective probability of detection. The subjective probability of detection is partly determined by the objective probability of detection, and also, for example, by coverage in the media, public information campaigns and anecdotes related by friends and acquaintances. When road users consider the subjective probability of detection to be sufficiently likely, they will avoid violating a regulation. The combination of enforcement and penalty is generally preventative when road users avoid traffic violations on the basis of the expected negative consequences. In other words, road users adapt their behaviour without having already been punished. In particular, frequently conducted and very visible traffic checks, which are unpredictable in terms of time and place and are combined with public information campaigns, bring about the general prevention of traffic violations. In addition, in interaction with the subjective probability of detection, the speed, certainty and severity of the imposed penalty also determine the general preventative effect. We speak of specific prevention when road users avoid committing traffic violations on the basis of fines or penalties they had to pay as a consequence of earlier violations. Specific prevention therefore involves a change in behaviour resulting from the penalty itself."

Traditional methods rely on radar and laser methods conducted by police patrols. These offer the advantage that offenders are directly approached by police officers. New methods use recording devices (camera, video) that are triggered automatically by speed violations. These offer high levels of continuous and widespread enforcement (ETSC, 2008).

In the Netherlands, four main speed enforcement methods are used (Goldenbeld, 2005):

- Automatic speed controls at permanent locations with fixed speed cameras.
- Speed controls at varying locations using radar cars, laser guns, or cameras hidden in objects – with or without stopping offenders.
- Mobile surveillances and stopping speed offenders.
- Speed controls in which the average speed of all passing vehicles along a particular road section is determined (known as section controls or average speed checks).

Hooke et al. (1996) noted that speed cameras reduced accidents by 28%. A study on the effect of speed cameras (permanent fixed cameras, but also mobile controls with speed cameras) on driving speeds and road safety in Great Britain showed large reductions in the number of speeding offenders and road crashes (Gains et al., 2005). The following estimates of reductions in injury crashes compared with regional trends were found: 22% and 33% fewer for fixed cameras on urban and rural roads respectively, 22% and 15% fewer with mobile cameras on urban and rural roads.

Besides infrastructure, education, information and enforcement, the characteristics of the vehicle and the use of new vehicle technologies could be beneficial in speed management.

2.3.3 The vehicle

Vehicle characteristics

Relatively little power is required to maintain legal speeds on a level road with no wind at 100 kph. Thus, for passenger vehicles, the surplus power normally available is able to accelerate the vehicle to speeds far in excess of the legal limits (OECD 2006). Kroon (1998) already stated that most technical vehicle improvements are geared towards upgrading power, performance and weight (e.g air-conditioning) instead of improving fuel efficiency or reducing speeding.

De Mol et al. (2009) conducted a study on the evolution of vehicle weight, engine power, and speed of the vehicles sold in Belgium in 2007. Data provided by the Belgian Vehicle Registration Service (DIV) were used, which contained information on the vehicles' make, model, cylinder capacity (cc), power to weight ratio, weight, top speed, CO_2 emissions (g/km) and fuel consumption. For each make, three car types were analysed: the standard version (SV), top version (TV) and best-selling model (BSM). The standard version is the lowest type within the make (the one with the most basic engine and options). The top version is the highest type within the make (the one with the most powerful engine and complete options). The best-selling model is the type within the make that is bought the most.

The data showed that, between 1993 and 2007, the average weight of a car has increased by more than 41 % (403 kg). Between 1999 and 2007, the average weight for the BSMs increased by 29% (311 kg). The power to weight (P/W) has also been increasing steadily. From 1993 to 2007 the P/W for the BSM's went from 40 to 63 (a growth of 58%) and for the TVs it went from 75 to 151 (a growth of 201%). During the same period (1983-2007), the speeds also increased. For SVs the top speed increased by 22 kph (a growth of 15%); for BSMs the top speed increased by 16% and for the TVs the top speed increased by 27%. The average top speed of the TVs in 2007 was 229 kph.

In terms of safety, driving with a bigger and heavier vehicle gives a more secure feeling to the driver. Since the design of most cars has resulted in an improved level of safety (also for smaller vehicles), it is assumed that larger and heavier vehicles will provide greater protection to the occupants in both single-vehicle crashes and multi-vehicle crashes than with smaller and lighter vehicles (Evans, 2001; Noland, 2005; Elvik, 2004). For car-drivers, being in a vehicle that is higher, longer, broader, and heavier may create an illusion of safety. But the fact is that these vehicle design attributes do not determine safety for the driver of the vehicle nor for the other road users. Kim et al. (2006) concluded that the probability of survival is most likely influenced by the physical characteristics of the vehicles involved in an accident and possibly by the characteristics and behaviour of driver and occupants. They also found that the probability of having an accident is most likely influenced by the driving behaviour and probably influenced by the vehicle's characteristics. Heavier vehicles can also influence the impact of accidents when vulnerable road users are involved. Roudsari et al. (2004) noted that the change in vehicle design and increase in the number of light truck vehicles (heavier vehicles, like SUV, pickups, etc.) have led to changes in the pedestrian injury profile: through the analysis of 552 recorded cases where pedestrians are involved in car accidents, pedestrians had a higher risk of severe injuries when struck by light truck vehicles (29%) compared with passenger vehicles (18%). The probability of death when pedestrians were hit by heavier vehicles was around 3 times higher than that for (normal) passenger vehicles. Besides the weight, power of the car and its top speed are factors in many accidents.

In-vehicle speed management technology
Different systems can be used to assist the driver to maintain the speed or prevent the driver from speeding. Some of these Advanced Driving Assistance Systems (ADAS) are described below.

Active Cruise Control (ACC) is an advanced cruise control system that can automatically adjust a car's speed in order to maintain a safe following distance. ACC is similar to conventional cruise control in maintaining a vehicle's pre-set speed. However, ACC can automatically adjust the speed in order to maintain a proper distance to a vehicle in front in the same lane. This is achieved through a radar headway sensor, digital signal processor, and longitudinal controller. If the vehicle ahead slows down, or if another object is detected, the system sends a signal to the engine or braking system to decelerate (AVV, 2007).

Morsink et al. (2006) conducted a literature overview and reported that most ACC studies indicated a significant decrease of speed variations due to ACC. This decrease led to stronger environmental benefits (decrease of fuel consumption and emissions) but not so strong to safety and traffic efficiency benefits. The safety benefits of ACC are found mostly on motorways in non-congested traffic and in good weather, with maximum accident reductions of about 10%. ACC effects on other road types need to be further studied, as well as the effects of different time headway settings. More positive effects are predicted for the next generation ACC, which will be more designed to detect hazards (e.g. by car-to-car communication) and to operate in congestion prone traffic.

Another ADAS safety system is Electronic Stability Control (ESC). ESC uses sensors to detect loss of control (ETSC, 2008). When the system detects that actual vehicle motion is different from the driver's desired path (as measured by the steering wheel sensor), it automatically applies braking and/or reduces engine power at each individual wheel to bring the vehicle back under the driver's control. ESC also has the effect of slowing the vehicle down during loss-of-control situations (especially in curves or on surfaces with different friction coefficients). Lie et al. (2004) analysed Swedish collision data to show that fatalities could be reduced by 16 to 20% by equipping vehicles with ESC.

The use of driving behaviour monitor systems (or black boxes) could also reduce speeding. Black boxes are called Event Data Recorders (EDR), when they only store information a couple of seconds before, during, and after an incident/accident. Privacy considerations are the major issue surrounding a broader use of EDR. If this can be resolved, EDR may be expected to have positive effects on speeding behaviour (OECD, 2006). It should be noted that these systems will make speed enforcement more effective, but they may also introduce new forms of control to prevent disconnection of the systems. Systems as EVI and black boxes may very well increase the legitimacy of the limits, and, as a consequence, the credibility of the enforcement. The possibility to give behavioural feedback may also lead to reward good behaviour, which may add to the system's effect (Morsink et al., 2006).

Intelligent Speed Assistance (ISA) refers to a collection of technologies that assist the driver in the task of speed control. ISA is an intelligent in-vehicle device that warns the driver about speeding, discourages the driver from speeding, and/or prevents the driver from exceeding the speed limit (Brookhuis & De Waard, 1999). ISA systems can be divided into different types (Morsink, et al., 2006) depending on how intervening (or permissive) they are. An informative (or advisory) system merely displays the speed in order, to remind the driver of changes in speed levels. A warning (or open) system cautions the driver if the posted speed limit at a given location is exceeded; the driver then decides whether to use or ignore this information. An intervening (supportive or half-open) system gives a force feedback through the gas pedal if the driver tries to exceed the speed limit (e.g. the active accelerator pedal). It is, however, still possible for the driver to overrule the counter-pressure initiated by the accelerator pedal. A mandatory (automatic control or closed) system will fully prevent the driver from exceeding the limit; in this case, the driver cannot overrule the system. Since the early 1980s the effects of ISA have increasingly been studied through different methodologies and data collection techniques, varying from traffic simulation, driving simulators, and instrumented vehicles to field trials (Carsten, 2002; Morsink, et al., 2006). Generally, ISA seems to have positive effects, reducing driving speed and speed violations (Agerholm, Waagepetersen, Tradisauskas, Harms, & Lahrmann, 2008; Driscoll, Page, Lassarre, & Ehrlich, 2007; Regan, et al., 2006; Várhelyi, Hjalmdahl, Hyden, & Draskoczy, 2004; Vlassenroot, et al., 2007). However, the effects depend on how intervening the systems are. A restrictive ISA (such as an intervening or voluntary) system seems more effective in reducing speed and speeding than an advisory (or warning) ISA (Carsten, 2008).

Of all the ADAS, ISA seems to be the most promising to assist the driver in staying within the set speed limit. In this dissertation, the focus will be on the use of ISA acceptance and acceptability.

2.3.4 Conclusion on speed management

There is no single best speed management measure to reduce speeding on roads. Rather it takes a combination of measures, including comprehensive infrastructure, credible speed limits, education, information, enforcement, vehicles, and vehicle-technologies. Speed management measures were explained by using the three pillars (the driver, environment, and vehicles) on which to intervene to achieve a better road safety. The benefit of speed management is that clear actions can be taken in all of these pillars, allowing for an effective ‘policy mix’ approach (Simcic & Townsend, 2008).

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3 Easy Going. Multi-Level Assessment of ISA

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Abstract
ISA involves an in-vehicle system that supports the driver in not exceeding the speed limit. Inappropriate speed or speeding is a major cause of road traffic accidents and strongly relates to the outcome of an accident. As such, ISA has the potential to substantially improve traffic safety and is recognized as a promising speed management policy. Over the past decades, a lot of research on ISA was conducted across Europe. This research involved different ISA systems (ranging from simple information provision to keeping the car at the local speed limit), and a variety of different methodologies (ranging from pilots and trials, to driving simulator studies, computer simulations and expert elicitation of opinions). The central notion in this chapter is to describe which evolutions were found about ISA around the world, to assess the effects of ISA on social, ecological, economical, political, and technical level. Two main questions will be answered by discussion and evaluation of some ISA studies and ISA developments: what do we know and what is still do be done? This will result in an overview of barriers and issues that are resolved and that still have to be resolved, to enable large-scale implementation.

3.1 Introduction

Speeding is a widespread problem and is a major source of road traffic externalities. Speeding affects road safety; it does not only increase the risk of getting involved in an accident, but it also affects the outcome or severity of an accident. Moreover, higher vehicle speed also contributes to increased greenhouse gas emissions, fuel consumption and noise, and to adverse impacts on the quality of life (OECD, 2006). Speed management can help achieve appropriate speed, taking into account mobility and economic needs, as well as safety and environmental requirements. Speed management implies a consistent policy that integrates information, education, road design, road signs, enforcement and vehicle technologies.

One of the solutions to solve speeding is making the road transport system more intelligent by implementing Intelligent Transport Systems (ITS). In-vehicle ITS systems that support the driver in operating the vehicle are called Advanced Driver Assistance Systems (ADAS). A promising ADAS that assists the driver in keeping the appropriate speed is called Intelligent Speed Adaptation/Assistant (ISA) (Brookhuis & De Waard, 1999).

ISA is an ADAS that may help the driver to cope with the (posted) speed limits. ISA can be described as a system that (1) 'knows' the real time location of a car (with the aid of GPS), (2) 'knows' the (posted) speed limit at that specific location (e.g. using in-vehicle speed database) (3) compares the speed with the (posted) speed limit and (4) if the speed is inappropriate intervenes with the driving task.

Many terms are used to describe these kinds of ADAS, like Speed Alert or Warning system, External vehicle speed control, intelligent speed information, intelligent speed assistant, etc. ISA can be categorized in different types, depending on how intervening (or permissive) they are (Morsink et al., 2006):

Table 3-1. Overview of different types of ISA (Morsink et al., 2006)

Level of support	Type of feedback	Definition
Informing (open)	Visual	The speed limit is displayed and the driver is reminded of changes in the speed limit.
Warning (open)	Visual/auditory	The system warns the driver when exceeding the posted speed limit at a given location. The driver decides whether to use or ignore the information or warning.
Assisting (half-open)	Haptic throttle	The driver gets a force feedback through the gas pedal if he/she tries to exceed the speed limit. Overruling of the system is still possible
Restricting (closed)	Dead throttle	The speed of the vehicle is automatically limited and the driver cannot overrule the system.

ISA can use three types of limits (Carsten & Tate, 2005); static speed limits (posted speed signs), variable speed limits (information about speed limits depending on the location) and dynamic speed limits (information based on actual road and traffic conditions).

Since the early 1980s the effects of ISA have increasingly been studied through different methodologies and data collection techniques, varying from traffic simulation, driving simulators, instrumented vehicles and field trials. Based on the outcome of the research, the relevant social, ecological, economical, political and technical aspects are described. This leads to an overview of barriers and issues that have to be resolved to enable large scale implementation.

3.2 Research on ISA

3.2.1 ISA field trials

One of the very first trials that were held was in France in the 1980s. Drivers tested a system related to a cruise control, which did not automatically set the correct speed (Saad & Malaterre, 1982). In the 1990s, new small tests were conducted in Sweden and the Netherlands. The drivers mostly drove in an instrumented vehicle on a test-route (Warren, 2006; De Waard & Brookhuis, 1999). In the late '90s different trials within a larger setting and with more vehicles started around Europe and in Australia. The most recent trials are described below.

Between 1999-2002 the Swedish National Road Administration (SRA) conducted a large-scale trial involving ISA in urban areas (Biding & Lind, 2002). The aim of the trial, which was conducted jointly by the SRA and four Swedish municipalities, was to learn more about driver attitudes and how they use the systems, the impact on road safety and the environment, the integration of the systems in vehicles and the prospects for ITS on a large scale. The systems were tested in Borlänge, Lidköping, Lund and Umeå, where the local authorities were responsible for running the trials in their respective municipalities. Different systems and technical solutions have been tested at the different trial sites. In Umeå a warning system was tested, where the driver received a warning signal (audio and visual) when the legal speed limit was exceeded. In Borlänge, a system was tested that used audio and visual warnings for violations of the speed limit and, in addition a display informed the driver about the existing speed limit on the road in question. In Lund, a system was tested that supported the driver's speed adaptation through an active accelerator, which implies that when the driver has reached the legal speed limit a counter pressure is applied to the accelerator. In Lidköping, both informative and active accelerator systems were tested. The results showed that, in general, positive effects on speeding behaviour were noted. The average speed on stretches of road has clearly fallen with ISA. The ISA vehicles ran more homogeneously and with less variation in speed, which probably increased safety even more. The acceptance of ISA in urban area was noted as rather high, compared with the acceptance of seat belts' use. Effects on speed differed very little between the systems. The driving speed fell on stretches by up to 3-4 kph for each of the systems. The difference between the systems for the entire road system at 30-50 kph, which is the main focus of the trial, amounted to only 0.3-0.4 kph.

Around the same period, in 1997, a national study in the UK started, using field trials and driving simulator studies during three years. In the field trials, test drivers tested two different intervening systems (Carsten & Fowkes, 2001). One of the systems could be switched on and off at will, while another was on at all times. The test drivers were divided into three groups, with 8 test drivers in each group. One group tested the system that could be switched off and another the system that could not be switched off. The third group was a control group. The systems were tested on a 67 km long test route including 30, 40, 60 and 70 mph speed limits. The results showed that the test drivers, who were able to switch off the system tended to do so when the traffic conditions gave them an opportunity to violate the speed limit. In 2001, a new project started, called ISA-UK (Carsten et al. 2008). Four field trials were conducted in different parts of the UK. In these trials, 80 private and professional test drivers drove 20 vehicles that had a system installed for six months (during the first and last month the system was not activated). The system disabled the test drivers to exceed the speed limit without using kick-down or pressing an emergency button. The behavioural results from the car trials showed that the overridable ISA that was used by the participants reduced the amount of speeding among every category of user. It also affected driving on every road category, except for the 60 mph rural roads where comparatively little speeding by the participants in the pre-ISA period was found.

Between October 1999 and October 2000 (AVV, 2001), 20 private cars and one bus equipped with a death throttle system (closed ISA) drove in a suburb of the city of Tilburg, the Netherlands. The goal of the trial was to demonstrate the feasibility of ISA as a speed management measure. Public acceptance and support for ISA was measured and information was collected about the technical requirements and functionalities, and the effects on driving behaviour. The trial consisted of 30, 50 and 80 kph speed limits. In total 120 drivers participated in the trial, each for 8 weeks. In the first two weeks, the system was switched off. After the first two weeks of each period, the system was activated, making it impossible for the test drivers to exceed the speed limits (unless the emergency button was pushed) whenever they drove within the test area roads. The speed limits could only be exceeded by use of the emergency button for deactivating the system. The results showed that the average speed, as well as the speed variation decreased.

In Denmark in 2001, 24 cars were equipped with an informative ‘sound and light’ system and the test-drivers drove for 6 weeks (Lahrmann et al., 2001). The results of the trial showed a mean speed reduction of 5 to 6 kph in general, but also large variations between individual drivers were noted. The speed violations reduced from 9-13 kph without driving with ISA, to 4-7 kph during the test period (Nielsen & Lahrmann, 2005).

In 2000, during a field trial in Finland (Päätalo et al., 2001), three different ISA-types, namely informative, compulsory and recording, were tested. The information system provided information regarding the current speed limit on a visual display and gave an audio warning. The compulsory system was a closed system and limited the maximum speed of the vehicle to the posted limit. The recording system displayed the percentage of speeding of the total driving time. The 24 participants drove the car along a test route on four separate occasions. The results indicated that drivers spent less time speeding when driving with one of the ISA systems operating and the reduction was the most for the compulsory system (6.7 km/h). Results from the workload data revealed that drivers found driving with the compulsory system most demanding with regard to required attention and concentration.

In France, a series of field trials with ISA started in 2001 and this time two large car manufacturers, Renault and PSA, were participating in the project (Ehrlich, 2006). A pre-assessment phase was first carried out using two prototype vehicles. The study was then extended to 100 test drivers who drove an instrumented vehicle for eight weeks. After the first two weeks, when no system was activated, each test driver tested three different systems for two weeks each. The first system tested, informed the test drivers of the current speed limit and warned them if this limit was exceeded. The second system made it impossible for the test drivers to exceed the speed limit without using kick-down. The third system also made it impossible for the test drivers to exceed the speed limit, but this system did not have any kick-down function. First results indicated that the informative ISA is less effective than the other systems. Speeding decreased with every system.

In October 2002, an ISA-trial in Belgium was started in Ghent (ISAweb.eu, 2005; Vlassenroot et al., 2007). Thirty-four cars and three buses were equipped with the 'active accelerator pedal'. In this system a resistance in the accelerator is activated when the driver attempts to exceed the speed limit. A total of 90 drivers participated in the field trial. The test area covered roads with speed limits of 30 kph, 50 kph, 70 kph and 90 kph. Data analysis showed a reduction in the amount of speeding due to the ISA-system. There were, however, still a large remaining percentage of speeding offences, especially in low speed zones. Differences between drivers were large. For some drivers speeding even increased despite activation of the system. For less frequent speeders average driving speed almost always increased and for more frequent speeders average speed tended to decrease. With the system, less frequent speeders tended to accelerate faster towards the speed limit and drove exactly at the speed limit, which caused average speeds to go up.

A cross-cultural study with ISA was held in 2003 and 2004 in Hungary and Spain (Várhelyi et al., 2005). In this study 20 Hungarian and 19 Spanish test drivers had two different systems installed in their vehicles for two months each (one month with the system activated and one month as a control period). Both systems informed the test drivers of the current speed limit. The advisory system used a sound and light system whereas the intervening system was an active accelerator pedal. The results showed that both mean speed and speed variation were reduced when driving with any of the two systems. The results also showed that the intervening system tended to be more effective than the advisory while, at the same time it was less accepted by the test drivers.

From February 2003 to March 2005 a trial was organized in Australia (Regan et al., 2006). In this trial 15 test vehicles were equipped with a warning ISA (visual and auditory signals), turning into an intervening ISA (upward accelerator pressure), if warning signals were ignored for more than 2 seconds. The vehicles were also equipped with a Following Distance Warning (FDW) system (aimed at preventing tailgating), a seatbelt reminder, a Reverse Collision Warning system (aimed to prevent collisions while driving backwards), and daytime running lights. A control group of 8 drivers was used. The control vehicles were not equipped with ISA or FDW. All 23 drivers drove at least 16,500 kilometres annually. The results showed a reduction in speed and speeding with ISA. The combination of ISA with FDW tended to have a better result than ISA alone.

In 2004, a new Danish trial started in North-Jutland (Lahrmann et al., 2007). The project is based on a 'Pay As You Drive' principle, which means that the ISA equipment not only gives a warning when the driver is speeding, but also gives penalty points which reduce a promised bonus of 30 % on the insurance rate. The project proceeded in a three-year test period with the goal to involve 300 car drivers as participants in the project. Results from 90 test-drivers showed that the percentage speeding of more than 5 kph on 80 km roads is reduced from 28% to 2%.

In December 2004 around 20 vehicles in the city of Stockholm in Sweden were equipped with 2 types of ISA: an active accelerator pedal and a vibrating accelerator pedal, which vibrated when the speed limit was exceed (Myhrberg, 2006). The purpose of the trial was to bring ISA knowledge and acceptance to Stockholm, necessary for the development of future ISA implementation. On average, ISA reduced speeding by 30%. The effect was noted better at higher speed limits.

In August 2006, a trial started in Karmøy situated on an island in Norway with young drivers between the age of 18 and 25 years (Berg et al. 2008). Insured customers of a certain company were invited to participate in the project. The participants received a 30 % discount on their car insurance premium during the 17 months test period. The ISA equipment was a warning system with sound and light. The participants were divided into three groups: participants motivated by traffic safety, participants motivated by the 30 percent discount on the car insurance, and participants motivated by both. The analysis shows that safety motivated drivers drove more carefully in terms of the amount of speeding than economically motivated drivers. Attitude data and participants' expectations with respect to the technology showed the same distinction.

Not much is known concerning the long-term effects of ISA use on the drivers' speed choice behaviour (long term being considered as more than a year's period). A study in Sweden (Börlange) showed that for the Assisting (half open) ISA the effect of ISA decreased year after year (Warner & Aberg, 2008), between 1999-2003.

3.2.2 ISA main results

Generally, ISA seems to have positive effects on driving speed and speed violations. The effects depend on how intervening the systems are set. A restrictive ISA seems more effective in reducing speed and speeding than an advisory ISA. Below a number of aspects concerning ISA are elaborated.

Safety effects

The most detailed prediction of overall network savings with ISA is provided by Carsten and Tate (2005). Table 3-2 shows the estimates of the overall system-wide collision savings for Great Britain, at various levels of collision severity, for various permutations of ISA. The scenario envisaged is that 100% of vehicles are equipped with ISA overnight.

Table 3-2. Best estimates (BE) of crash savings by ISA type and crash severity, assuming a penetration rate of (nearly) 100% (Carsten & Tate, 2005)

System type	Speed limit type	BE of injury crash reduction	BE of fatal and serious crash red.	BE of fatal crash reduction
Informing	**Static**	10%	14%	18%
	Variable	10%	14%	19%
	Dynamic	13%	18%	24%
Voluntary automatic control	**Static**	10%	15%	19%
	Variable	11%	16%	20%
	Dynamic	18%	26%	32%
Mandatory automatic control	**Static**	20%	29%	37%
	Variable	22%	31%	39%
	Dynamic	36%	48%	59%

ISA systems are divided into the broad classes of Advisory, Driver Select, and Mandatory systems. Advisory ISA displays the speed limit and reminds the driver of changes in the speed limit. Voluntary ISA is linked to the vehicle controls but allows the driver to enable and disable control by the vehicle of maximum speed. With Mandatory ISA, the vehicle is limited at all times. Each broad class of ISA can have speed limits in fixed, variable or dynamic forms (where dynamic also includes variable capability). With "Fixed" speed limit data, the vehicle is informed of the posted speed limits. With "Variable" data, the vehicle is additionally informed of certain locations in the network where a lower speed limit is implemented. With “Dynamic” data, additional lower speed limits are implemented because of network or weather conditions, to slow traffic in fog, on slippery roads, around major incidents, etc. Thus, with a Dynamic system, speed limits are current in terms of time.

Effects on the environment
It is expected that ISA will have a positive effect on fuel consumption, emissions, dust and noise. Not many research initiatives focused on the effects of ISA on the environment, although some results can be mentioned from field trials. In Sweden, Várhelyi et al. (2004) noted a reduction of CO by 11%, NO_x by 7% and HC by 8% in a 50 kph-area. In the Australian trial, Regan et al. (2006) noted a 4% reduction of fuel consumption and a 4% reduction of CO_2 emissions, when ISA is used in combination with FDW on 80 kph zones.

It is also noted that the effect of speed on emissions is complex. The optimum speed, the speed at which emissions are minimized, varies according to the type of emission and type of vehicle. Typically, pollutant emissions are optimized for constant speed of 40-90 kph. It should also be noted that, in steady driving conditions, CO and CO_2 emissions, in terms of g/km travelled, are highest at very low travel speed (15 kph or less) (OECD, 2006).

Liu et al. (1999) studied the ISA effects on network efficiency, fuel consumption and emissions through detailed micro-simulations. The ISA effects were modeled for the urban network in the morning peak and in the off-peak, rural two-lane road and motorway. Predicted fuel savings were 8% for urban peak, 8% for urban off-peak, 3% for rural road and 1% for the motorway at an ISA penetration level of 100%. Furthermore, they found that the emissions of CO, NOx and HCs varied by only +/- 2% for all ISA penetration rates.

Effects on traffic efficiency
Research concerning the effect of ISA on traffic efficiency is limited but the overall perspective seems good. Biding and Lind (2002) did not find any effects of ISA on travel times. It is assumed (Hogema et al., 2000) that a higher capacity and a more homogeneous traffic flow would be achieved due to ISA adjustments of the speed. Swedish trials also showed that drivers of vehicles equipped with ISA approached roundabouts, intersections and curves smoother in terms of deceleration (Várhelyi and Makinen, 2001).

Side Effects
Different studies indicated that the vehicle following gap reduced (Persson, 1993, Comte 2000), this lead to closer car following behaviour. Várhelyi et al. (1998) conclude that safer car following behaviour (bigger vehicle following gap) occurred on urban roads (30-50kph). However, on 70-90 kph roads the tendency was the opposite and driver vehicle gaps decreased (meaning riskier car following behaviour). Vahelyi et al. (2004) found no evidence that the behaviour of ISA drivers towards other road users improved. The assumed effect of ISA on give-way behaviour varies. Early research by Persson et al. (1993) indicated a slight increase in incorrect give way behaviour at intersections. Others found no negative effects (Várhelyi et al. 1998, 2004) or even a slightly positive effect (Almquist & Nygard, 1997 source Várhelyi et al., 1998). It is concluded that overtaking behaviour did not change (Comte, 2000; Várhelyi & Makinen, 2001) also no loss in vigilance was found (Comte, 2000).

Different trials indicated an increase in travel time. In 1998, Várhelyi et al. conclude that the travel time increase due to ISA was 2.5-2.8% depending on the country (Netherlands, Spain or Sweden). Other research also reports an increase in travel time due to ISA (Várhelyi &

Makinen, 2001;Liu & Tate, 2004) a small effect was found by Broekx and Panis (2004). Despite the increase in travel times, micro simulation showed that ISA does not lead to increased traffic jams (Liu & Tate, 2004).

Most studies indicate that ISA results in a reduced driver comfort. Várhelyi and Makinen (2001) report that drivers report to feel an increased frustration. Trials in the Brookhuis and De Waard studies (1997, 1999) indicate a slight increase in mental workload. Rook and Hoogema (2005) looked at the effects of ISA feedback force (for haptic throttle) on frustration level and workload. They found amongst others that high force ISA leads to more workload and frustration than low-force ISA. Comte and Jamson (2000) found no increase in workload.

Acceptance of ISA

Acceptance of ISA is one of the key elements for the (potential) success and effectiveness of the system. We can distinguish the users' acceptance, which give an indication on how users (test-drivers) cope with the system and the acceptability or support, which indicates in turn how potential users will react when ISA is implemented (Vlassenroot et al, 2008).

Morsink et al. (2006) describe an "acceptance versus effectiveness" paradox, the more effective ISA is on road safety (e.g. restricting ISA), the less accepted it is by the users. Brookhuis and De Waard (1999) showed that the acceptance of the system strongly depends on the mode of the used feedback. In the field trials in Hungary and Spain, a comparative study was made between an auditory warning system and active accelerator pedal (assisting system). In Hungary, most drivers preferred auditory and visual feedback to the haptic feedback pedal (Falk et al., 2004). However, it must be noted that comparison between the different systems is not that much researched (Carsten, 2002; Morsink et al., 2006).

Also drivers' characteristics are important for the acceptance of ISA. Jamson (2006) noted that frequent speeders were less likely to support an ISA system. Hjalmdahl (2004) found that drivers, who were willing to use ISA, already drove at a speed close to the speed limit, while those who drive fast wanted to abort the trial after using the system.

In most trials the acceptance of ISA increased after using the system in the trial, compared with the opinions they gave before they used ISA (Biding & Lind, 2002; Vlassenroot et al., 2007; Harms et al., 2007; Young et al., 2006). This indicates that trying the system and having experience will influence the user acceptance of ISA.

It has to be noted that, in general, the research on user acceptance varied a lot between the different trials (Vlassenroot et al., 2008) and no coherent acceptance indications were described. Carsten (2002) noted that the attitudinal research on acceptance of ISA could be criticized for not being sufficiently rigorous.

Over the past years, some studies were done to determine the willingness to pay for ISA. Interesting are the studies performed after trials, questioning people regarding their willingness to pay before and after they used ISA. After the Swedish pilots, people who had the experience with driving with ISA were asked whether they wanted to keep the system after the trial. Only 28.4% indicated to be willing to keep the system. Drivers indicated to be willing to pay an average of 90 Euros' to keep the system. The market value was estimated to be 180 Euros on new cars, 155 Euros in case of retrofit. Over the past decade, other studies looked into the market price of ISA as well (Marchau, 2000; Argiolu & Van der Pas, 2006).

Public Support or acceptability of ISA

Not much research was conducted during the trials on the acceptability of ISA by non-ISA users. De Mol et al. (2000) did a large-scale questionnaire in Belgium about the public support for speed measures, including ISA. Most of the respondents did recognize that speed and excessive speed is a problem. The acceptability of ISA was quite large; the mandatory ISA-system was not accepted by 30 %, advisory ISA was accepted by 82 %. Outside built-up areas 47 % were not in favour of a mandatory ISA, and on motorways 60 % did not accept mandatory ISA. In built-up areas almost 70 % accepted mandatory ISA.

In the SARTRE project (2004) over 24,000 drivers in 24 European countries were interrogated about road safety issues. One of the questions concerned the perceived usefulness of a system that prevents exceeding the speed limit. Less than 50% in Northern Europe, about 55% in Western and Eastern Europe and about 65% in Southern Europe would find such a system very or fairly useful. Piao et al. (2005) report results from a survey on ISA in three European cities. In all three cities there was a strong support for an informative ISA but very little support for a haptic throttle or restricting ISA. Up to 70% of the drivers said they would like to use ISA systems in residential areas.

Legal aspects

Legal aspects are often mentioned as a barrier for ISA implementation (Marchau et al., 2006) In general, research shows that most ISA system do not intervene more with the driving task than other available systems on the market. Based upon this some authors argue that the clarification of the product liability will not be a problem (Goodwin, 2006). Jamson et al. (2006) mention that there are regulations that label it an offence to modify braking systems. This makes it complicated to implement a system that more strongly intervenes with the driving task by braking by the vehicle. Furthermore, systems that draw power from the vehicle need to be approved and tested by an approved test organization before it can be implemented. Van Wees (2004) did a very elaborate study into this subject for the Netherlands and clearly pinpoints which additional legislation is desirable. Van Wees argues that there are some complex legislative problems before the ISA can be implemented in the EU. Furthermore Van Wees states that in case of ISA mal-functioning the user can give reason for an imputability defense, which has the likelihood of succeeding. In order to implement ISA Van Wees (2004) advised to implement explicit legal regulations either risk and liability regulations or traffic insurance regulations. To which extent the absence of this legislation is a barrier for ISA implementation remains unclear.

In the PROSPER-project (Project for Research On Speed adaptation Policies on European Roads), SWECO (2005) did a study on legal matters concerning ISA based on expert opinions. They concluded that systems who would be introduced on a voluntary basis, no major legal risks would appear since the actors concerned, will mainly have the same responsibilities/liabilities as of today. Common for all the respondents is that the driver is always responsible for her/his driving. However, if intervening ISA systems would be put on the market in combination with a mandatory introduction, the legal situation would change. They noted that the driver wouldn't be in complete control of the vehicle at all times while driving. SWECO (2005) also noted that the industry is more in favour of an informative ISA. The authorities responsible for road safety are more supportive to the principle of ISA system controlling the vehicle speed. A main conclusion in PROSPER was that ISA implementation on the European road network is more connected with organizational difficulties and challenges than with legal risks and constraints.

3.3 Ongoing issues towards implementation

The potential of ISA has been recognized, trials indicated that the ISA technology works, and that ISA has a considerable potential to contribute to traffic safety. Furthermore, it is generally considered that the effects of ISA on road safety, the environment and the quality of life are beneficial and, as indicated above, policymakers are shifting more and more from technological and behavioural research towards the implementation aspects of ISA. Traffic safety problems are huge and, moreover, transport traffic safety goals are not met, making the question ‘Why does ISA implementation go so slow?’ a relevant and unavoidable one.

To reach the stage of a ready-for-implementation ISA, a lot of research was conducted during the past 15 years. However, considering the research setup of the trials it is noted that every research and every trial had its own method and approach. This makes comparison between results of different trials very difficult. Carsten (2002) noted the missed chances within the ISA trials. Until today no systematic investigation of the impact of the different levels of ISA intervention has been made. Long-term effects of ISA on driving behaviour are poorly investigated. The acceptability of ISA or what kind of system would be preferred by potential users has only been investigated on a small scale and no in-depth analysis has been made.

Discussions about implementation of ISA have been carried out since 2002 (Carsten, 2002), but there are still issues that have to be resolved, e.g. regarding the technical architecture and speed limit databases implementation and maintenance.

3.3.1 Technology developments and speed information databases

Although there is no sign of ISA implementation in the road transport system yet, policymakers recognized the potential of ISA and stimulated research on different levels.

Many research activities funded by the European Union have constructed a framework which is of great use in the development of a speed limit database: SpeedAlert (2005) investigated and developed a framework to harmonize the in-vehicle speed alert concept definition, and to investigate the first priority issues to be addressed at the European level, such as the collection, maintenance, and certification of speed limit information. In the research of ActMap (Flament, 2006) mechanisms for online incremental updates of digital map databases in the vehicle was investigated and created. In the MAPS&ADAS subproject of PREVENT, the use of digital maps as primary and/or secondary sensors for ADAS was investigated.

Besides these European projects, many national initiatives were undertaken. In Sweden (NVDB project, 2000), and Finland (DIGIROAD project, 2006) the speed limit database is seen as a part of the national road database, which contains different kind of road information. In Denmark the registration is based on all speed signposts in the county of North Jutland, including approximately 22,000 km of roads. A GPS logger, with a special designed keyboard, has been used for this purpose. This special keyboard made it possible to gain this information in only about four weeks. In the Netherlands, a speed limit database has been made available on the Internet, which should become 98% accurate in two years time. The information could be filled-in online. In Belgium (De Mol & Vlassenroot, 2006), the Flemish Government started to make a digital inventory of every vertical road sign, including speed limits on all types of roads.

It can generally be concluded that, at European level the major technical guidelines and protocols have been developed. Within the national initiatives the focus was more on an operational level, concluding in legislations, national protocols, basic tools and field practices.

It is noted that still most of these activities are not fully known by policy-makers. If it can be said that today the focus on ISA research has shifted more and more towards developing implementation strategies for ISA, a central notion is that policymakers do not have a clear picture of the ITS conditions, goals and concepts contributing to road safety or mobility. A certain risk-avoiding attitude towards ISA can be noted among policymakers, who still are the key-figures in conducting implementation of ITS.

3.3.2 Implementation barriers

Over the past decade research has been carried out regarding barriers for implementation. When it comes to ISA implementation several barriers can be derived from the literature (ETSC, 2006; Marchau, 2000). In general it can be said that legislation, technical reliability, and the benefit to the user were important barriers for implementation:

Liability aspects
Both in the PROSER as in the FADAS research, experts indicated that liability issues and legislation were the most important barriers for implementation of ISA. Most investigators (legal experts), however, point out that the reliability issues for the informing and warning types of ISA are by no means different than that of other driver support technologies that are currently implemented on a large scale (Albrecht 2005 cited in Goodwin, 2006). For the more intervening types of ISA (half-open and closed ISA), this might be more difficult especially when introduction takes place of a mandatory system (Sweco, 2005).

Reliability issues
Trials in many countries have indicated that ISA is a proven technology. There is still room for improvement but there is no reason for extending implementation for reliability issues. Technology will keep on being improved in the meantime. Important issues are indicated to be related to the HMI (Human-Machine Interaction) interface (FADAS, PROSPER, ETSC). When it comes to reliability of the speed limit database, research shows that only few countries have a speed limit database that is accurate enough to use. However, as mentioned above, it is possible to create such a database within relatively short term.

The perceived benefit by the users
Although experts indicate that a major barrier for ISA implementation is the fact that users do not see the benefit of the system, this is contradictory to the results of different studies. The SARTRE 3 research (2003) interrogated drivers across the EU (23 countries). Overall, 60% of the drivers indicated to support more severe penalties for speeding (varying levels between 19% and 80%), contradicting the idea that people do not see the benefit of ISA. Furthermore, the SARTRE 3 survey also demonstrated that across Europe, about 55% of drivers would find a system preventing them to exceed the speed limit, “useful” or “very useful”. Research performed in the UK shows similar results (MORI, 2002). Furthermore, research shows that people who tried ISA are willing to use ISA on a voluntary basis. In Europe, between 60% and 75% of drivers who have tried ISA technologies, said they would like to have the system in their own cars (Peltola & Tapio, 2004.). Research performed as part of the pilot in Sweden, showed that ISA drivers indicate they are willing to keep ISA on a voluntary basis, and are even willing to pay for it (Adell, 2008).

So, on the one hand experts indicate that there are major barriers for implementing ISA; on the other hand experts prove that none of these barriers are really a barrier for implementation. To cope with these barriers over the past decade, researchers started gradually researching implementation strategies.

3.3.3 Implementation policies

Tate & Carsten (2008) made a study based on their field trials in the UK to predict the safety-impacts of ISA. It also examined hypothetical scenarios for ISA implementation and investigates how those scenarios might affect overall safety gains with ISA. Two alternative scenarios were examined, a market driven scenario in which drivers choose to adopt ISA and an authority driven scenario with more encouragement of ISA adoption. The analysis indicated that over a 60-year period from 2010 to 2070, the market driven scenario is expected to reduce fatal accidents by 10%, serious injury accidents by 6%, and slight injury accidents by 3%. The authority driven implementation scenario is expected to reduce fatal accidents by 26%; serious injury accidents by 21%; and slight injury accidents by 12%. The economic benefit associated with the predicted crash reductions under both the implementation scenarios outweighed the costs, thus justifying the deployment of ISA. The market driven implementation scenario resulted in benefit-to cost ratios in the range of range 1.8 to 3.0. The authority driven implementation of ISA produced benefit-to-cost ratios in the range 2.8 to 4.8.

Different investigators looked at new policymaking approaches to deal with the uncertainties surrounding ISA implementation (Agusdinata et al., 2005; Marchau et al, 2009; Van der Pas et al, 2007). They suggest new adaptive approaches to implement ISA. This involves strategies where you start implementing ISA on a small scale (e.g. only for young drivers in an area), learn regarding the uncertainties over time, and adopt the policy over time. To support building such adaptive policies new modelling approaches are used (exploratory modelling), this allows decision making regarding ISA implementation despite large uncertainty.

At the EU level (European Commission, 2008) a proposal for directive is made called “laying down the framework for the deployment of Intelligent Transport Systems in the field of road transport and for interfaces with other transport modes”. In this directive, together with the action plan for the deployment of ITS in Europe (European Commission, 2008), optimization of the collection and provision of road data, which also will conclude speed limit data is one of the action points. Some countries, as described before, already have these data but it seems that large-scale implementation actions are not made. In the mean while it seams that some local governments are not waiting for the initiatives made on national or regional level. It is noted that local governments are directly confronted with the problems that speed causes and therefore they want to take the initiative for themselves (De Mol & Vlassenroot, 2006). For example in the city of London (Keith, 2008), Transport for London (TfL) have produced, and will continue to maintain a digital map of all London's speed limits. This map has been made available free of charge to anyone who wishes to use the map for personal use in their own navigation systems, or to create commercial applications. Also TfL works together with companies and fleet owners to promote the use of ISA.

3.4 Discussion and conclusion

The last decades a lot of research concerning ISA has been performed. Several trials with different types of ISA have shown that ISA can be an efficient and effective way to reduce speed and speeding and as such have a positive effect on traffic safety. It is also expected that ISA will have a positive effect on fuel consumption, emissions, dust and noise. There is no doubt about the fact that ISA is among the most tested and investigated ITS. However large-scale implementation of the most effective ISA (Assisting and restricting ISA) seems far away. A point of criticism across all the researches is that the research on user acceptance varied a lot between the different trials and no coherent acceptance indications were described. It can be noted that the attitudinal research on ISA was not sufficiently rigorous which also gave the opponents of ISA the chance to criticize the benefits of the system. The many researches and trials gave the possibility to gain a better insight on the acceptance and behaviour of the drivers. Some investigators mention the acceptance versus effectiveness paradox; the more effective ISA is on road safety (e.g. restricting ISA), the less accepted it is by the users. This could make the implementation of ISA more difficult.

Additionally, ISA is one of those systems where the acceptance gets higher if the driver is enabled to test the system. Frequently it was said that you could talk about ISA as long as you wanted but the best to convince somebody of the benefits is to lead him or her drive with ISA.

All in all we can conclude that the test-phase of ISA is over and that implementation strategies should be developed, although some barriers were found. One of the major issues is the development of a speed limit database. National and regional initiatives are made and on European level – with the action plan on ITS – governments will be stimulated to develop a national digital road database. Some stakeholders also indicated that some legal issues needs to be resolved, especially when there would be malfunctions of ISA (certainly if a restrictive ISA is used). But it is also noted that these issues are not of such an order that it would make the introduction of ISA difficult; it seems that some problems are more connected with organizational difficulties and challenges than with legal risks and constraints.

If ISA were to be introduced, it would be more beneficial if governments would be involved in the implementation strategies of ISA. This could be done by supporting or creating a (technical) framework that would enable the use of ISA, or even actively promote ISA by giving subsidies or doing some other positive actions. We also noticed that local governments are taking the initiatives and are not waiting for the decisions that are to be made by higher (national) governments. Policy-makers have the key-role in the implementation of ISA because mainly they are the problem owners, so they should do things like: (i) to communicate about ISA; to create more observability and political awareness of ISA (e.g. like the initiative on ISAweb.eu); (ii) to look for niches and implement ISA where it can be successful and; (iii) to make a case for mandatory implementation because ISA is a preventive innovation and those who need ISA the most would never voluntary adopt ISA.

Initiatives taken by private companies to allow information about the speed limits or a warning if exceeding the limit in navigation systems can only be seen as a positive evolution in the use of ISA, but we conclude that after a test-period of 25 years the time has come to allow a broader public to experience the benefits of ISA. Only then an answer to the question how people react when using ISA in the real world would be given and maybe then we will know what the long-term effects would be. This would open new possibilities in the research field of Intelligent Speed Adaptation.

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4 Driving with Intelligent Speed Adaptation: Final Results of the Belgian ISA-trial

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Abstract
In October 2002 the first ISA-trial in Belgium was started in Ghent. Thirty-four cars and three buses were equipped with the "active accelerator pedal". In this system a resistance in the accelerator is activated when the driver attempts to exceed the speed limit. If necessary, the driver can overrule the system. The main research goals of the trial in Ghent were to evaluate the effects of ISA on speed-change, traffic safety, drivers' attitude, behaviour and drivers' acceptance. To study these effects of the ISA-system both surveys and logged speed data were analysed. In the surveys drivers noticed that the pedal assisted them well in upholding the speed limits and that the system increased driving comfort. Most important drawbacks were technical issues. Data analysis shows a reduction in the amount of speeding due to the ISA-system. There is however still a large remaining percentage of distance speeding, especially in low speed zones. Differences between drivers are large. For some drivers speeding even increases despite activation of the system. For less frequent speeders average driving speed almost always increases and for more frequent speeders average speed tends to decrease. With the system, less frequent speeders tend to accelerate faster towards the speed limit and drive exactly at the speed limit instead of safely below, which causes average speeds to go up.

4.1 Introduction

Excessive speed can be considered as a contributory factor in road accidents. Not only can it be the cause of accidents, it also defines the level of impact. Finch (et al, 1994) declared that reducing speed with 1 kph could lead to 3% less accidents risk. Inappropriate speed is involved in around one-third of the accidents resulting in vehicle occupant fatalities (ETSC, 1995).

In 2000, the European Union (2001) has set the ambitious target to reduce the number of fatal accidents by half before 2010. Many different European countries have therefore taken actions to increase road safety. One of these actions is the further development of intelligent transport systems that potentially have a significant role to play in road safety. Indeed, since Intelligent Speed Adaptation (ISA) is considered as a useful device to reduce inappropriate speed, it may contribute to increase road safety.

ISA is an intelligent in-vehicle transport system, which warns the driver about speeding discourages the driver from speeding or prevents the driver from exceeding the speed limit (Regan et al., 2002). Most ISA-devices are categorized into three types (ETSC, 2005) depending on how intervening (or permissive) they are. An informative or advisory system will only give the driver feedback with a visual or audio signal. A supportive or warning ISA system will intervene when the speed limit is overruled. For example, the pressure on the accelerator pedal will increase when the driver attempts to drive faster than the speed limit. A mandatory or intervening system will totally prevent the driver of exceeding the limit: the driver cannot overrule these systems.

Several trials are already held across Europe, with different types of ISA. In the Netherlands, a mandatory system has been used. The United Kingdom, instead, focussed on an advisory system (Carsten and Fowkes, 2000). In Sweden, a range of different types of systems was tested in different cities (Vägverket, 2002). Special focus in Sweden was on the “active accelerator pedal.” The same system is also used in the Belgian trial.

From October 2002 until January 2004, an ISA-trial has been held in the city of Ghent (Belgium). 34 cars and 3 buses were equipped with an ISA-system called the “active accelerator pedal”. To study the effect of the ISA-system on speed-change, traffic safety, drivers’ attitude, behaviour and drivers’ acceptance, surveys and analyses of driving data were held. In this paper, the results of this trial will be reported.

4.2 Background of the Ghent ISA-trial

In this trial, a half-open or supportive ISA-system was used. This system is better known as the ‘Active Accelerator Pedal (AAP) or ‘Limit Advisor’ manufactured by the Swedish company Imita. This system has a force feedback function, which is a mechanical resistance applied to the accelerator pedal as a distinct moveable pressure point.

The test area covered the city of Ghent, within the ring road R4. All legislated speed limits (30 kph, 50 kph, 70 kph, 90 kph) within this area were put on a digital map. Inside the test-area the system could not be switched off. Outside the test-area, the participants could choose to enter a speed limit manually to activate the system.

In total, 37 vehicles participated in the ISA-trial. 20 vehicles were owned by private test-drivers, 17 vehicles were owned by companies: 6 cars of the City of Ghent (1 of the Social

Services), 5 vehicles of the Ghent University, 3 buses of the regional public transport company, 2 vehicles of the Province of East-Flanders and 1 of Volvocars Ghent.

To recruit private test-drivers, advertisements were published in different media. Possible candidates could respond by letter to receive an application form. 108 drivers were retained as potential candidates. The drivers were selected from those 108 applicants based on technical feasibility of installation of the system inside the car, gender and age. It was difficult to have equal age and gender groups because a low number of women had respond. 20 candidates ere selected as test-drivers: 11 male and 9 female drivers. Also, not every selected driver was the only driver of the vehicle. The total number of voluntary drivers was 28, spread over the 20 private cars.

Companies selected their cars themselves, only based on the given criteria of technical feasibility of installation. The gender and age of these test-drivers were not known in advance. By these selected cars it was assumed that there would be more than one driver, for example the bus drivers. The total (restricted) number of test drivers was 62: 42 male and 20 female spread over different ages.

4.3 Research goals and methodology

The main research goals of the trial in Ghent were to evaluate the effects of ISA on speed-change, traffic safety, drivers' attitude, behaviour and drivers' acceptance. Two methodologies were used: (1) a behavioural study using questionnaires and (2) data-logging. The questionnaires were held once before driving with the AAP, during the trial (AAP active) and at the end of the trial. Data logging was done during whole the trial.

4.3.1 Measuring the carrying capacity

How people think about mobility in relation to speed and excessive speed was a major issue of interest. It was considered that people's attitude about speed and speeding can have a main influence on their driving behaviour with ISA and, furthermore, in their acceptance of ISA. To determine these attitudes, a research method in a study carried out previously by the Belgian Road Safety Institute (BIVV) and the Centre of Sustainable Development / Ghent University was adopted (De Mol et al., 2000). This study measured the acceptance of ISA by the general public. The method denotes how people see mobility and transportation in relation with road safety, especially with respect to speed, speeding and speeding restrictions. This carrying capacity is based on the attitudes and opinions given by individuals, which stand for the general public. The concept determines several layers with mutual relations and will be explained in more detail below (see Figure 4-1).

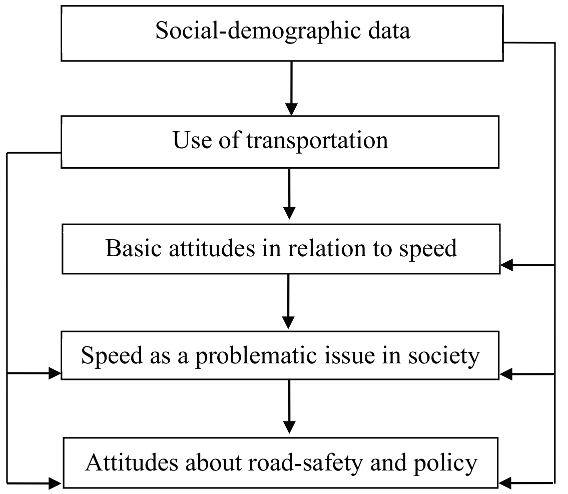

Figure 4-1. Framework for measuring the carrying capacity

Socio-demographics and the use of transportation
Socio-demographic issues and individual transportation habits are assumed to act as the 'basic' factors for the creation of a carrying capacity. These determinants will influence almost all the layers of the model.

Basic attitudes
Furthermore, it is assumed that driving behaviour is influenced by habits, rational decisions and emotional impulses (Levelt, 1998). Slotegraaf (1997) declared that vehicles are not only a mode for transportation but also a way of expression with some symbolic sense: in this relation it can be seen as a manner of self-expression and social positioning (status). In a certain way, attitudes also denote how people come to rational decisions. Behaviour in traffic is determined by the intentions people have, which are determined by the positions or attitudes that people have in traffic. In this study, attitudes must be seen as the positions taken by individuals about traffic and traffic safety issues.

The basic attitudes in this research denote how people see mobility and transportation, in particular the perception of speed in relation to motorised vehicles. The basic attitudes were: 'driving is only satisfying with a nice car'; 'speeding is exciting'; 'drivers have to be too aware of other road users'; 'if I drive, I live it up'; 'driving fast saves time'; 'a car is only for use of transportation'; 'driving fast is liberating'; 'people should be stimulated to use the car less'; 'driving fast is fun'.

A problematic issue in society
A social carrying capacity is also determined by 'being a (problematic) issue in society' (Molin, 1998). If there is no social indication that there is a problem about road safety, speed and speeding, future acceptance on ISA will be hard to achieve.

These indications are related to the actual situation on road categorisation and speed limits, and how people see their own behaviour on speed and speeding. Questions were posed about how people see the relation between road accidents and speed; in which conditions speed and speeding will be a problem; determination of speeding behaviour; and the feeling of insecurity.

Attitudes about road safety and policy
Some of the abstract norms and values are made concrete in issues concerning how people think about road safety measures. At this level, the 'real' discussion on possible acceptance will take place.

These 'layers' can be interpreted as sequential: the basic attitudes will determine how issues about speed and speeding will be notified as problematic and how people will experience the policy on road safety to handle the problem of speeding. For example: A driver, who describes his car as liberating and exciting and drives fast, will not recognise speeding as a problem. This driver will also not see measures taken against speeding as a priority or as being useful.

4.3.2 Measuring the acceptance of the ISA-device

Two major methods were used for measuring the acceptance of ISA. The first method was the procedure of Van Der Laan, Heino and De Waard (1996). Acceptance is measured by direct attitudes towards a system and provides research with a system evaluation in two dimensions. The technique consists of nine rating-scale items. These items are mapped on two scales, a scale denoting the usefulness of the system, and a scale designating satisfaction. A second method was defining the voluntary use of the AAP. Outside the test-area the system could be activated manually (or voluntary). Both questionnaires as well as data-logging were held.

4.3.3 Data-logging

Source data
For this project all the vehicles were equipped with a data logger. The logging was started as soon as the ignition was turned on. The downloaded data were stored in a SQL-database for further analysis. To exclude incorrect loggings, a filter was applied on all fields. Due to these filters, 19% of all data was withdrawn. From around 99 million loggings, 80 million loggings are used for further analyses.

During the project several problems occurred related to the logging of the data: the system did not log according to the initial specifications. There was no logging of 'feedback active'. Therefore, it was not measured directly whether a feedback (pressure on the accelerator pedal when exceeding the speed limit) was provided to the driver. Also in the period before activating the ISA-system (26 October 2002) reference measurements were carried out to analyse the driver's behaviour in normal conditions. When analysing the first logged data, the data revealed that the speed measurements were not correct. This was due to the fact that before activating ISA, most of the loggings were done outside the ISA-zone, and therefore the speed logging was not correct. Because it was not possible to recover the data for the reference period, the demo had to be prolonged with a reference period after the ISA-active period. In this additional period, the feedback of the accelerator pedal was deactivated but not the display of the speed limit. So in a way this resulted in an open ISA instead of a non-ISA reference. Therefore to describe the results of the logged data, the indications of 'AAP active' and 'AAP inactive' are used instead of 'ISA' or 'No ISA.' Also it must be considered that the drivers had experienced driving with the AAP, so for the time of deactivation, awareness of the implemented speed limits; of driving the correct indicated speed limit could have been occurred. These remarks should be kept in mind while reading the results of the logged data.

Analysis of driving data

Several studies have already been undertaken to study the behavioural impact of Intelligent Speed Adaptation systems (ISA). These studies have indicated the positive effects of ISA on speeding behaviour. However, how these effects are calculated varies significantly among studies. In Päätola (et al., 2001) average speeds and the number of made speed violations were analysed. Average driving speed is hereby calculated by taking the mean value of recorded loggings. Distinction has been made between overall driving speed and driving speed without stops, stops being defined as speeds below 1 kph. Effects on speeding are examined by comparing the percentage of time that drivers speed. Average speeds for the Tilburg trial are calculated similarly (AVV, 2001). Data are however grouped for specific road sections. Besides average speeds, speed distributions and standard deviations were calculated to study the effect on driving behaviour.

Some studies only use a limited selection of logged data. For instance, data analysis for Spanish and Hungarian trials in the European PROSPER-project focuses on mid-block speed data (Várhelyi et al., 2005). This limits the analysis to top speeds. Using mid-block speeds, the effects of ISA are expected to be more significant compared with the analysis of complete data sets as lower speeds at; for example, intersections are not taken into account. Effects on acceleration behaviour below the speed limit are also not included. In Várhelyi (et al., 2004) acceleration behaviour is looked into separately by analysing data over a distance of 80 meters before mid-block location. A selection of mid-block speeds implies that a choice has to be made on the locations to be analysed. Which locations are selected could significantly influence the results. The risk of including logging errors or errors in speed maps is however limited.

In the European MASTER-project speeding behaviour on specific stretches was analysed. For every 10 metres along these stretches, logged speeds were recalculated by interpolating measured speeds on nearby locations (Várhelyi et al., 1998). By interpolating speeds to fixed locations, a bias towards slow speeds would be avoided. This bias can occur due to the fact that a higher number of loggings per metre are recorded at slow speeds compared with high speeds, causing slow speeds, which were logged more, to be weighted heavier in the calculations. A similar method was used to study the effects of an informative ISA-system in Denmark where the number of logs per meter is equated with a number of fictive log records (Madsen, 2002).

To study behavioural effects for the Ghent trial, the following parameters were examined: average speed, standard deviation, 85 percentile speed, percentage speeding and speed distribution. All data are included to avoid the impact of the choice of locations on the results. These parameters are calculated both time-based and distance-based. A time-based calculation signifies that all logged data are weighted equally. Time-based speeds are based on average speeds at which people travel per second. This means that zero speed (0 kph) is incorporated in the calculation of average speeds. These calculations are useful to estimate effects on travel time. Distance-based speeds are calculated based on average speeds at which people travel per metre. Idling is not incorporated in the calculation as no distance is covered and higher speeds are weighted more heavily in the calculation of averages as more distance is covered per second. A bias towards slow speeds is hereby avoided. Only distance-based results are reported in this paper.

4.4 Results on the carrying capacity

4.4.1 Basic attitudes in relation to speed

The results from the study indicate that ISA has a certain effect on the drivers' opinion on basic attitudes. Basically, most of the drivers did not think that driving fast is fun (average, more than 70%), or exciting (average, more than 53%). Their opinions about these issues did not change dramatically during or after the trial. More people agreed on 'driving fast is liberating' during (79%) than before (69%) or after (71%) the trial. More than 75% did not agree with the attitude 'if I drive, I live it up', although this opinion increased (84%) during the trial and decreased (74%) afterwards. Before the trial, 1 out of 5 drivers agreed that 'driving fast saves time'. During the trial only 5% shared this opinion and after the trial, only 1 out of 10 thought that 'driving fast saves time'. Before (84%), during (82%) and after (86%) the test, a huge majority agreed that 'people should be stimulated to use the car less' and that 'a car is only a way of transportation' (around 70%). Before the trial, 38% thought that 'driving is only satisfying in a nice car'. During the test, most of them (43%) were neutral, while after the trial most did not agree.

4.4.2 Speed and speeding as a problem

The attitudes on speed and speeding were analysed before, during and after the trial. The following possible attitudes were given to the test-drivers: 'speeding is dangerous'; 'speeding is sportive'; 'speeding is reckless'; 'speeding causes the most traffic accidents'. Although their opinions changed during and after the trial, most of the drivers confirmed that speeding is 'dangerous', 'reckless' and 'not sportive'. The most remarkable changes were about their opinion of 'speeding causes the most traffic accidents': 74% were agree before, 69% during, and 56% after the trial.

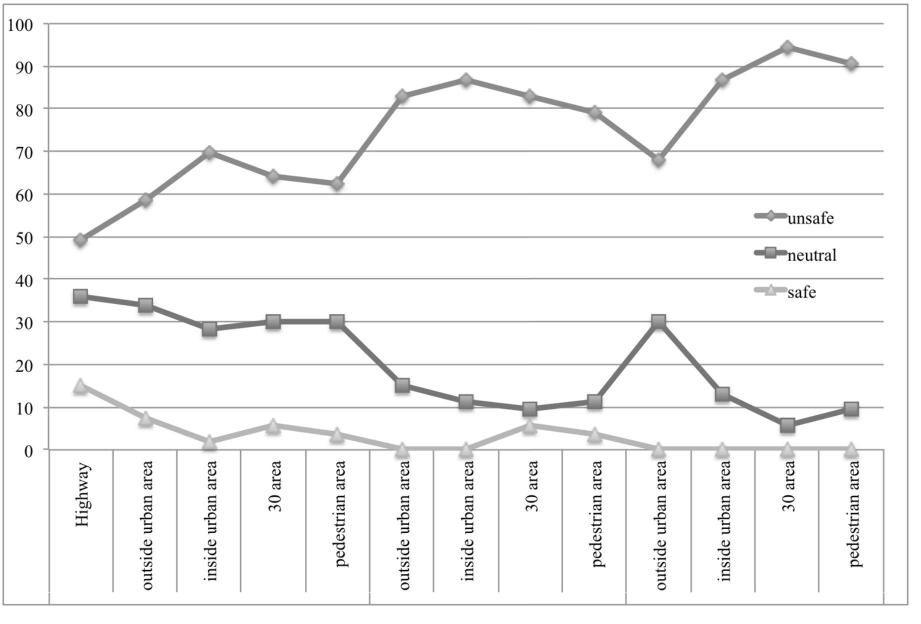

Figure 4-2. Feeling of insecurity in different roles

The drivers were also asked if they felt safe or unsafe when they saw other cars driving too fast in different speed areas (see Figure 4-2).

The respondents would never feel safe as a pedestrian in any speed area when other cars were driving too fast. The test-drivers felt the most insecure as a pedestrian in 30 kph area (94%) and pedestrian areas (90%). As drivers, 49% felt unsafe on highways, 70% in urban areas when they noticed other cars driving too fast. As cyclist, 87% felt unsafe in urban areas, 83% outside urban and 30 kph areas, and 79% in pedestrian areas.

4.4.3 Road safety policy and measures taken against speeding

The test-drivers were asked their opinion about the different speed limits in different areas. On average, more than 60% of the drivers declared before, during and after the trial that the speed limits are good in all areas. Remarkably, however, during and after the trial, more and more drivers claimed that speed limits in 30-areas (23% before, 36% during, 41% after) and pedestrian areas (82% before, 61% during, 51% after) are too low. The main reason was that with the AAP, they were forced to adhere to the speed limits in these areas. Most drivers said that ‘driving 30 kph or 15 kph is too slow’, although they did not want to declare that ‘30 kph areas and pedestrian areas are not useful for road safety’.

The test-drivers were asked two questions about measures taken against speeding: how important is it to take actions against speeding in different speed areas, and which methods are the most appropriate?

The test-drivers declared that taking action against speeding is a priority in urban areas (53%), followed by 30 kph zones (51%), pedestrian areas (47%), outside urban areas (34%) and highways (28%). However, the respondents argued that it is not important to take measures against speeding on highways. According to the respondents, they believed that the best methods taken against speeding are police controls and speed cameras, followed by speed bumps. Road safety campaigns were not believed to be effective.

4.5 The drivers’ acceptance of ISA

4.5.1 Acceptance scaled on usefulness and satisfaction

All drivers (total) accepted the active accelerator pedal (see Figure 4-3). After the trial, they experienced the pedal as being even more satisfying. The most pleased with the active accelerator pedal were the private drivers. During the project, they found it more useful but less satisfying than after the project. The most remarkable change is seen by the non-private drivers: while during the project they experienced it as not satisfying, although useful, they declared it was more satisfying and useful after the trial.

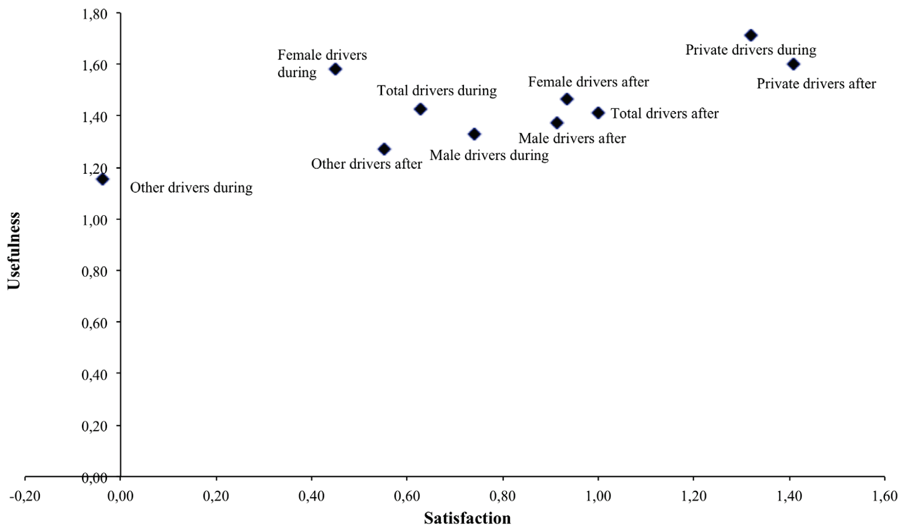

Figure 4-3. Acceptance, scaled on usefulness and satisfaction of the active accelerator pedal

4.5.2 Voluntary use of the AAP outside the test-area

The drivers were also asked if they used the AAP manually (voluntary) outside the test-areas, and if so, on which roads. Mostly, it was used on highways (56% during, 60% after) and outside urban areas (56% during, 50% after), less in urban areas (46% during, 41% after) or 30 kph roads (33% during and after) outside the test area.

Additionally, the data logging provides information on when drivers are outside the ISA-zone. However, no speed limits were available in these areas and the gas pedal was not activated. Drivers did however have the possibility to manually insert the speed limit into the system. This manual mode caused the active gas pedal to be operational. Whether the system was activated or not, was logged during the trial. The speed limit, which was inserted by the test-drivers, was however not recorded. Some drivers for instance stated in the survey to insert a speed of 130 kph on 120 kph roads to use the pedal as some kind of cruise control. Nevertheless, the percentage of loggings where the ISA system was manually activated is still a good indication of the willingness of people to use the system.

Results in Figure 4-4 below show that in about 30% of the time, a speed limit was manually inserted into the system. This percentage tends to increase as the trial continues. The percentage in month 7 is much lower than in other months: the holiday period and festivities in the city centre could explain this decline; for example vehicles from organisations were used less. During the deactivation period, the system could not be manually used outside the area, therefore it must be noted that the strong drop in figure 4 during the deactivation period is only caused by the difference in time when the AAP in the cars were deactivated. This period started half September and ended half October.

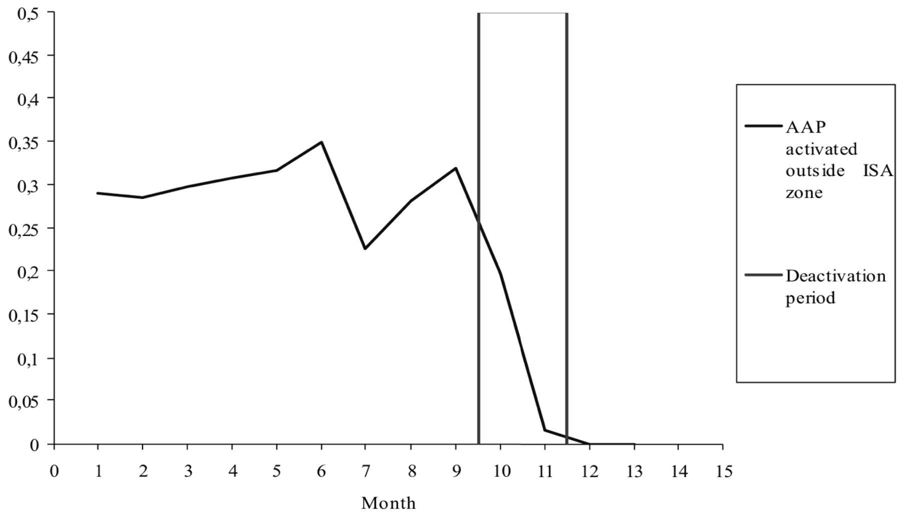

Figure 4-4. Percentage of loggings outside ISA zone with AAP manually activated

At the end of the trial, the private test-drivers could choose to keep the ISA-system in their car. 15 private car holders chose to keep the system in the vehicle after the test-period, which is a significant indication that there is an acceptance of the active accelerator pedal. The main reasons given for keeping the system was that it was assisting, comfortable and provided relaxed driving.

4.6 Driving behaviour with ISA

To conclude, based on the questionnaires, we report the most remarkable experiences expressed by the drivers:

- 3 out of 5 drivers declared that they drove more comfortably and relaxed than without ISA
- 1 out of 3 drivers declared that they had more consideration for other road-users.
- The drivers looked less often at the speedometer and they let their foot 'rest' relatively often on the counterforce of the accelerator pedal, even as some of them tried to drive in such way that the pedal would not be activated.
- Most drivers did not notice any difference while driving with or without the active accelerator pedal with respect to looking at the speed signs, recognition of and involvement in certain traffic situations or keeping distance with other cars. If they experienced some changes it was more in favour of driving with ISA.
- 1 out of 2 test-drivers declared that they less overtook while driving with ISA.
- 1 out of 2 drivers found it easier to keep a constant speed with ISA.
- The ISA-system assisted them well to maintain the right speed. Certainly for upholding the 30 kph limit of which they noted that it was not an easy speed to drive at without assistance.

4.7 Aggregated speeds

Table 4-1. Driving speeds average, standard deviation and 85 percentile of test area

Speed limit	Km driven	AAP Inactive V	SD	V85	AAP active V	SD	V85	Change in V	SD	V85
30 kph	5569	23.8	11.4	39	23.8	10.2	36.5	0	-1.2	-2.5
50 kph	95509	30.9	14.9	49.9	31.6	14.6	49.6	0.7	-0.2	-0.4
70 kph	13297	47.5	19.3	71.3	47.5	19.1	68.9	0	-0.2	-2.5
90 kph	17194	69.1	19.3	89.4	68	17.6	86.9	-1.1	-1.7	-2.5

V = mean speed, SD = standard deviation, V85 = 85 percentile

The average speed (V) indicated no significant difference between AAP inactive en AAP active (Table 4-1). Only at 90 kph, the average speed decreased with 1.1 kph. 90 kph-zones were mostly rural roads and it was assumed that frequent speeding without ISA would happen more in these area. In 50 kph-zones, where they drove the most, the average speed increased with 0.7 kph. A possible explanation of this effect was that 'slow drivers' – drivers who would not exceed the speed limit, but would rather drive under – were now driving more near the speed limit with the AAP. The V85 in the 50 kph-zones, where the change in speed was noted minimal (0.2 kph) when driving with AAP, could also show the effect as described before. To compare the driving speeds with and without AAP, the V85 could give a better indication because extreme 'fast speeding' was eliminated. In 30 kph, 70 kph and 90 kph areas, the driving speeds decreased with 2.5 kph, which prove the effect of the active gas pedal. It must also be mentioned that the drivers were still driving to fast with the AAP in 30 kph-areas. Some assumptions about driving behaviour in lower speed area are mentioned in the discussion / conclusion.

4.8 Speeding behaviour

4.8.1 Perception of speeding behaviour

Compared with their speeding behaviour before ISA, the test-drivers declared that they were driving less fast during the project (see Table 4-2). On highways, the answer on 'never speeding' increased during the project with 49%, outside urban areas with 26%, in urban areas with 16% and in 30 areas with 7%. The answers on 'regularly speeding and mostly speeding' decreased on most categories during the trial. The answers given after the trial on 'never speeding' stayed level for outside urban areas, in urban areas and 30 roads.

Table 4-2. Perception of speeding behaviour (in percentage)

	Highway			Out urban area			In urban area			In 30-area		
	B	**D**	**A**	**B**	**D**	**A**	**B**	**D**	**A**	**B**	**D**	**A**
Not known	12.8	12.8	12.8									
Never	12.8	51.3	28.2	38.5	64.1	56.4	35.9	51.3	51.3	38.5	43.1	43.6
Sometimes	59	28.2	46.2	41	28.2	28.2	48.7	41	35.9	38.5	46.2	38.5

B = Before, D= During. A = after

4.8.2 Speeding

The percentage of the total amount of made speed violations of the test-drivers decreased when the active gas pedal was operational. Effects were largest in zones with the highest speed limit. Although speeding is reduced, there still remained a large percentage of speeding. Especially in the 30 km/h zone the effect on speeding was minimal, although the amount of speeding was high. The counterforce, exerted by the pedal, wasn't strong enough to discourage drivers to exceed the speed limit (see table 4-3).

Table 4-3. Percentage of distance speeding in test area

Speed limit	Km driven	AAP inactive	AAP active
30 kph	5569	45.90%	42.80%
50 kph	95509	14.70%	13.10%
70 kph	13297	17.60%	12.60%
90 kph	17194	13.50%	3.80%
Total	131569	16.30%	13.10%

4.8.3 Evolution of speeding

An important issue with making use of an active accelerator pedal was the applied counterforce. Speed offences can again become more frequent as drivers get used to the counterforce exerted by the pedal. To test this effect, loggings were compared on a monthly basis (see figure 4-5). Deactivation of the pedal took place for all cars during month 10 and month 11. In these periods both loggings with and without the AAP-system activated were logged. After these months only loggings without the system were recorded.

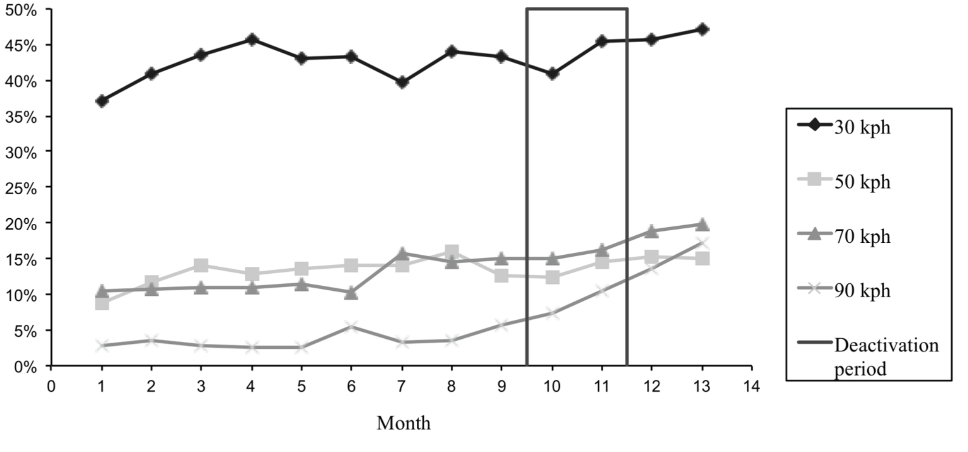

Figure 4-5. Percentage of distance speeding on monthly basis for different speed zones

In all speed zones, speed offences had increased in month 9, just before the start of the deactivation period, compared with the first month. In low speed zones speed offences increased rapidly the first three months and then staid more or less at the same level until deactivation. In high-speed zones the increase was more gradually.

4.8.4 Driver-specific analysis

The effect of the AAP system on total speeding was already mentioned. Effects of the system were largest in 90 kph zone and lowest in the 50 kph zone. Speeding remained by far largest in the 30 kph zone. To study the effect on speeding more into detail, results are given per driver in the figures 4-6 and 4-7 below.

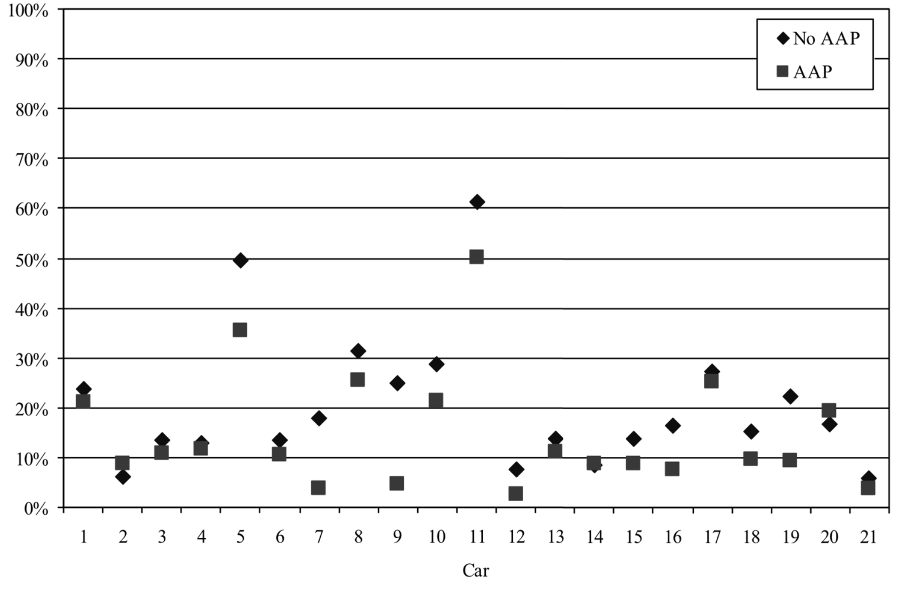

Figure 4-6. Percentage of total distance speeding per car

Differences between drivers were large. Distance speeding without the system varied between 6% and 61%. With the system this varied between 3% and 50%. For most drivers speeding reduced with the system. There are however 3 out of 21 cars for whom speeding even had increased (cars 2, 14 and 20).

Effects on average driving speed were also very diverse. For 8 out of 21 vehicles the average driving speed increases. For less frequent speeders average driving speed almost always increased. Of the 10 least frequent speeders, 9 had an increase in average speed due to activation of the AAP. For more frequent speeders average tended to increase. Of the 10 most frequent speeders, 8 had an increase in average speed due to activation of the AAP.

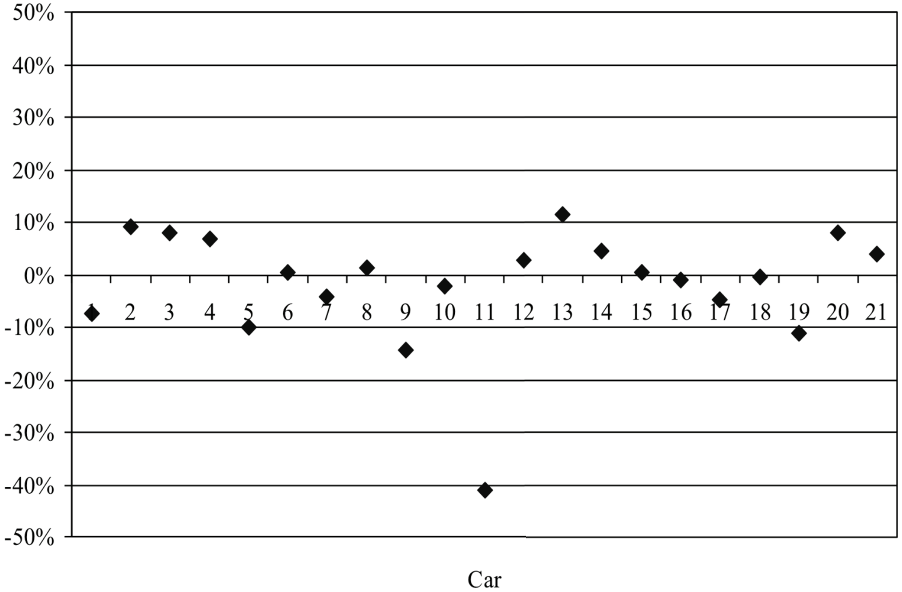

Figure 4-7. Relative change of average driving speed due to activation of AAP system

4.9 Conclusions and discussion

Comparison of logged speed data during the activation period and speed data after this period showed that ISA had an effect on speeding. Effects were highest in the 90 km/h zone where speeding decreased by almost 10%. At lower speed limits effects were smaller although speeding was more frequent. In the 30 kph zone distance speeding decreased from 45.9% to 42.8%, which means that the counter pressure was overridden in a vast amount of distance. Comparing effects on a monthly basis showed a higher amount of speeding at the end of the activation period than at the beginning. Especially in low speed zones speeding increased during the first months of usage.

Differences between drivers were however large. Distance speeding with the system varied between 3% and 50%. For most drivers speeding reduced with the system. Average speed of less frequent speeders tended to increase as drivers accelerated faster to the speed limit and drove exactly at the speed limit in stead of safely below. Average speed of more frequent speeders tended to decrease.

The aggregated speed effects even indicated that drivers with the AAP will drive closer towards the speed limit.

When questioning basic attitudes in the surveys, most of the drivers did not think that driving fast is fun, liberating or exciting, before, during or after the project. Most drivers declared that speeding is dangerous, reckless and not sportive. Driving with ISA changed their behaviour on speeding: during the project, most of the drivers declared that they never drove faster on highways, outside urban areas, in urban areas and 30-zones. The drivers used the system voluntary on highways and outside urban areas, which gave a first indication of their acceptance of the active accelerator pedal. They also experienced the pedal as satisfying and useful. After the trial, the private test-drivers could choose to keep the ISA-system in their car. 15 private car holders chose to keep the system in the vehicle after the test-period, which was a significant indication that there is an acceptance of the active accelerator pedal. The drivers noticed that the system assisted them well in upholding the speed limits and provided for comfortable and relaxed driving, although certain technical issues could be better.

The drivers' perception on the effect of the system was evaluated more significant than the results from the logged speed data. Data logging problems could have influenced these results. The logged data were fully analysed without making any distinction in road-characteristics. In this trial, the logged data was analysed in total. In similar trials only stretches of roads were examined. The benefits are here that the research environment is controlled. Total analyses, like in this trial, make it possible to have a full picture of all the driving behaviour in the test-area.

Although the drivers declared that ISA is most useful in lower speed-areas, observed driving behaviour showed the opposite. It is assumed that different factors could have influenced the drivers. It is considered that factors, also described by Parker (1992), Brown (2002) and Levelt (1998), like driving behaviour of other (non-ISA) drivers and discrepancy between the design of the road and the speed limit encouraged the test drivers to speed. These effects were not measured, but reports of some drivers could acknowledge this. Also these factors will not fully explain the speeding in lower kph zones.

As noted the less change in perception of their speeding behaviour in the questionnaires, the experience of 'driving slow' and the logged data could indicate that there is less acceptance of the 30 kph speed limit, although they also had declared to understand the benefits towards road safety of lower speed area. This effect of non-adaptation when even speed warning devices are used could be seen as disturbing for road safety measures. Lower speed limits like 30 kph (areas) are assumed to harmonise motorised with non-motorised traffic on an acceptable and safe manor in the benefit of all road users. Mostly this would indicate road infrastructure measures to support visualisation for the road users, limitation of passing motorised traffic, etc. (Broeckaert, De Mol, 2004). A lack of tradition, less sensitization and the sporadic coherence in implementation of lower speed areas led also to a general modest acceptance of 30 kph areas in Belgium. The driving behaviour of the ISA test-drivers must be placed in this context, certainly because during the project the 30 kph areas in Ghent increased significant. These results about the speeding behaviour must not be seen as indications about 'the failure' of 30 kph areas, but should be noted to give an impulse into future research about implementation, visualisation and acceptance of embedded speed limits.
As a final conclusion it can be noted that ISA can have benefits in road safety and could even open new debates about speed policies. In this trial ISA could be seen as a supportive system in road safety, but can not be seen as the only manner to reduce speed violation. The use of ISA must also be geared to other road safety policies in reducing speed: better understanding of speed areas by drivers and better embedding of speed limits in relation with the use of the road should be considered.

many initiatives on intelligent transport systems (ITS) and ISA are taken on European and national level: implementation strategies, research and initiatives on collecting speed limit data, legislation issues and better technical speed warning devices. At the other hand the discussion about ITS can open new debates about road safety measures taken today. ITS can support these measures but also will open the debate about new or to improve old policies. The main question can be asked how the general public, car manufactures and other actors will stand for these new devices and how they can be convinced to accept new legislation in relation to ITS. Future research on these topics would be considerate as a prior challenge about road safety and ITS.

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5 Towards Defining a Unified Concept for the Acceptability of Intelligent Transport Systems (ITS): a Conceptual Analysis Based on the Case of Intelligent Speed Adaptation (ISA)

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Abstract
A key success factor in the future implementation of new in-vehicle technologies is in understanding how users will experience and respond to these devices. Although it is recognized that acceptance, acceptability and/or support is important, consistency in the definition of acceptability, and how it can be measured, is absent. In this paper we conceptualize acceptance as the attitudes towards a new device after its introduction and acceptability as the attitudes to it before its introduction. It is our goal to describe and conceptualize the most common and relevant socio-psychological factors that can influence acceptance and acceptability of Intelligent Speed Adaptation (ISA). By analysing the different theories and methods used in ISA trials we arrived at the 14 most potential indicators that could influence the definition of acceptability and acceptance. A test survey was conducted to

determine if these indicators are relevant and if they affect acceptability. The use of a factor analysis helped to single out those questions that were deemed relevant in doing our conceptual acceptability analysis, and to allocate correlations between the different items. We conclude that we have found a concept with some main possible indicators that directly influence the acceptability of ISA.

5.1 Introduction

In their white paper "European Transport Policies for 2010: Time to Decide", the European Commission stated that the main challenges for sustainable mobility include a reduction of congestion, an increase in traffic safety (a 50% reduction in fatalities in 2010 compared with 2000), an increase in energy efficiency, and a reduction of dependence on fossil fuels (European Commission, 2001). The use of different transport technologies (also known as Intelligent Transport Systems or ITS) may play a significant role in achieving these policy goals. Many ITS applications in the field of traffic management and travel information that are already on the market have proved their effectiveness. These systems support transport system users, traffic managers, and fleet operators with traffic and travel information. However, to achieve the stated EC transport policy goals, the implementation of more advanced ITS applications is required, with active intervention in vehicle driving tasks. This category of ITS device is also known as the Advanced Driving Assistance Systems (ADAS) that partially take over driving tasks such as distance keeping, lane keeping, overtaking, and so on. Many research initiatives on different ADAS technologies are being conducted at international, national, and regional level. While most studies focus on the technological feasibility of ADAS and its intended impacts, an important question as to whether these new technologies will be accepted and used remains unanswered.

ADAS vary from relatively simple systems that provide drivers with basic information to relatively complex systems that take over parts of the drivers' tasks to achieve 'good' driving behaviour (Brookhuis & De Waard, 2005). The need to understand how users experience and respond – or not – to the support of ADAS is important for determining how drivers' needs can be integrated into the development and implementation of ADAS. In general, understanding potential users' points of view has been roughly noted as acceptance or acceptability. Although several studies have examined acceptance and/or acceptability of ADAS there is little consistency on what is understood by acceptance or acceptability and, equally important, how these factors can be measured (cf. Molin & Brookhuis, 2007). The present paper aims to define acceptance and acceptability, and to determine which indicators should be considered relevant for their measurement. Our application involves Intelligent Speed Adaptation (ISA). ISA is a traffic safety device that warns the driver about speeding, discourages the driver from speeding, or prevents the driver from exceeding the speed limit (Brookhuis & De Waard, 1999), and hence, can be considered an ADAS application.

The aim of this paper is first to define acceptance and acceptability, i.e. to develop a theoretical framework that concurs with our conceptualization. We introduce our definitions of acceptance and acceptability, and give a brief overview of current theories and methods used in ISA trials. Based on these theories and methods we then define similarities between the items or determinants that lead to the selected indicators. In section 3 we outline a conceptual framework. This framework forms the basis for constructing a test survey to discover which indicators can be considered relevant, and if they are, what correlations exist between the described indicators. In section 4 we describe the research method used for the test survey. In section 5 we summarize the results of our test survey based on factor analysis. In the final section we set out our conclusions and propose avenues for future research.

5.2 Defining acceptance and acceptability in ITS and ISA research

5.2.1 What is acceptance and acceptability?

Acceptance, acceptability, social acceptance, public support, social support, etc. are all terms frequently used to describe a similar phenomenon, how potential users will react and act if a certain measure or device is implemented. The interest in defining acceptance or acceptability lies in the precondition that the effectiveness and success of a measure will increase if there is public/social support for it. Under favourable conditions a positive assessment leads to an increased willingness to accept a measure and even to support it actively (Nelissen & Bartels, 1998; Goldenbeld, 2002). Although it is recognized that acceptance, acceptability, and support are important, a clear definition of what acceptance and acceptability are and precisely how they should be measured is still absent (Adell, 2008a; Regan et al., 2006; Vlassenroot, 2006).

To a certain extent the terms acceptance and support are strongly related. Goldenbeld (2002), however, introduces an important nuance between both concepts. The basic idea is that even if acceptance exists, it would not necessarily lead to the support of a measure.

In the field of ITS, Ausserer and Risser (2005) define acceptance as a phenomenon that reflects to what extent potential users are willing to use a certain system. Hence, acceptance is linked closely to usage, and acceptance will depend on how user needs are integrated into the development of the system. Nielsen (cited in Young et al., 2003) described acceptability as related to the question of whether the system is good enough to satisfy all the needs and requirements of the users and other potential stakeholders. More generally, in Rogers' (2003) diffusion of innovations, acceptability research is defined as the investigation of perceived attributes of an ideal innovation in order to guide research and development to create such an innovation. Van der Laan et al. (1997) distinguished between user acceptance and social acceptance. User acceptance is directed more towards evaluation of the ergonomics of the system while social acceptance is a more indirect evaluation of consequences of the system.

In another distinction between acceptance and acceptability, Schade and Schlag (2003) described acceptance as the respondents' attitudes, including their behavioural responses, after the introduction of a measure, and acceptability as the prospective judgement before such future introduction. In this case, the respondents will not have experienced any of the measures or devices in practice, which makes acceptability a construction of attitude. In our research, we are more interested in defining the social aspects that could lead to public acceptability. Our research target group will not have experienced driving with ISA. Therefore, the term acceptability should be preferred, whereas in the literature this difference is not always found.

The lack of a theory and definition regarding acceptance has resulted in a large number of different attempts to measure ITS acceptance, often with quite different results (Adell, 2008a). Some existing theories were used to measure these within the acceptance and acceptability research of ITS. In the next sections we describe some of the 'general' user acceptance models, acceptability theories, and research into ISA.

5.2.2 User acceptance models and theories

One of the most frequently used frameworks to define acceptance is the Theory of Planned Behaviour (TPB). Based on the Theory of Reasoned Action (Fischbein & Ajzen, 1975), the TPB assumes that behavioural intentions, and therefore behaviour, may be predicted by three components (Van Acker et al., 2007, 2010): attitudes towards the behaviour, which are individuals' evaluation of performing a particular behaviour; subjective norms, which describe the perception of other people's beliefs; and perceived behavioural control, which refers to people's perception of their own capability.

TPB has been used successfully to predict behaviour in a wide variety of applied research settings within different domains, including several studies dealing with driving behaviour and traffic safety, such as the effects of drinking and driving (Aberg, 1993; Parker et al., 1992a), driving violations (Parker et al., 1992b), and speeding and speed behaviour (Elliot et al., 2005; Haglund et al., 2000). Warner and Aberg (2006) specifically used the TPB related to the use of ISA. Comparing self-reported speeding of test drivers within an ISA trial with logged data explained 28% of the variance in logged speeding. In their study, Warner and Aberg (2006) noted that perceived behavioural control did not add significantly to the prediction of drivers' logged speed.

Another successful model is the Technology Acceptance Model (TAM) (Davis et al., 1989). TAM was designed to predict information technology acceptance and usage on the job. TAM assumes that perceived usefulness and perceived ease of use determine an individual's intention to use a system with the intention to use serving as a mediator of actual system use. TAM has been used – in the field of ITS – in the prediction of electronic toll collection (Chen et al., 2007).

Van der Laan et al. (1996) published a simple method to define acceptance. Acceptance is measured by direct attitudes towards a system and provides a system evaluation in two dimensions. The technique consists of nine rating-scale items. These items are mapped on two scales, the one denoting the usefulness of the system, and the other satisfaction.

Venkatesh et al. (2003) noted that there are several theories and models of user acceptance of information technology, which presents researchers with difficulties in choosing the proper model. Venkatesh et al. (2003) found different underlying basic concepts in acceptance models by means of a detailed description and analysis of different models such as TPB, the motivational model, TAM, innovation diffusion theory, and combined models. Based on these theories, they constructed a unified model they named the Unified Theory of Acceptance and Use of Technology (UTAUT). In the UTAUT, four constructs play a significant role as direct determinants of user acceptance: (i) performance expectancy – the degree to which an individual believes that using the system would help him or her to attain gains in job performance; (ii) effort expectancy – the degree of convenience with the use of the system; (iii) social influence – the importance of other people's beliefs when an individual uses the system; and (iv) facilitating conditions – how an individual believes that an organizational and technical infrastructure exists to support use of the system. The supposed key moderators within this framework are gender, age, voluntariness of use, and experience. Although in several models, 'attitude towards use', 'intrinsic motivations', or 'attitude towards behaviour' are the most significant determinants of intention, these are not mentioned in the UTAUT. Venkatesh et al. (2003) presumed that attitudes towards using the technology would not have a significant influence.

Stern (2000) developed the value–belief–norm (VBN) theory to examine which factors are related to acceptability of energy policies. Stern and colleagues proposed the VBN theory of environmentalism to explain environmental behaviour, including the acceptability of public policies. They proposed that environmental behaviour results from personal norms, that is, a feeling of moral obligation to act pro-environmentally. These personal norms are activated by beliefs that environmental conditions threaten the individual values (awareness of consequences) and beliefs that the individual can adopt to reduce this threat (ascription of responsibility). VBN theory (Steg et al., 2005) proposes that these beliefs are dependent on general beliefs on human–environment relations and on relatively stable value orientations. VBN theory was successful in explaining various environmental behaviours, among which consumer behaviour, environmental citizenship, willingness to sacrifice, and willingness to reduce car use (Stern et al., 1999; Nordlund & Garvill, 2003).

Schlag and Teubel (1997) defined the following essential issues determining acceptability about traffic measures: problem perception, important aims, mobility-related social norms, knowledge about options, perceived effectiveness and efficiency of the proposed measures, equity (personal outcome expectation), attribution of responsibility, and socio-economic factors.

5.2.3 Acceptance measurements in ISA trials

In our approach we want to describe the most common and relevant socio-psychological factors that influence acceptance and acceptability of ITS and actively interact with vehicle driving tasks. We will focus on ISA. ISA can be categorized within different types, depending upon how interventionist (or permissive) they are (Morsink et al., 2006).

Table 5-1. Overview of different types of ISA (Morsink et al., 2006)

Level of support	Type of feedback	Definition
Informing (open)	Visual	The speed limit is displayed and the driver is reminded of changes in the speed limit.
Warning (open)	Visual/auditory	The system warns the driver when exceeding the posted speed limit at a given location. The driver decides whether to use or ignore the information or warning.
Assisting (half-open)	Haptic throttle	The driver gets a force feedback through the gas pedal if he/she tries to exceed the speed limit. Overruling of the system is still possible
Restricting (closed)	Dead throttle	The speed of the vehicle is automatically limited and the driver cannot overrule the system.

In most ISA studies, acceptance and acceptability refer to the opinions, attitudes, and values of the users relative to the experience they had when driving with the system (Brookhuis & De Waard, 1999; Comte et al., 2000; Vlassenroot et al., 2007; Young & Regan, 2007). In these studies, acceptance is measured by comparing behavioural changes when driving without ISA before using the device and driving with ISA and finally driving without ISA after the test period (Adell et al., 2008; Biding & Lind, 2002; Hjalmdahl & Várhelyi, 2004; Katteler, 2005). Brookhuis and De Waard (1999) defined these behavioural changes as the level of adaptation instead of acceptance. Adaptations are those behaviours that may occur following the introduction of changes to the road-vehicle user (Dragutinovic et al., 2005).

Therefore, adaptation will better describe the behavioural outcomes (and changes) when drivers have experienced the device, while acceptance will be more related to the attitudes, norms, and beliefs that may influence adaptation. Goldenbeld (2002) has noted that opinion and attitude studies are the most widely adopted research methods for measuring acceptability and acceptance of road safety measures.

Based on recent ISA field trials in different countries, certain directions for defining acceptance can be found. Although the main research set-ups and methods used were different in most trials, some common ground is evident.

In a large-scale ISA trial in Sweden, different types of ISA were tested voluntarily by 10,000 drivers between 1999 and 2002 (Biding & Lind, 2002). In these trials, acceptance was measured by relating attitudes to traffic safety and speed with experience of the tested ISA, willingness to pay, performance when using ISA, and the Van der Laan scale.

In the Dutch ISA trial (Ministerie van Verkeer en Waterstaat: Adviesdienst Verkeer en Vervoer, 2001) a mandatory (closed) system was tested, implying that the drivers could not violate the speed limit. The acceptance aspect focused primarily on the influence of ISA on drivers' tasks (e.g. driving behaviour inside and outside the limited areas), technical functions of ISA, and ergonomic issues.

In the Australian trial (Regan et al., 2006), the acceptance study was based on the model of Davis and Nielsen (cited in Young et al., 2007). The five main constructs were usefulness (users perceive the system to serve a purpose), effectiveness (users believe that the system does what it is designed to achieve), usability (the ease of use of the system), affordability (willingness to pay), and social acceptability (broader scale that users may take into account in assessing whether ISA is acceptable). The scope of research in the Australian trial involved other ITS devices such distance-keeping warning.

In 2001, a new trial started in the UK, called ISA-UK (Carsten et al., 2008). In four field trials conducted in different parts of the UK, 80 private and professional test drivers drove 20 vehicles that had a system installed over a period of six months (during the first and last month the system was not activated). The system made it impossible for the test drivers to exceed the speed limits without using kick-down or pressing an emergency button. Predicting speeding behaviour and drivers' attitudes was assessed by using TPB related to speeding in three scenarios: speeding on a motorway, urban 40 mph road, and residential 30 mph road. The impact of ISA on acceptance was rated using dimensions of usefulness and satisfaction.

In 2004 an ISA experiment with 20 vehicles was conducted near Versailles, France (Pianelli et al., 2007). A survey was carried out to study the drivers' acceptance of the system and to define both their attitudes and social representations of speed and ISA. This means that the behaviour of individuals and groups is directly determined by the responses they show for an objective or to the situation in which they find themselves. Social representations guide relationships, communications, and social practices.

In a Belgian trial (Vlassenroot et al., 2007), drivers drove with an active accelerator pedal, implying that the drivers received feedback through a push-back of the accelerator if they sped. The concept of acceptance was based on a framework designed to define public opinions on speed measures and ISA. This framework denotes how people view mobility and transportation in relation to road safety, especially with respect to speed, speeding, and speeding restrictions. Based on this framework, basic attitudes to road safety, speed, and speeding, and recognition of speed as a problem in society and attitudes about road safety and policy could be measured, distinguishing between different socio-demographic backgrounds of transport users. Further aspects were the voluntary use of the system outside the test area, willingness to pay, and the scaling of the use of ISA on satisfaction and usefulness (Van der Laan et al., 1997).

A Danish trial (Harms et al., 2007) used an open ISA system, based only on information about speeding, in combination with other incentives when driving safely (e.g. lower insurance premiums). This trial focused on the influence of background factors such as age and driving experience, questions related to driving style, attitudes to safe driving, driving speed and speed limits, and to risky traffic behaviour. The respondents were also asked to judge a number of frequently used ISA features, and to anticipate effects of driving with ISA.

Molin and Brookhuis (2007) defined problem awareness, car drivers' beliefs about the selected policy instruments, and car drivers' personal characteristics as the main variables that would influence ISA acceptability. De Mol et al. (2001) based ISA acceptability measurement on the attitudes and opinions given by individuals, which stand for the general public. Within this concept several layers with mutual relations were defined, with the socio-demographic issues and the individual transportation habits as the 'basic' factors for the creation of public support. The basic attitudes denote how people perceive mobility and transportation, in particular the perception of speed in relation to motorized vehicles. Public support is also determined by 'being a (problem) issue in society', because, if there is no social indication that a problem about the relationship between road safety, speed, and speeding is perceived, there will be no change in future acceptance. Some of the abstract norms and values are made concrete in issues concerning how people think about road-safety measures. At this level a 'real' discussion on possible acceptance should occur. Within the SARTRE (Social Attitudes to Road Traffic Risk in Europe) project (Drevet, 2004) some questions related to how people noticed speed and speeding, and were brought into relation with willingness to use a speed-limiting device. Some of the aspects used in acceptance research and in acceptability research are mutual.

As a reminder, we will define acceptance as the reaction (beliefs and attitudes) of individuals, based on their behavioural reactions *after the introduction* of a measure or device. Acceptability describes the prospective judgement of measures *to be introduced* in the future. In our further research we will focus on acceptability instead of acceptance.

5.3 Conceptualization of the model

The previous sections described how methods and theories are used to distil the most relevant determinants that could influence acceptance and acceptability. In these theories and methods we tried to find which items were related to each other. Venkatesh et al. (2003) did a similar exercise to build their UTAUT model. Table 5-2 gives an overview of some of the theories used to select the indicators.

Table 5-2. Examples of theories used to select the indicators

		Individual factors		Att. to driving beh.	Resp. Aw.	Pers. & soc. aims	Problem perc.	Exp. or/and know.	social norms	Affordability	Per. Effect.	Satisfaction	Equity	Per. usability	Per. Useful.	Per. Effic.
Acceptance models	**TPB (2002)**			Att. towards beh.					Subj. Norm							Per. Beh. Cont.
	TAM (1989)								Subj. Norm					Perc. Ease of use	Per. Useful.	
	UTAUT (2003)	Age	Gender					Experience	Social Influence				Volunt. of use	Effort Expectancy	Perfor. Expect.	Facil. Cond.
	V. D. Laan scale (1994)											Satisfaction			Useful.	
Acceptability models	**Schade & Schlag (2003)**		Socio-eco factors		Respons.	Pers. aims to reach	Problem perc.	Knowledge	Social Norms		Perc. Effect.		Equity			
	VBN theory			Values	Ascr. of respons.	Personal norms		Ecological worldview			Aware. of cons.					
ISA research acceptance	**SE (2002)**			Att. to traf. Saf.				Experience		Willingness to pay		Satisfaction			Useful.	
	NL (2001)													Ergonomics	Drivers' tasks	
	AUS (2006)									Affordability	Effect.			Usability	Useful.	Soc. Accept.
	F (2007)			Social Repr.										Ease of use		
	B (2007)		Socio-demo. B.	Attitudes to safety			Probl. Aware.			Willingness to pay		Satisfaction			Useful.	Effic.
	DK (2007)		Backg. fact.	att. to safe driving										Judgment on ISA features		
ISA research acceptability	**Molin & Brookhuis**		Personal charact.	car drivers' beliefs			Probl. Aware.									
	Garvill et al.	Age	Gender	Exceed	Moral obligation		Risk		Traffic pace							Diff./easy
	De Mol et al.		Socio-demo. B.	Att. to safety			Probl. Aware.			Willingness to pay		Satisfaction			Useful.	Effic.

In Figure 5-1 a distinction is made between general indicators (related to the context awareness of the system) and system-specific indicators (directly related to the characteristics of the device). The 14 indicators are considered to be the most relevant that can or will influence acceptance/acceptability. These general and specific indications will influence each other and the level of acceptance and acceptability. We give a brief description of every indicator.

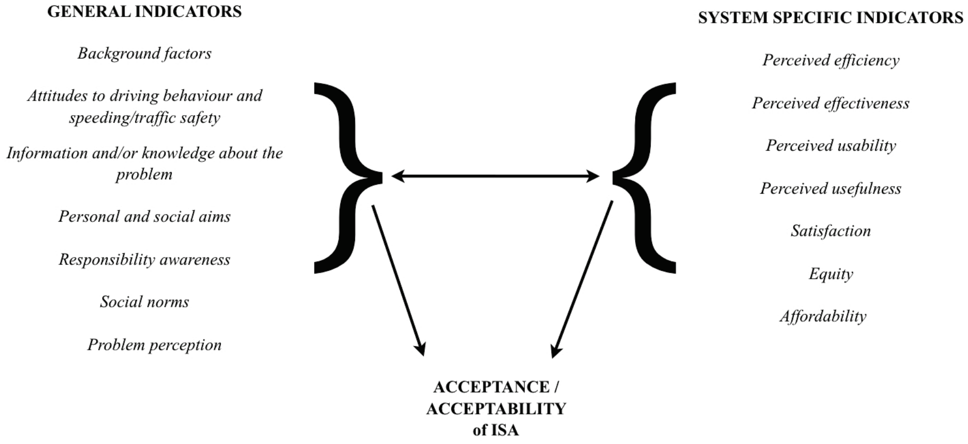

Figure 5-1. General and system specific indicators that can influence acceptance or acceptability

5.3.1 General indicators

Individual factors

Gender, age, level of education, and (income) employment are considered to influence how people think about speed and speeding and therefore on the use of ISA. Gender and age are considered as relevant determinants within the performance of speeding behaviour. Speed is more associated with young drivers (Ingram et al., 2001; Parker et al., 1992a; Stradling et al., 2000), and more specifically, with young male drivers (Stradling et al., 2003). Although male drivers are more likely to speed, some studies noted that a difference between sexes could not be found. Shinar et al. (2001) analysed the proportion of licensed drivers that reported that they drive within the speed limits. They noted that age, education, income, and gender are relevant factors in speeding behaviour. Shinar et al. (2001) observed that drivers who were more educated and had a higher income (related to employment) were more likely to report that they sped than the less educated and poorer respondents.

Attitudes to driving behaviour and speeding/traffic safety

Travel behaviour, driving style and the choice of vehicle are also related to speeding behaviour. Silcock et al. (2000) noted that people admitted to driving faster in more powerful and comfortable cars. Moreover, Steg et al. (2001) conducted a study to clarify the importance of symbolic-affective as opposed to instrumental-reasoned motives for car use. These motives for car use can have an impact on why individuals drive too fast, or whether they would or would not accept ISA. Stradling et al. (2003) examined the demographic and driving characteristics of speeding, violating, and thrill-seeking drivers. They concluded that in England drivers who speed, who violate other rules of the road, and who seek excitement when driving, pose greater risks to themselves and to other road users. Stradling et al. (2003)

also found two population groups whose driving behaviour put themselves and other road users at risk. The first group was young and mostly, but not exclusively, male drivers. The second group was drivers from high-income households, living out of town, driving larger-engine cars for high annual mileage as part of their work. Crash involvement has been noted as a possible influence on speed and speeding behaviour. In relation to defining the acceptance and acceptability of ISA, the influence of travel behaviour, car use, vehicle choice, and driving style should be considered relevant indicators.

Personal and social aims
Schade and Schlag (2003) describe personal and social aims as the dilemma between social or personal aims and benefits. They assume that a higher valuation of common social aims will be positively related to acceptability. Clearly, people who want to drive as fast as possible will have a lower acceptability and acceptance of ISA. Another issue is the effect of speeding measures on individual freedom. Policies or devices that seriously affect individual freedom will be less acceptable (De Groot & Steg, 2006).

Social norms
Perceived social norms and perceived social pressure refer to the (assumed) opinions of their peers multiplied by the importance of the others' opinions for the individual. In other words, social norms refer to an individual's assumptions about whether peers would think that he or she should accept the device (Ajzen, 2002; Schade & Schlag, 2003). It is assumed that peers, e.g. co-workers or specific other road users, will influence the attitudes and behaviour of individuals

Problem perception
The extent to which speeding is perceived as a problem is a necessary indication in defining acceptance and acceptability. There is common agreement that high problem awareness will lead to increased willingness to accept solutions for the perceived problems (Schade & Schlag, 2003; Steg et al., 1995; Eriksson et al. 2006; Goldenbeld, 2002; Molin & Brookhuis, 2007; De Mol et al., 2001).

Responsibility awareness
This concept is based on the norm activation theory (Schwartz, 1977) and environmental travel demand management studies (Eriksson, 2006; Steg & De Groot, 2006; Stern, 2000). Responsibility awareness explains how an individual stands in respect to the issue of whether it is the government (others/extrinsic) or the individual (own/intrinsic) that is deemed to be responsible. It is assumed that environment-preserving behaviour becomes more likely if individuals perceive the damaging consequences of their own actions on the environment and others, and at the same time ascribe the responsibility for the consequences to themselves (Schade & Schlag, 2003).

Information and knowledge about the problem
The level of acceptability can depend on how well-informed the respondents are about the problem and about any new device that is to be introduced to solve the problem (Schlag & Schade, 2003; Steg et al., 1995). The hypothesis may be that the more that people are informed, the higher the acceptance/acceptability will be. However, better knowledge about a problem can also lead to less acceptance/acceptability for a specific solution caused by, for instance, awareness of alternatives to solve the problem.

5.3.2 Device-specific indicators

Device-specific beliefs are directly related to the characteristics of the system. Seven indicators could have the potential to define acceptance or acceptability and how user needs are integrated into the system. As noted, ISA acceptance is related to drivers' attitudes and behaviour about speed and speeding. Therefore, the previously noted concepts of general beliefs must be taken into consideration and will influence specific beliefs for defining acceptability of ISA.

Perceived efficiency
Perceived efficiency indicates the possible benefits users expect of a concrete measure (or device) as compared with other measures.

Perceived effectiveness
Effectiveness refers to the system's functioning according to its design specifications, or in the manner it was intended to function (Young et al., 2003). In most ISA trials, this was found through an evaluation of the technical/ergonomic issues. The main question in these trials remained whether the system assisted the driver to maintain the proper speed. The level of effectiveness can depend on how interventionist a system is or was. For instance, an advisory system can be considered as less effective than a system that prevents the driver from exceeding the speed limit.

Perceived usability
Perceived usability is the ability to use the system successfully and with minimal effort. Usability is also an indication for how users understand how the system works. User friendliness can be associated with usability: the users will expect a service that does not distract or overload them with information and (difficult) tasks (Landwehr et al., 2005).

Perceived usefulness
Perceived usefulness is related to how the system supports the drivers' tasks and driving behaviour. Usefulness is, in a certain way, different from effectiveness. A potential user can find ISA effective in general but not for his own driving behaviour. Young et al. (2003) define usefulness as the degree to which a person believes that using a particular system will enhance his or her performance.

Satisfaction
Satisfaction is one of two factors derived form the items within the ITS acceptance scale that Van der Laan et al. (1997) developed to study user acceptance.

Equity
In general, equity refers to the distribution of costs and benefits among affected parties. However, from a psychological viewpoint, perceived justice, integrity, privacy, etc., are basic requirements for acceptability. This may differ from the objective costs and benefits, but equity is an important indicator influencing personal perceptions (Schade & Schlag, 2003). The integrity of driver information, privacy, and loss of certain freedom in driving can be an issue for willingness to use ISA.

Affordability
It may be assumed that socio-economic status will affect acceptance and acceptability, as users will consider ISA as a symbol of status ('having ISA as a new gadget or feature'), or

they will want to be among the early adopters (Rogers, 2003). On the other hand, affordability will depend on the individual's budget and/or public/private funding. It is to be expected that low-income groups will be more opposed to ISA. In many trials acceptance was defined by willingness to pay for ISA (Vlassenroot et al., 2007; Biding & Lind, 2002; Hjalmdahl, 2004). The willingness to pay will depend on income, but in many trials it is assumed that the more people are willing to pay, the higher the acceptance and acceptability will be. Incentives such as lower road taxes and lower insurance fees can stimulate the acceptance or acceptability of ISA (Lahrmann et al., 2007; Schuitema & Steg, 2008).

5.4 Research methodology

In the previous section we described the most relevant indicators that could influence acceptance and acceptability based on previous research and methods. In this section we want to develop our conceptual framework operational. To this end, we developed and tested a first survey.

5.4.1 Survey set-up

Based on the literature about acceptance and acceptability theories and models, different factors and some 250 possible questions from past surveys – some questions had multiple sub-questions – were found. These questions were categorized into questions about (i) personality characteristics, (ii) problem recognition related to speed and speeding, (iii) the use and integration of the actual methods to counter speeding, and (iv) the use of the new technology (ISA) to counter speed and speeding. These clusters made it possible to identify similar questions and to redefine some questions. The above-mentioned 14 indicators were also positioned in these clusters.

In the second phase only questions relevant to defining the indicators were withheld: about 60 questions were deemed relevant. A first survey was made, based on these questions. Some of the questions were redefined and only the most relevant questions were taken into account. The number of main questions was reduced to 36, most of which consisted of different items (sub-questions) that had to be rated (besides some identification questions) on a 5-point Likert-scale. To reduce the number of items that the respondents had to fill in, in questions relating to car choice and responsibility awareness, respondents were asked to rank the items from most important to least important.

A Web survey was assembled using the open source program 'Limesurvey' and sent first to colleagues for testing. Using their comments, especially about user friendliness, a pilot test survey was made and circulated by mail and the popular networking site Facebook. The goal was to reach 150 respondents. Based on the answers of these respondents some modifications were made to improve the survey and some of the early responses were processed to find out if the questions would cover the described indicators (main variables).

Finally the definitive Web survey was published online. The goal was to have at least 1000 respondents in Belgium (Dutch-speaking part) and 1000 respondents in The Netherlands. The Web address of the survey was distributed by the Flemish and Dutch motoring organizations. In Flanders a motoring organization sent an email newsletter to their members, in the Netherlands, the link to the survey was announced on motoring organization's website.

The same survey will be given to certain stakeholders involved in transport policy and ITS deployment, who will be asked to estimate how people would answer the questions.

5.4.2 Data analysis

While we used factor analysis in our analysis of the pilot test-survey data, we are aware that this approach has some limitations. For instance, the analysis depends very much on researchers' interpretation of results. However, the goal of this analysis is to find some first indications and relationships to define our concept of acceptability. Second, factor scores provide a means to summarize information on a large number of variables in a manageable and meaningful form.

5.5 Primary results from the pilot test survey

In total 217 individuals responded to the questionnaire, but only 148 respondents completed the survey. The answers of these 148 respondents were analysed. Factor analysis was used to investigate if the questions and sub-questions (see Table 3) covered the pre-defined indicators and if some other (internal) relations could be found. Some of the indicators consisted of different items, which covered a series of sub-questions (e.g. the indicator of problem perception consisted of items such as accident influence, attitudes about speeding, etc). These sub-questions will be reduced to factors that cover the items within the indicator or main variable.

The indicators of 'individual factors', 'travel behaviour', 'driving style, and car use' are not given in the first analysis. Questions relating to usability were not asked as the respondents had not experienced the system and it was difficult to predict how the Human–Machine Interface (HMI) would be developed in the future. The 'responsibility awareness' indicator was asked in the survey but could not be processed in the factor analysis because of a wrong question set-up in the survey. In the future survey this indicator will be asked differently (on a Likert-scale instead of ranking).

5.5.1 Factor analysis

In general our questions covered every indicator that we intended to ask in the large survey (see Table 5-3). Factor analysis is made per indicator or item. Most of the indicators or items within the indicators loaded onto one factor. Some of the most relevant ones are described below.

Table 5-3. Factor loadings for the pre-defined indicators and (sub)-items

Indicator/variables	Fact. 1	Fact. 2	Fact. 3	Indicator/variables	Fact. 1	F. 2	F. 3	F. 4
Problem Perception				**Usefulness**				
Accident influence	*Eigenvalues Cumul.:*		*58,22%*	Opinions about WHICH ITS useful	*Eigenvalues Cumul.:*			*66,15%*
Driving under influence of drugs	-0,08	0,41	**0,60**	Black box	-0,08	0,20	**0,70**	-0,15
Driving under influence of alcohol	0,00	0,07	**0,84**	Alcohol lock (no starting)	**0,63**	0,11	0,40	0,09
Less driving experience	-0,02	**0,87**	0,03	Alcohol warning	**0,58**	0,27	0,23	0,14
Inappropriate speed	0,24	0,04	**0,60**	Seat belt reminder: no starting every passenger	**0,89**	0,12	0,06	0,05

Other inexperienced drivers	0,13	**0,84**	0,10
Bad weather conditions	**0,65**	0,23	-0,29
Mobile phone use while driving	**0,61**	0,13	0,18
Bad infrastructure	0,46	**0,52**	0,23
Risk-seeking behavior	**0,64**	-0,08	0,48
Fatigue	**0,71**	0,01	-0,10
No distance keeping	**0,70**	0,01	0,27
<u>Attitudes about speed and speeding</u>	*Eigenvalues Cumul.:*		*81,98%*
Speeding and danger	0,09	**0,93**	
Speeding and excitement	**0,92**	0,02	
Speeding and fun	**0,86**	0,28	
Speeding and freedom	**0,82**	0,18	
Speeding and safety	0,23	**0,90**	
<u>When is speeding not safe</u>	*Eigenvalues Cumul.:*		*80,84%*
Speeding as criminal act in residential zone	0,44	**0,82**	0,13
Speeding as criminal act in school area	0,56	**0,70**	0,18
Speeding as criminal act in urban area	**0,77**	0,44	0,21
Speeding as criminal act outside urban area	**0,79**	0,35	0,28
Speeding as criminal act on highways	**0,67**	0,26	0,20
Speeding as irresponsible act in residential zones	0,32	**0,86**	0,10
Speeding as irresponsible act in school area	0,49	**0,72**	0,17
Speeding as irresponsible act in urban area	**0,78**	0,28	0,33
Speeding as irresponsible act outside urban area	**0,78**	0,18	0,38
Speeding as irresponsible act on highways	**0,75**	0,15	0,36
Speeding as 'a mistake' in residential zones	-0,09	**0,79**	0,52
Speeding as 'a mistake' in school area	0,15	0,51	**0,74**
Speeding as 'a mistake' in urban area	0,43	0,21	**0,79**
Speeding as 'a mistake' outside urban area	0,42	0,11	**0,81**
Speeding as 'a mistake' on highways	0,38	0,11	**0,82**
<u>Speed limits</u>	*Eigenvalues Cumul.:*		*74,28%*
The best limit in residential z.	**0,69**		
The best limit in school area	**0,81**		
The best limit in urban area	**0,79**		
The best limit' outside urban area	**0,80**		
The best limit on highways	**0,74**		
Personal and social aims	*Eigenvalues Cumul.:*		*58,80%*
speeding in normal conditions	**0,83**		
Speeding when wet surface	**0,62**		
Speeding during the night	**0,67**		
Speeding while overtaking	**0,71**		
Speeding when in a hurry	**0,76**		
Speeding when road is famil.	**0,87**		

Seat belt reminder: no starting driver	**0,90**	0,20	-0,03	0,02
Collision warning	0,20	**0,82**	-0,03	0,15
Active cruise control	0,22	**0,69**	0,36	-0,09
Distance warning	0,16	**0,77**	0,19	0,10
Supportive ISA	0,22	0,18	**0,69**	0,32
Informative ISA	0,00	0,25	-0,11	**0,81**
Closed ISA	0,27	0,04	**0,76**	0,14
Warning ISA	0,16	-0,09	0,27	**0,67**
<u>Usefulness Informative ISA</u>	*Eigenvalues Cumul.:*			*89,52%*
Useful-useless	**0,94**			
Bad-good	**0,92**			
Effective-superfluous	**0,96**			
Assisting-worthless	**0,96**			
Raising Alertness-sleep-inducing	**0,95**			
<u>Usefulness Warning ISA</u>	*Eigenvalues Cumul.:*			*82,45%*
Useful-useless	**0,89**			
Bad-good	**0,86**			
Effective-superfluous	**0,93**			
Assisting-worthless	**0,95**			
Raising Alertness-sleep-inducing	**0,91**			
<u>Usefulness Supportive ISA</u>	*Eigenvalues Cumul.:*			*82,62%*
Useful-useless	**0,93**			
Bad-good	**0,83**			
Effective-superfluous	**0,93**			
Assisting-worthless	**0,93**			
Raising Alertness-sleep-inducing	**0,92**			
Satisfaction				
<u>Satisfaction Open ISA</u>	*Eigenvalues Cumul.:*			*90,42%*
Pleasant-unpleasant	**0,94**			
Nice-annoying	**0,96**			
Irritating-likeable	**0,94**			
Undesirable-desirable	**0,97**			
<u>Satisfaction Warning ISA</u>	*Eigenvalues Cumul.:*			*80,28%*
Pleasant-unpleasant	**0,86**			
Nice-annoying	**0,92**			
Irritating-likeable	**0,90**			
Undesirable-desirable	**0,91**			
<u>Satisfaction Supportive ISA</u>	*Eigenvalues Cumul.:*			*84,11%*
Pleasant-unpleasant	**0,91**			
Nice-annoying	**0,91**			
Irritating-likeable	**0,93**			
Undesirable-desirable	**0,92**			

Speeding when there is nobody else on the road	**0,80**		
Speeding when very little change 'to get caught'	**0,80**		
Speeding when you will not bring others in danger	**0,81**		
Social norms	*Eigenvalues Cumul.:*		*68,95%*
Speeding to impress others	**0,814**		
Speeding to compete with other drivers	**0,748**		
Speeding if other drivers push me to drive faster	**0,734**		
Speeding when peers of same age as passenger	**0,806**		
Speeding when passengers	**0,742**		
Speeding to go with the flow	**0,685**		
Effectiveness/Efficiency	*Eigenvalues Cumul.:*		*61,46%*
Opinions about measures to counter speeding			
Campaigns to counter speeding	0,42	-0,48	
Speed camera's to counter speeding	**0,85**	0,03	
Police controls to counter speeding	**0,84**	0,00	
Speed humps to counter speeding	**0,64**	0,01	
In-vehicle technology to counter speeding	0,20	**0,89**	
Opinions about WHICH ISA-effectiveness	*Eigenvalues Cumul.:*		*67,88%*
To cope with the limits in residential area	**0,88**		
To cope with the limits in urban area	**0,88**		
To cope with the limits outside urban area	**0,87**		
To cope with the limits on highways	**0,78**		
To reduce fuel consumption	**0,78**		
To reduce emissions	**0,77**		
To increase traffic safety	**0,81**		

Equity		
Which ISA for who	*Eigenvalues Cumul.:*	*70,62%*
Young drivers	**0,87**	
Elder drivers	**0,86**	
All drivers	**0,79**	
Experienced drivers	**0,84**	
Vans	**0,89**	
Trucks	**0,85**	
Motorcycles	**0,84**	
Buses	**0,86**	
Taxi's	**0,90**	
Bad drivers	**0,69**	
Which ISA when	*Eigenvalues Cumul.:*	*70,90%*
Informative ISA	**0,85**	
Warning ISA	**0,87**	
Supportive ISA	**0,81**	
Affordability	*Eigenvalues Cumul.:*	*70,11%*
Informative ISA	**0,81**	
Warning ISA	**0,89**	
Supportive ISA	**0,81**	

Problem perception

The extent to which speeding was perceived as a problem is a necessary indicator for defining acceptance and acceptability. Four items were considered relevant in defining perception of this problem: (i) what will cause accidents, (ii) attitudes to speed and speeding, (iii) insecurity feelings when speeding, and (iv) opinions about posted speed limits.

Noteworthy is that 58.2% of the variance is explained by three factors regarding causes of accidents. Speeding and driving under the influence of alcohol and drugs are loaded onto the same factor. Speeding, alcohol, and drugs are considered to be the main issues in accident risks. For factor 2, more ‘indirect issues’, such as no experience as a driver, infrastructure, and inexperienced other drivers, are loaded. On factor 1 other recognized issues that can cause accidents, such as thrill-seeking behaviour, poor distance keeping, fatigue, and weather conditions, are loaded.

On the attitudes to speed and speeding, some issues are loaded onto a factor that would explain the relationship between traffic safety and speeding (danger and safety) and a factor that would explain the emotional experience and perception of speeding (fun, excitement, and freedom).

Three factors related to the feeling of insecurity about whether inappropriate speed is noticed are found. It is noted that almost every time the problem of speeding in lower speed areas such as school environments and residential zones are loaded onto one factor (factor 2). We may assume that driving too fast in these areas is almost unforgivable for our respondents. On the other hand, it could be that when asked about speeding in these areas, people would be better able to imagine school and residential surroundings than when asked about urban or non-urban zones.

Personal and social aims and social norms
Clearly, people who want to drive as fast as possible according to their own preferences will have a lower acceptability and acceptance of ISA.

For this indicator it was difficult to find relevant questions that are related to personal and social aims when speeding. Therefore the ‘personal and social aims’ are put into different kind of situations. Through this factor analysis we may conclude that these items are relevant.

Perceived social norms and perceived social pressure refer to the assumed opinions of peers. Our survey attempted to assess peer pressure relative to speed and speeding.

Effectiveness and efficiency
In most ISA trials this was done through an evaluation of the technical/ergonomic issues. The main question in these trials remained whether the system supported the driver to maintain the legal speed. Almost every item about ‘finding a measure effective to counter speed’ was loaded onto one factor. In-vehicle technology was loaded onto factor 2. We assume that because in-vehicle technology was not yet available the respondents would value this in a different way than the other measures. Campaigns had a negative loading (-0.48) on the second factor.

Usefulness
Perceived usefulness is related to how the system will support the drivers’ tasks and driving behaviour. In our questionnaire we compared the ISA system with other ITS and used the usefulness items from the van der Laan scale. Four factors were distinguished when we asked about the usefulness of different ITS systems. Factor 3 was mainly related to perceived feelings of freedom and privacy, such as closed and supportive ISA (less individual control of speed and speeding) and the black box (which can monitor driving behaviour). Collision warning, active cruise control, and distance warning systems were loaded highest onto the same factor (factor 2). ITS systems related to avoiding an accident were found together. On factor one, systems were found that prevent the driver from starting. It seems also that open and warning ISAs are found on one factor (systems related to speeding behaviour), except for those ISA systems that could be considered as reducing the feeling of freedom in driving.

Usefulness and satisfaction (van der Laan-scale items)
As described above, usefulness and satisfaction are considered important items for defining acceptance. Our acceptability research also investigated these items with a view to evaluating an informative warning and supportive system. The results indicated a good relation between the items of satisfaction and usefulness.

Equity and affordability
To define equity, the respondents had to indicate when they would use a certain system. The choices they had, were: (1) never, (2) if 90% or more of every vehicle was equipped, (3) if 60% of every vehicle was equipped, (4) if 30% of every vehicle was equipped, (5) if 10% or less of every vehicle was equipped. Affordability was rated on a scale from 1 to 5 (from 1 = I want to buy it, 3 = need of incentives, 5 = I never want to buy it). In addition, one factor was found for the equity items and one for the affordability items.

5.5.2 Correlations between factors

In Table 5-4 the correlations between the different factors are given. Only the highest and most significant correlations per item are described (instead of factors). These ‘raw’ data could give a first indication of whether there are relations between the 14 indicators.

A low correlation was found between almost all general indications and between the device-specific indications. Strong correlations were found (R^2 more than 0.80) between the van der Laan items’ usefulness and satisfaction. Generally, we can conclude that the items are relevant for defining the acceptability of ISA.

A moderate level of correlation was found between the items ‘accident influence’ and ‘opinions about measures to counter speed’, ‘attitudes about speed and speeding and speed limits’ and ‘attitudes about speed and speeding’ and ‘personal and social aims’. This was the only moderately significant correlation between ‘personal and social aims’ and some items of ‘problem perception’.

Only low levels of correlation were found between ‘social norms’ and some items of ‘problem perception’, ‘personal and social aims’, and the ‘usefulness’ item about ITS. The indicator of effectiveness and efficiency also had a moderate correlation with the usefulness and satisfaction items of a supportive system and with relative equity. The equity item when ISA was installed correlated well with affordability. Moderate levels of correlation were found between the acceptability of ISA and ISA effectiveness, ITS usefulness, usefulness of informative system, and equity. A marked correlation is found between acceptability and usefulness and satisfaction of a supportive system.

In future research based on large-scale survey results, this model should be re-estimated, allowing more relevant relations to be found.

Table 5-4. Correlations between different items based on results of the pilot survey

	Accept. of ISA	Acci. Infl.	Att. about speed	speed not safe	Speed limits	Pers. & soc. aims	Social norms	meas. counter speed.	WH. ISA-effect.	WH. ITS use	Use. Inf. ISA	Use. War. ISA	Use. Sup. ISA	Sat. Op. ISA	Sat. War. ISA	Sat. Sup. ISA	ISA who	ISA when	Affor.
Accept. of ISA						-,243**	-,210**		,462**	,406**	-,532**	,203**	,692**	-,544**	,204**	,693**	,422**	-,284**	-,243**
Problem Perc.																			
Accid. Infl.			,308**	,200*	-,225**	,311**			,236**										
Att. Speeding		,308**			-,465**	-,428**		,345**	,265**									-,219**	
speeding not safe		,200*			,350**	,249**	,214**											,211**	,217**
Speed limits		-,225**	-,465**	,350**		,456**		-,265**	-,303**	-,225**									,232**
P&S. aims	-,243**	,311**	-,428**	,249**	,456**		,313**	-,267**	-,250**	-,278**								,309**	,278**
Social norms	-,210**			,214**		,313**				-,228**									
Effect./Effic.																			
Op. Measures		,464**	,345**		-,265**	-,267**			,243**	,272**									
ISA-effect.	,462**	,236**	,265**		-,303**	-,250**		,243**		,387**	-,262**		,400**	-,275**		,423**	,513**	-,266**	-,238**
Usefulness																			
ITS useful	,406**				-,225**	-,278**	-,228**	,272**	,387**		-,261**		,439**	-,260**		,429**	,364**	-,255**	-,310**
Useful. Info. ISA	-,532**								-,262**	-,261**				,961**			-,202*		
Useful. Warn. ISA	,203**														,909**				
Useful. Sup. ISA	,692**								,400**	,439**						,932**	,352**		
Satisfaction																			
Satis. Info. ISA	-,544**								-,275**	-,260**	,961**						-,217**		
Satis. Warn. ISA	,204**											,909**							
Satis. Sup. ISA	,693**								,423**	,429**			,932**				,436**		
Equity																			
ISA for who	,422**								,513**	,364**	-,202*		,352**	-,217**		,436**			
ISA when	-,284**		-,219**	,211**		,309**			-,266**	-,255**						-,180*			,506**
Affordability	-,243**			,217**	,232**	,278**			-,238**	-,310**								,506**	

*. Correlation is significant at the 0.05 level . **. Correlation is significant at the 0.01 level .

5.6 Conclusions

It is recognized that knowledge concerning the level of acceptance or acceptability of a measure is important for future implementation of in-vehicle technologies. Ironically, a clear definition of what acceptance and acceptability are or how they should be measured is still lacking. In this paper we aimed to improve on this lack of knowledge. We made a distinction between acceptance and acceptability based on time and experience of the individual, whereby acceptance entails beliefs and attitudes, based on their behavioural reactions after the introduction of a measure. Acceptability describes the prospective judgement, based on attitudes and beliefs about a measure, without experience, to be introduced in the future.

New vehicle technologies such as ISA are difficult to implement. Therefore there is a need to understand which factor or indicator would influence future drivers' acceptability or acceptance. Based on different socio-psychological theories and methods used in ISA trials we found 14 relevant indicators that we divided into general indicators (related to persons' psyches, social values and norms at that time, and so on) and device-specific indications (factors that are directly related to the device itself). These 14 indicators were presented to randomly selected respondents (through new Internet media) in a test survey. The main goal of this survey was to find if the distilled indications and the questions were relevant, and if some relations could be found between the indicators . Through the use of factor analysis we found out that our questions were relevant for every item and some correlations were found between the items. It is also noted that some indicators would directly influence the acceptability of ISA while some would influence others more indirectly. This first step in our research enabled us to conduct a relevant large-scale survey among the general public in The Netherlands and Belgium on the acceptability of ISA.

In the second phase of our research analysis, following the large-scale survey, the data will be processed to define how indicators relate to each other and how they fit the model. This model will be used to define how far implementation strategies should be taken to encourage higher acceptability and future acceptance of ISA. Some cross-cultural research will also be done and the answers related to answers given by different stakeholders.

One of the key issues is how the public will react if ITS is implemented. The understanding of the defined indications that will influence acceptability and acceptance may support decision-makers in developing an appropriate implementation strategy. Through the construction of this framework, we want to provide decision-makers with methods and procedures that are easy to use and understand, based on well-accepted socio-psychological models.

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6 The Potentials for In-car Speed Assistance Systems: Results of al Large Scale Survey in Belgium and the Netherlands

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Abstract
Speeding is generally considered to be a major cause of road traffic accidents. In-car speed assistance systems aim at reducing speeding. Several trials with different types of in-car speed assistance systems, in particular Intelligent Speed Assistance (ISA), have shown that ISA can be an effective way to reduce speeding. A basic condition for achieving significant improvements in safety involves the adaptation of ISA among vehicle drivers on a large scale. This paper focuses on the issue of acceptability of ISA. It is based on a large-scale survey of 6370 individuals in Belgium (Flanders region) and 1158 persons in the Netherlands. The respondents indicated that they believed that their own driving behaviour is of great influence on accidents and traffic safety, and that contextual issues like infrastructure or other drivers are less important. Almost 95% of the respondents are in favour of ISA: seven out of ten drivers state that they want to have some informative or warning system. Three out of ten

drivers even wanted to go further, they indicated a preference for a restricting type of ISA. However, drivers would only choose for more restricting systems if the penetration rates of such systems in the vehicle market were high enough.

6.1 Introduction

Advanced Driver Assistance Systems (ADAS) involve in-vehicle systems that aim at improving vehicle-driving tasks. One of the most promising ADAS, aimed at reducing inappropriate speed, is Intelligent Speed Assistance (ISA). ISA is an intelligent in-vehicle device that warns the driver about speeding, discourages the driver from speeding, and/or prevents the driver from exceeding the speed limit (Brookhuis & De Waard, 1999; Carsten & Tate, 2005; Marchau, et al., 2005; Regan et al., 2006).

Most ISA systems use GPS and a digital speed limit database: the position of the vehicle is determined using a GPS-receiver. The position is used to retrieve the speed limit or other information from a database. The information is then reported to the driver. ISA can enforce three types of limits (Carsten & Tate, 2005): (i) static speed limits (posted speed signs), (ii) variable speed limits (spatially: information about speed limits depending on the location, e.g. lower speed around pedestrian crossings) and (iii) dynamic speed limits (in terms of time: information based on actual road and traffic conditions, e.g. reduced speed due to weather conditions). ISA-devices can be categorized in different types depending on how much they intervene in the vehicle-driving task (or how the information is communicated to the driver). An informative or advisory system displays the recommended speed limit to remind the driver of the changes in speed levels. A warning or open system cautions the driver if the posted speed limit at a given location is exceeded; the driver then decides whether to use or ignore this information. An intervening, supportive or half-open system gives a force feedback through the gas pedal if the driver tries to exceed the speed limit (like the active accelerator pedal (AAP)). It is however still possible for the driver to overrule the counter-pressure initiated by the accelerator pedal. A mandatory, automatic control, restrictive, or closed system will fully prevent the driver from exceeding the speed limit; the driver cannot overrule the system.

Several studies and field trials have indicated that ISA reduces speed and speeding (Agerholm et al, 2008; Carsten and Tate, 2005; Vlassenroot et al., 2007) that ISA is effective for traffic safety (Agerholm et al., 2008) that ISA is expected to be beneficial for the environment because of the estimated reduction in speed and speed variance (Regan et al., 2006; Várhelyi et al. 2004); and thus that ISA can lead to a more homogeneous traffic flow (Hogema, 2002).

Although there has been no large-scale implementation of ISA yet, there have been promising initiatives in recent decades at European and national levels with respect to the development of technical feasibility frameworks (like geographical information storage, GPS-accuracy, vehicle communication, etc.) and speed limit databases (Vlassenroot et al., 2008). It could be generally concluded that, at the European level the major technical guidelines and protocols for the feasibility and deployment of in-vehicle ITS have been developed. Within the national initiatives the focus has shifted towards a more operational level, including legislation, national protocols, basic tools and field practices. Another important factor for future implementation of ISA is understanding how users will experience and respond to these devices and to what extent drivers are willing to accept ISA. The interest in defining acceptance or acceptability lies in the precondition that the effectiveness and success of ISA will increase if there is public/social support for it. Under favourable conditions a positive assessment leads to an increased willingness to accept ISA and even to support it actively.

Brookhuis and De Waard (1999) noted that the acceptance of ISA strongly depends on the mode of the used feedback. In field trials in Hungary and Spain (Falk et al., 2004), a comparative study was made between an auditory warning system and active accelerator pedal (assisting system). In Hungary, most drivers preferred auditory and visual feedback to a active accelerator pedal. Also drivers' characteristics are important for the acceptance of ISA. Jamson (2006) noted that frequent speeders were less likely to support ISA. Hjalmdahl and Verhalyi (2004) found that drivers, who were willing to use ISA, already drove at a speed close to the speed limit, while those who drive fast wanted to abort the trial after using the system. In most trials the acceptance of ISA increased after using the system in the trial, compared with the opinions they gave before the trial (Vlassenroot et al., 2007). This indicates that trying the system will positively influence the user acceptance of ISA. Additional studies were done to determine the willingness to pay for ISA. Drivers indicated a willingness to pay an average of 90 Euros for installing the system in their vehicle. The market value was estimated to be 180 Euros on new cars, 155 Euros in case of retrofit (Van der Pas et al., 2008). Not much research was conducted during the trials on the acceptability of ISA by non-ISA users. De Mol et al. (2001) did a large-scale survey in Belgium about the public support for speed measures, including ISA. Most of the respondents recognized that speed and excessive speed is a problem. The acceptability of ISA was quite large: although the mandatory ISA-system was not acceptable to 30 % of the respondents, advisory ISA was acceptable for 82 % of the respondents. In addition, the acceptance for mandatory ISA varied substantially across different road types: outside urban areas 47 % of the respondents were not in favour of a mandatory ISA, on motorways 60 % of the respondents did not accept mandatory ISA while in urban areas almost 70 % accepted mandatory ISA. In the SARTRE project (Drevet, 2004) over 24,000 drivers in 24 European countries were questioned about road traffic safety. One of the questions concerned the perceived usefulness of a system that prevents exceeding the speed limit. Less than 50% in Northern Europe, about 55% in Western and Eastern Europe and about 65% in Southern Europe would find such a system fairly or even very useful. Piao et al. (2005) reported results from a survey on ISA in three European cities. In all three cities there was strong support for an informative ISA but very little support for the active accelerator pedal or restrictive ISA. Up to 70% of the drivers said they would like to use ISA systems in residential areas.

It is noted that, in general, the research on user acceptance and public acceptability varied a lot between the different trials and studies, and no coherent acceptance indications were described. Carsten (2002) stated that the attitudinal research on acceptance of ISA could be criticized for not being sufficiently rigorous. Although, it is recognized that acceptance, acceptability, and adaptation of ISA are important, a clear definition of what acceptance and acceptability is and precisely how it should be measured is still unclear (Dragutinovic et al., 2005; Adell, 2008). The lack of a unified theory and definition regarding acceptability has resulted in a large number of different approaches to measure ITS acceptance and acceptability (Vlassenroot et al., 2006), often with quite different results.

In our study we tried to describe the most relevant factors that could determine acceptability. Based on a previously held literature review and analyses of the methods used in different ISA-trials and technology acceptance theories (like theory of planned behaviour (TPB), technology acceptance model (TAM)), the most relevant determinants that influences acceptability have been identified (Vlassenroot et al., 2010)

In this paper, the different indicators that define the acceptability of ISA are explored, by the use of a large-scale survey among drivers. In section 2, our method is described. In section 3 the main results are given. Finally conclusions are made and discussed in section 4.

6.2 Method

6.2.1 Theoretical background

In this study, a distinction was made (see Fig. 6-1) between general indicators (related to the context awareness of the system) and system specific indicators (directly related to the characteristics of the device). The definition of every indicator is described below.

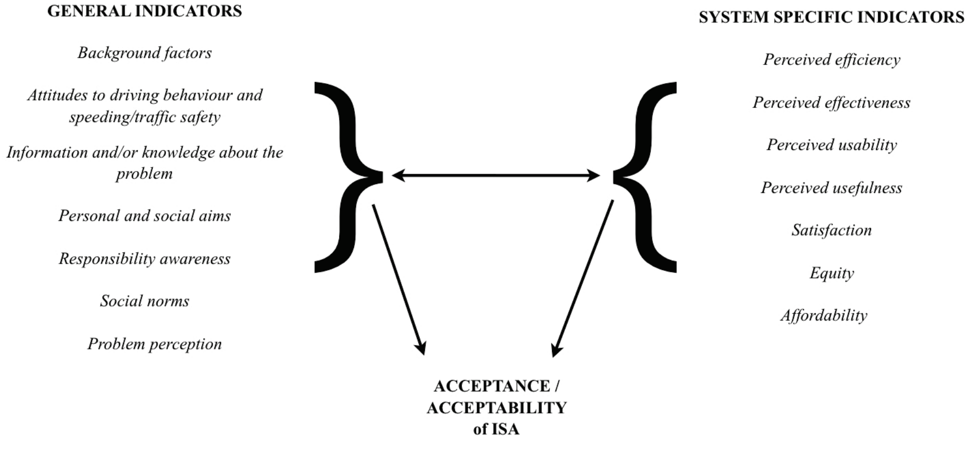

Figure 6-1: Indicators that could influence the acceptability of ISA

General indicators
Gender, age, level of education and (income) employment are the *individual indicators* and are considered to have an important influence on how people think about speed and speeding and, therefore, on the use of ISA (Parker & Stradling, 2001). On the *Attitudes to driving behaviour and speeding/traffic safety*, travel behaviour and driving style are brought into relation with speeding behaviour (Stradling et al., 2003) Schade and Schlag (2003) describe *personal and social aims* as the conflict between social or personal aims. They assume that a higher valuation of common social aims will be positively related to acceptability. Perceived *social norms* and perceived social pressure can be measured by quantifying the (assumed) opinions of others (peers) multiplied by the importance of the others' opinions for the individual (Azjen, 2002). *Problem perception* has been defined as the extent to which speeding is perceived as a problem. There is common agreement that high problem awareness will lead to increased willingness to accept solutions for the perceived problems (Goldenbeld, 2002; Steg et al., 1995). *Responsibility awareness* explains how much an individual recognise responsibility for the perceived problem: is it the government (others/extrinsic) or is it the individual itself (own/intrinsic) (Schade and Baum, 2007)? The level of acceptability for ISA can depend on how well informed (*information and knowledge about the problem)* the respondents are about the problem and about the (new) device that is introduced to solve the problem (Schade and Baum, 2007; Steg et al., 1995).

Device specific indicators
The *perceived efficiency* indicates the possible benefits users expect of a concrete measure (or device) as compared to other measures. *Effectiveness* refers to the system's functioning according to its design specifications, or in the manner it was intended to function (Young et al., 2003). *Perceived usability* can be defined as the ability to use the system successfully and with minimal effort (SpeedAlert, 2005). *Perceived usefulness and satisfaction* are indicators from the acceptance scale of Van der Laan et al. (1997). This scale was developed to study user acceptance. Acceptance is measured by direct attitudes towards a system and provides a system evaluation in two dimensions. The technique consists of nine rating-scale items, each a 5-point Likert scale. These items are mapped on two subscales, a scale denoting the usefulness of the system, and a scale designating satisfaction. *Equity* refers to the distribution of costs and benefits among affected parties. However, from a psychological point of view, perceived justice, integrity, privacy, etc., are considered basic requirements for acceptability (Schade & Baum, 2007). In many trials acceptance was also defined by *willingness to pay* and *affordability* of ISA (Biding & Lind, 2002; Broekx et al., 2006; Hjalmdahl & Várhelyi, 2004). Giving incentives like lower road taxes, lower insurance fee, can stimulate the acceptability of ISA (Lahrmann et al., 2007; Schuitema & Steg, 2008).

In our conceptual study on acceptability it was noted that these indicators had the highest potential to predict acceptability. However not many acceptability studies were conducted, and thus not every indicator has been adequately studied in previous acceptability research (De Mol et al., 2001; Garvill et al., 2003). In the next section we describe how the theoretical acceptability concept has been translated in a survey.

6.2.2 Survey setup

Based on the literature about acceptance and acceptability theories and models, different factors and some 250 possible questions from past surveys – some questions had multiple sub-questions – were found (for a full discussion see Vlassenroot et al., 2010). These questions were categorized into questions about (i) personality characteristics, (ii) problem recognition related to speed and speeding, (iii) the use and integration of the actual methods to counter speeding, and (iv) the use of the new technology (ISA) to counter speed and speeding. These clusters made it possible to identify similar questions and to redefine some questions. The above-mentioned 14 indicators were also positioned in these clusters.

In the second phase only questions relevant to defining the indicators were retained: a list of about 60 relevant questions was used as a starting point. The number of main questions was then reduced to 36, most of which consisted of different items (sub-questions) that had to be rated on a 5-point Likert-scale.

A first version of a web-based survey was next assembled using the open source program Limesurvey. This survey was tested among colleagues. Using their comments, especially about user friendliness, a second version of the survey was made and circulated by mail and the popular networking site Facebook. The goal was to reach 150 respondents. Based on the answers of these respondents some modifications were made to improve the survey and some of the early responses were processed to find out if the questions would cover the described indicators (main variables).

The final web-based survey was put online at the end of September 2009. The web-address of the survey was published by the Flemish and Dutch motoring organisations. In particular, in Flanders an email newsletter was sent to the VAB members. In the Netherlands, the link to the survey was first only announced on the ANWB website. Because of the initial low response rate in the Netherlands an additional email newsletter was sent, but only to the 'active members.' (i.e. members that pay a fee to ANWB for several kinds of services e.g. breakdown services).

6.3 Results

6.3.1 Background information

Background characteristics of respondents
In total 6370 individuals (see Table 6-1) responded to the web-survey in Belgium and 1158 persons in the Netherlands. Of these 7528 respondents 5599 responses of car drivers were considered useful for further analysis.

Most respondents were male (79%), probably because most VAB and ANWB members are male. Only 2% of the respondents were younger than 25 years, while 27% were between 25 and 45 years, and 71% of the respondents were older than 45 years.

The Z-test indicated that our sample of responses differs significantly from drivers' license owners in Belgium and the Netherlands. Our sample was only representative for Belgian drivers between the ages of 35 and 44. For the respondents in the Netherlands it was possible to compare with the national figures (SWOV, 2010). In Belgium it was only possible to compare with the results collected from a large-scale travel behaviour survey (OVG, 2010). In our sample, drivers younger than the age of 34 are underrepresented, and the age group 45 – 64 is overrepresented relative to the population of drivers' license owners in Belgian and the Netherlands. More male and elder drivers have participated.

Although our sample was not representative for the whole population of drivers' license owners in the Netherlands and Flanders, both motorist organisations indicated that our results were relevant compared to their member-databases, although exact data of every parameter (e.g. education level) was not available. This can partly be explained by the fact that predominantly elderly people have a membership of the motorist organisations. One out of two drivers had a "higher education" (university). This was expected since using a web-survey specifically stimulates people with a higher education to participate (Van Acker et al., 2007). 49% of the drivers have no children living at home.

Table 6-1. Individual factors of the Belgian and Dutch respondents

	Belgian Flemish	Owner of drivers' license* (2007)	Z-test	Dutch	Owner of drivers' license** (2008)	Z-test	All Resp.
Response							
Response	6370	7621		1158	10321996		7528
N (withheld)	4641	7621		958	10321996		5599
Gender (in %)							
Male	77.3	53.6	P<0.01	89.4	53	P<0.01	79.4
Female	22.6	46.4	P<0.01	10.6	47	P<0.01	20.6
Age (in %)							
17-24	1.4	10.0	P<0.01	2.5	7.9	P<0.01	1.6
25-34	9.0	15.6	P<0.01	6.5	17.7	P<0.01	8.6
35-44	19.0	18.9	n.s.	13.7	20.9	P<0.01	18.1
45-54	30.0	18.3	P<0.01	25.0	21.8	P<0.05	29.1
55-64	26.9	14.9	P<0.01	34.4	16.9	P<0.01	28.2
65 +	13.4	22.2	P<0.01	17.8	14.8	P<0.01	14.1
Education (in %)							
Higher education	58.2	28.5	P<0.01	53.9	-	-	57.4
Secondary education	39.2	54.5	P<0.01	44.9	-	-	40.2
Primary education	1.8	15.4	P<0.01	0.8	-	-	1.7
No education	0.7	1.6	P<0.01	0.3	-	-	0.6
Family-situation (in %)							
No children	48.5	-	-	58.7	-	-	49.1
Oldest child < 12 y.	19.2	-	-	14.3	-	-	18.4
Oldest child > 12 y.	13.3	-	-	12.7	-	-	13.2
Oldest child > 18 y.	19.0	-	-	14.3	-	-	18.2

Driving and travel behaviour
Over 90% of the respondents were private vehicle owners, 13% of the respondents had a company car (some of the respondents had more than one vehicle). About 30% of the respondents drove up to 10 000 km/year, 48% between 10 000 and 25 000 km/year and 22% more than 25 000 km/year. It can be stated that our figures on mileage did not differ much from the nationally reported averages: the average driver in Belgium would drive around 11 000 km/year, in the Netherlands the average driver would drive around 15000 km/year (Federal government, 2010; ANWB, 2010).

Almost 76% of the drivers had been involved in an accident: 77% had only small damages, 18% had an accident with mildly injured people, 4% with severely injured people and 1% were involved in an accident with one or more casualties. In total 51% reported using the car to go to work or school, 73% used their car for shopping and 74% used a car for leisure activities.

Information about ISA
Half of the drivers indicated being familiar with systems that can give information about the posted speed limits. Over 60% of the respondents were aware that speed limit advice can be found in today's navigation systems; 14% knew the concept of ISA and 20% indicated they were familiar with the term 'speed alert systems'. Only 5% of the respondents had knowledge about the local ISA-trials conducted in Ghent (B) or in Tilburg (NL).

6.3.2 General indicators

Problem perception
The respondents were asked to evaluate which traffic offenses or situations would have an impact on traffic accidents on a 5-point Likert scale (see Table 6-2).

Table 6-2. The influence of traffic situations and offences on accidents

	No Influence 1	**2**	**3**	**4**	**High influence 5**
Driving under influence of alcohol or drugs	0.1	0.5	2.9	7.6	**88.8**
Little driving experience	0.3	5.5	24.8	**36.6**	32.7
Inappropriate speed	0.5	3.5	11	27.9	**57.2**
Other, less experienced drivers	0.5	7.2	28.1	**37.1**	27.2
Bad weather conditions	0.2	5.7	29.8	**38.4**	25.9
Mobile phone use (without using a car-kit)	0.9	5.8	18.3	31.5	**43.6**
Bad infrastructure	0.7	10.7	30.5	**34.1**	24.1
Other risk-seeking behaviour	0.1	0.9	7	27.5	**64.5**
Fatigue	0.1	0.8	10.4	39.3	**49.5**
Insufficient distance keeping	0.3	1.8	11.4	35.8	**50.7**

According to the respondents, 'driving under influence' is considered the number one cause of an accident (89% said it has a high influence), followed by 'taking risks' (65%), 'inappropriate speed' (57%), 'not keeping distance' (51%) and 'fatigue' (50%). Most of the drivers attributed accidents to their own driving behaviour instead of other (contextual) influences like bad weather (26%), bad infrastructure (24%) or other drivers (27%).

The drivers were asked how often they would drive faster in areas with different speed limits. One out of two drivers indicated that 'sometimes' they would drive faster, 30% regularly drives too fast outside urban areas and on highways, while 22% would drive faster in 30 kph areas, and only 10% drive faster in urban areas. The respondents were also asked to indicate the best and safest speed for the different areas. Related to this question respondents had to indicate when a speeding offense is made, which maximum speed would be considered as an honest mistake (e.g. misinterpretation of a (non posted) limit) and which speed should be considered as irresponsible (Table 6-3).

Table 6-3. Responses on safest speed, mistaken and irresponsible speeding offenses

Speed zone (official limit)	Safest indicated speed (median in kph)	'Tolerable' speeding offense (median in kph)	Irresponsible speeding offense (median in kph)
Home zone (20 kph)	30	30	50
30 area (30 kph)	30	40	60
Urban area (50 kph)	50	60	80
Outside urban area (80 or 90 kph)	90	100	120
Highway (120 kph)	130	130	160

Except for home zones and highways, the drivers indicated the legal posted limit as the best and safest speed. Most of the drivers stated that driving 10 kph more than the posted limit can be considered as a (forgivable) mistake. Driving more than 30 kph too fast in home zones, 30 kph areas and urban areas, and driving more than 40 kph too fast outside urban areas and highways were noted as irresponsible offenses. The respondents are relatively tolerant about the driven speed as an irresponsible speeding offense, although they indicated that they would not speed very often.

Personal and social aims

The respondents were given different descriptions of situations in which they could choose to maintain the speed, to drive slower, or to drive faster: one out of two drivers will slow down if they think that they could endanger other road users, in the other situations they would maintain the speed or drive faster: two out of three respondents will drive faster in the situation of being in a hurry for an appointment and in the situation if there is nobody else on the road. One out of two drivers would speed during the night, 44% would drive too fast if the roads are familiar. Finally, 41% would speed if they were certain that there is no or little speed enforcement, 58% would maintain the speed in this situation.

Responsibility awareness

The respondents had to indicate how much responsibility (from no responsibility to high responsibility on a 5-point scale) each different actor has, and whether these actor(s) had to do something about the problem of speeding. 81% indicated that they are responsible themselves as drivers. 77% stated that the police are responsible to counter speeding, 63% puts the responsibility on the politicians and 54% on the road authorities.

Perceived effectiveness of ITS

Prior to analysing more specific aspects about ISA, the respondents were asked to evaluate other ITS systems. This approach is assumed to give an indication how the respondents feel about ITS in general and how they think about the use of ITS would impact their driving behaviour.

Table 6-4. Valuation of effectiveness of different ITS by respondents

	Not efficient 1	2	3	4	Very efficient 5
Following Distance Warning (FDW)	18.7	11.7	19.8	24.3	25.5
Adaptive Cruise Control (ACC)	22.4	14.1	18.2	20.6	24.7
Collision Warning systems	10.3	9.3	18.3	25.0	37.1
Seat belt reminder: Car would not start if the driver does not wear the seat belt	24.8	10.3	15.5	17.5	31.9
Seat belt reminder: Car would not start if everybody in the car is not wearing seat belt	25.1	11.7	16.5	18.1	28.6
Alcohol-warning: Gives only a warning-signal when intoxicated	20.5	8.6	14.8	18.1	38.0
Alcohol-lock	21.7	8.2	11.3	13.9	45.0
Black box: Monitoring of driving aspects	27.1	11.6	18.0	19.9	23.4

Table 6-4 plots the subjective effectiveness of different ITS systems for the drivers in our sample. Instead of the name of a certain ITS system, a description of its functionality was presented to the respondents. The alcohol-lock is considered most efficient (45%), followed by the alcohol-warning systems (38%) and the collision warning systems (37%). If the scores on 4 and 5 are combined, at least 40% of the respondents prefer an in-vehicle ITS device: 62% are in favour of a collision warning system and 59% are for the alcohol-lock. Even the black box is considered to be efficient by 43% of the drivers. It is concluded that the respondents are certainly interested in different kinds of in-vehicle ITS systems.

6.3.3 Device specific indicators

Perceived efficiency of ISA

According to the respondents, they believed that the most effective measures against speeding are police controls (81%) and speed cameras (78%), followed by the use of technology in the vehicle (69%). Speed bumps (48% noted as effective) and road safety campaigns (15% noted as effective) were not considered to be very effective. The drivers recognized that technology could help to reduce speed offenses or even help to maintain the speed.

The respondents were also asked which ISA-system they preferred. The four different ISA types were explained to the respondents. Only the description of the system was given. For instance, informative ISA was presented as a system that can give information about the speed limit. The results show that 30% of the respondents were in favour of an informative system, 38% of the respondents preferred a warning system, 12% of the respondents a supportive system (active accelerator pedal) and 15% of the respondents a restrictive system. Only 5% of the respondents indicated that they did not want any ISA, whereas 27% of the respondents indicated that they would prefer an interfering type of ISA than over an informative type system.

Perceived effectiveness of different ISA types
The respondents were asked to indicate which system would be the most effective in different speed zones and for different reasons.

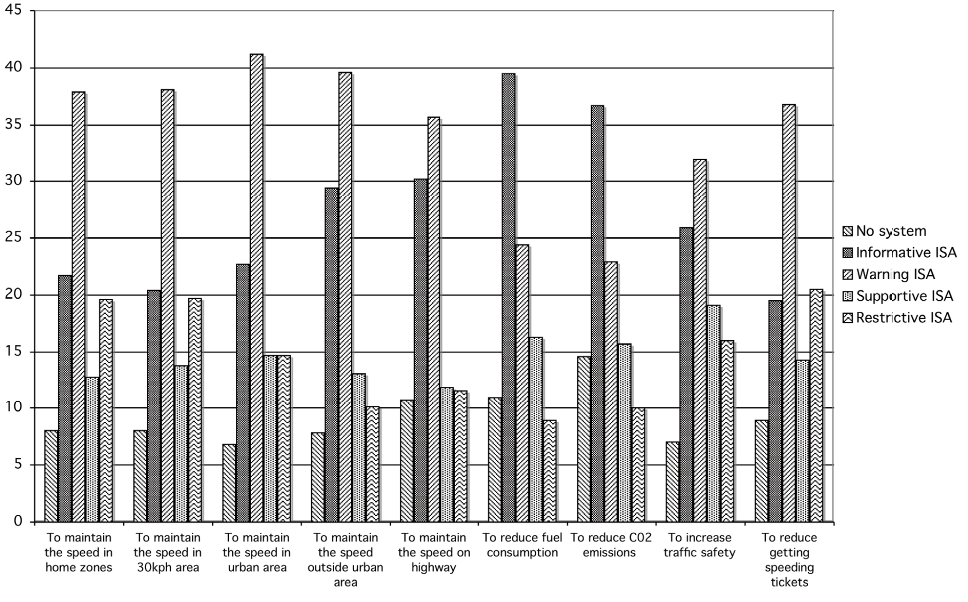

Figure 6-2: Valuation on effectiveness of different types of ISA in different speed area]

Warning ISA has been considered as the most effective in all speed zones (38% in home zones and 30 kph areas, 41% in urban areas, 40% outside urban areas, and 36% on highways). The higher the speed zone, the less an intervening system was chosen. In low speed zones, restrictive ISA had a somewhat better support (20% in home zones and 30 kph zones). The respondents indicated that an informative system would be most sufficient to reduce fuel consumption (40%) and CO_2 emissions (43%). A warning system would increase safety best (32%) and would help most to reduce the chance of getting speeding tickets (37%).

Note that most drivers preferred a warning ISA, although studies (Morsink et al., 2006) indicated that the more restrictive a system is, the better it would be for traffic safety and for the environment. The respondents would choose those systems that still give a certain feeling of freedom, but would be beneficial for their own driving behaviour as well.

Perceived usefulness and satisfaction
In Figure 6-3, the respondents' opinions on usefulness and satisfaction have been scaled. The respondents could only evaluate their preferred system, not every system, i.e. when a respondent indicated a preference for a closed ISA, he or she could only scale the 9 items on satisfaction and usefulness with respect to a closed system.

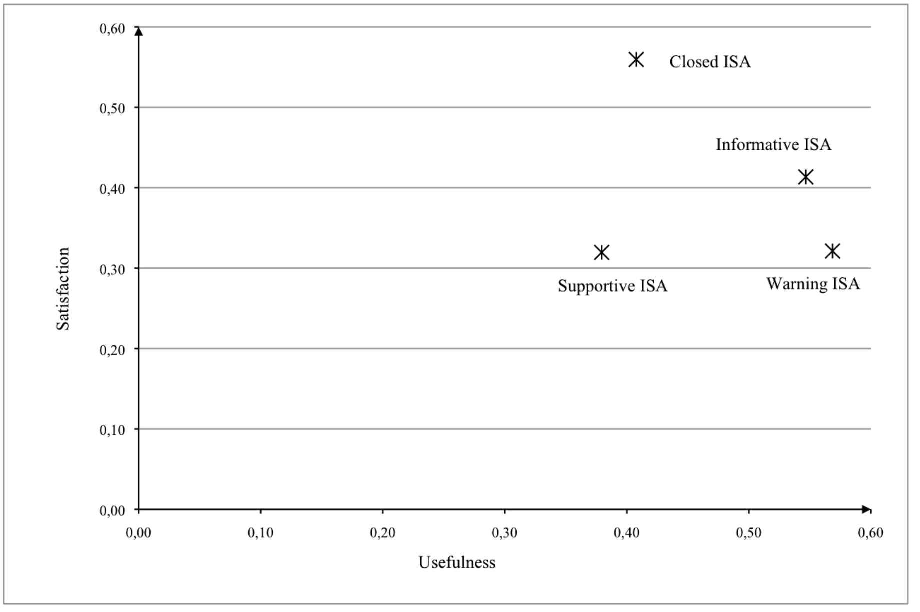

Figure 6-3: Drivers' opinion of ISA scaled on usefulness and satisfaction

All four systems were evaluated as positive. Drivers who chose to have closed ISA find it more satisfying. Respondents who preferred a warning ISA find it more useful. The supportive system has been evaluated as less satisfying and useful in relation to the other systems. It is assumed that it would be more difficult to evaluate a supportive system because it is far more difficult to imagine how it would work, or how it would feel.

Equity

Equity was measured by asking respondents when they are willing to install a certain type of ISA and for whom a certain system would be considered to be most useful.

The drivers were asked to indicate at which ISA penetration level they would decide to install ISA (Figure 6-4). One out of four drivers would install informative ISA if only 5% of the population would have this kind of system, while half of the drivers indicated that they would rather not choose to have restrictive ISA in this case. It is noted that the more intervening a system is the higher the penetration level has to be before a driver would choose to have it.

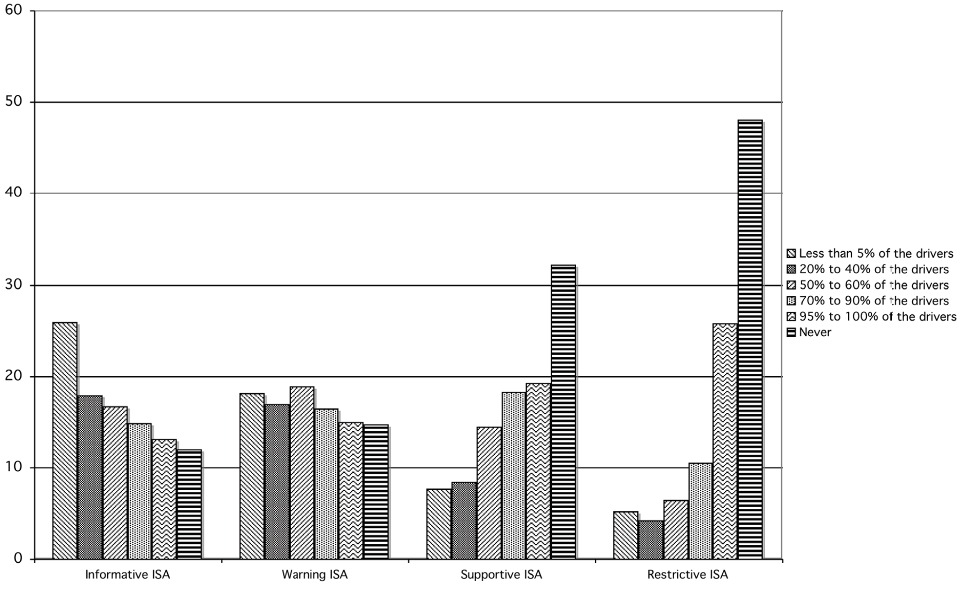

Figure 6-4. Level of penetration that would influence the drivers' choice on a certain ISA system

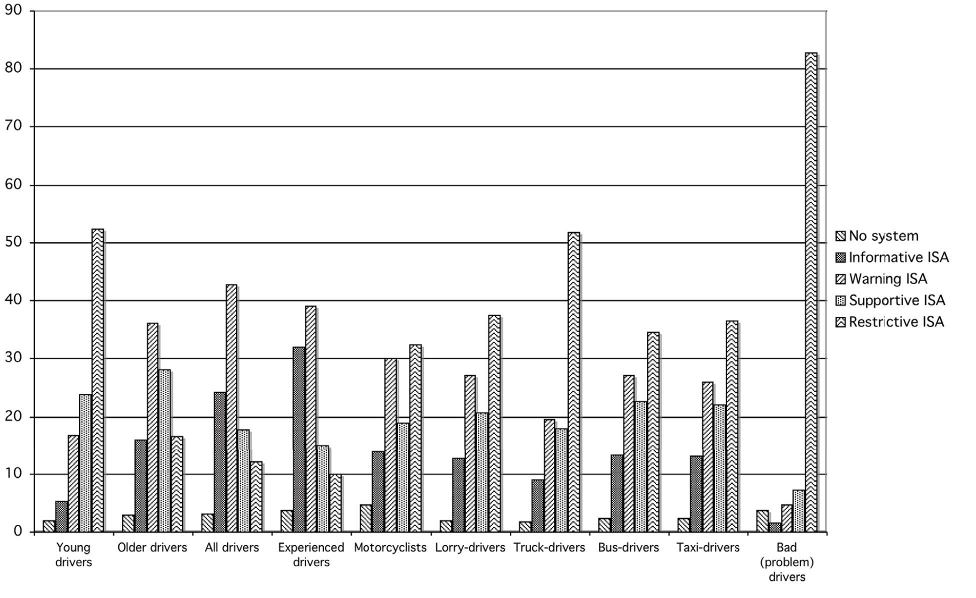

Figure 6-5. Indication for which drivers a certain type of ISA would be the most beneficial

Eight out of ten drivers indicated that problematic or frequent speeding drivers should be using restrictive ISA. At least one out of two respondents stated that professional drivers should use intervening systems like supportive and restrictive ISA. This also gives a certain indication about the safety and 'speeding' image of these professional drivers. There was a strong opinion among our respondents that young drivers should be equipped with more intervening systems, 52% are in favour of restrictive ISA. It should also be noted that 97% stated that ISA is beneficial for all drivers, i.e. 24% informative ISA, 42% warning ISA, 18% supportive ISA and 12% restrictive ISA.

Willingness to pay
In this part of the survey, the respondents could indicate their preferred financial strategy to buy different ISA devices.

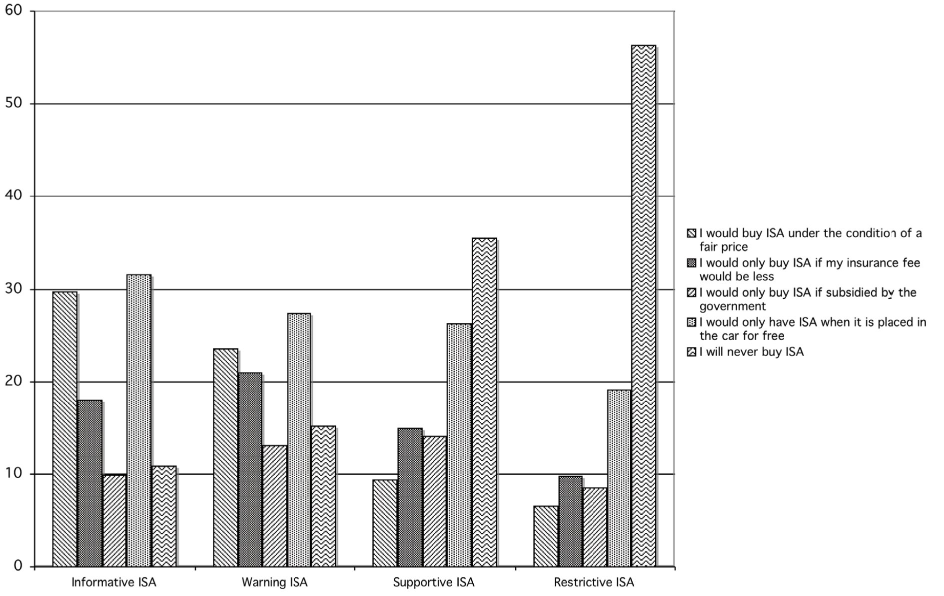

Figure 6-6. Willingness to pay for different ISA-types

For almost every type of ISA a certain specific strategy could be adopted. Although free placement is preferred for every system, most respondents are willing to pay for informative (30%) or warning ISA (24%) if the price is fair (e.g. compared with the price of a standard navigation system). Supportive ISA still got rather high resistance (36%) but a smaller insurance fee (15%) and subsidies (14%) could convince people to install it. The best implementation strategy for a restrictive type of ISA would be free placement (19%), but one out of two drivers would still not want to have it.

6.4 Conclusion and discussion

Although the high respond rate of our survey, it is stated that our results cannot be generalised to all the drivers in Flanders and the Netherlands, as the sample seems to represent the driving population only on mileage.

The general indicators revealed that the drivers' opinions on the current posted speed limits were positive. The drivers would chiefly maintain the speed if they are driving in urban areas, although in 30 kph-zones they would speed more often. These results are in line with the Belgian, Dutch and Swedish ISA-trials (Biding & Lind, 2002; Morsink et al., 2006; Vlassenroot et al., 2007).

The respondents considered that behavioural aspects are a greater cause of accidents than contextual issues. The drivers were also relatively positive about the use of ITS to support their driving behaviour. Already in 2004, the SARTRE research project indicated that drivers rated the use of certain ITS as positive, although the choice between the systems was limited (GPS, ISA, alcohol-lock, driving monitor). In our study it is noted that for these devices the ratings were even higher. This can be a good indication that drivers would like to have even more support when driving.

Almost 95% of the respondents stated that they are in favour of a certain ISA-system. In many studies (Molin & Brookhuis, 2007; Morsink et al., 2006) effectiveness was found as a relevant criterion to determine acceptability, however it was also stated that there is a difference in peoples' opinion on the effectiveness and the found results in trials. In our study, open systems were considered the most effective ones, although it is stated from a safety point of view that (semi)-closed systems are considered better. Morsink et al. (2006) and Marchau et al. (2010) explained this as the 'acceptance versus effectiveness' paradox: the more intrusive and controlling ISA systems are, the more positive effects they have on speed behaviour of drivers. However, these more effective but also more intervening ISA systems, at the same time turned out to be the less acceptable types of ISA systems.

Closed ISA was more preferred (it was even found more satisfying and useful) than supportive ISA. This can be reported as a remarkable result. This might be explained by the fact that for the respondents it was more difficult to understand how the supportive systems exactly work in practice and therefore it was less preferred.

Although the support for ISA is high, the respondents indicated that it would not be unconditional. The more the implemented system would be intervening in their perceived control of the driving experience, the higher the penetration level has to be. This level of 'equity' is mostly not investigated in other trials or ISA-researches. However, in other traffic and transport studies (e.g. tolling) this is more investigated and gave a good indication for future implementation actions (Schade & Baum, 2007). For whom a specific system type should be implemented has been studied in most ISA-studies. The participants of our study felt that young and professional drivers (especially trucks and buses) should have a more intervening system. This was also stated in other trial reports (Marchau et al., 2010); however in our survey many respondents also stated that ISA would be beneficial for all drivers. Like in many ISA-studies (Morsink et al., 2006) the implementation of restrictive ISA was considered a good solution to stop frequent speeders.

This study also indicated that incentives could increase the support for more intervening systems however it would still be difficult to lead people accept restrictive ISA. A market-driven implementation would be sufficient to implement the open systems. Tate & Carsten (2008) examined a market driven scenario in which drivers choose to adopt ISA, and an authority driven scenario with more top down encouragement of ISA adoption. The analysis indicated that over a 60-year period from 2010 to 2070, the market driven scenario is expected to reduce fatal accidents by 10%, serious injury accidents by 6%, and slight injury accidents by 3%. The authority driven implementation scenario is expected to reduce fatal accidents by 26%; serious injury accidents by 21%; and slight injury accidents by 12%.

To conclude, this study indicated that ISA is acceptable for most drivers, which is positive in terms of potential implementation. The high possible acceptability of ISA by drivers should also stimulate further development of the feasibility framework of ISA and other ITS by governments. Many ITS, like ISA, will need road information about the speed limits: most of these speed limit databases are in development or premature for high-scale use (SpeedAlert, 2005;Vlassenroot et al., 2008)

This paper also described an attempt to come to a more general framework in the field of ISA and ITS acceptability. Many studies on acceptability can be criticised for not being sufficient. This study aims to contribute to the development of a more robust framework.

Future steps in this research, based on the results of the large-scale survey, are to define how the indicators relate to each other and how well they would predict the acceptability based on the conceptual model. A cross-cultural analysis between the Dutch and Belgian drivers will be conducted. In addition, acceptability variance of ISA among different age groups will be examined.

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7 What Drives the Acceptability of Intelligent Speed Assistance (ISA)?

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Abstract
To have knowledge about the acceptability of Intelligent Transport systems (ITS) is most beneficial for the development of supported implementation strategies. So far, different theories and methods, also stemming from other domains, have been used to define and conceptualize the notion of acceptability. In a previous paper, we developed a theoretical concept to define acceptability of ISA based on different theories and methods used in ITS & ISA research. In the current paper we aim to find out which predefined indicators are relevant to define the acceptability of ISA. Background factors, contextual issues and ISA-device related factors are used as indicators to predict the level of acceptability. Structural Equation Modelling (SEM) is used to define the direct and indirect effects.

7.1 Introduction

In December 2008, the European Commission (2008) took a major step towards the deployment and use of Intelligent Transport Systems (ITS). In the Action Plan on ITS, the EC suggested a number of targeted measures and a proposal for a Directive laying down the framework for their implementation. The main policy objective is to come to cleaner, safer, more (energy) efficient and more secure transport and mobility. The Action Plan stated that better use should be made of the newest active safety systems, such as Advanced Driver Assistance Systems (ADAS), with proven benefits in terms of in-vehicle safety for the vehicle occupants and other road users (including vulnerable road users).

One of the most promising ADAS, aiming at reducing inappropriate speed, is Intelligent Speed Assistance (ISA). ISA is an intelligent in-vehicle device that warns the driver about speeding, discourages the driver to speed, and/or prevents the driver from exceeding the speed limit (Brookhuis & De Waard, 1999). ISA-devices can be categorized into different types (Morsink et al., 2006) depending on how intervening (or permissive) they are. An informative or advisory system displays the speed to inform and remind the driver of the changes in speed levels. A warning or open system cautions the driver if the posted speed limit at a given location is exceeded; the driver may then decides whether to ignore or comply with this information. An intervening, supportive or half-open system gives a force feedback through the gas pedal at the moment the driver exceeds the speed limit (active accelerator pedal). However, it is still feasible for the driver to overrule the counter-pressure initiated by the accelerator pedal. A mandatory, automatic control or closed system will fully prevent the driver from exceeding the limit; hence, the driver cannot overrule the system.

Since the early 1980s the effects of ISA have increasingly been studied through different methodologies and data collection techniques, varying from traffic simulation, driving simulators, instrumented vehicles up to field trials (Carsten, 2002; Morsink et al., 2006). Generally, ISA shows positive effects on driving speed and speed violations (Agerholm et al., 2008; Driscoll et al., 2007; Regan et al., 2006; Várhelyi et al., 2004; Vlassenroot et al., 2007). The magnitude of the effects mainly depend on how intervening the systems are set. A restrictive ISA seems more effective in reducing speed and speeding than an advisory ISA. Tate and Carsten (2008) conducted a study based on their field trials in the UK to predict the safety-impacts of ISA. Possible policies for ISA implementation were examined, investigating how these policies might affect the overall safety benefits. Two alternative policies were examined: a market driven policy in which drivers choose to adopt ISA and an authority driven policy with more encouragement of ISA adoption. The analysis indicated that over a 60-year period from 2010 to 2070, the market driven policy is expected to reduce fatal accidents by 10%, serious injury accidents by 6%, and slight injury accidents by 3%. The authority driven implementation policy is expected to reduce fatal accidents by 26%; serious injury accidents by 21%; and slight injury accidents by 12%.

With respect to ISA implementation, it is essential to know whether the general public will accept the system or not. Brookhuis and De Waard (1999) stated that the user-acceptance of the system strongly depends on the mode of the used feedback. Morsink et al. (2006) describe an “acceptance versus effectiveness” paradox: the more effective ISA is on road safety (e.g. restricting ISA), the less accepted it is by the users. It is recognized that acceptance, acceptability, and public support are very important for ISA implementation. Consensus about the definition of acceptance and acceptability and how these should be measured is, however, still lacking (Adell, 2007; Regan et al., 2006; Vlassenroot et al., 2006). It is stated that in many trials and studies on ISA, acceptability research has been approached differently. The use of different methods in ISA studies lead to a main criticism that the results are inconsistent: a criticism that could be used as a 'show-stopper' in the development of implementation strategies. Also, most ISA studies focused only on a few determinants of acceptability. A relevant distinction can be made between user acceptance and potential acceptability. E.g. Schade and Schlag (2003) described acceptance as the respondents' attitudes, including their behavioural responses, after the introduction of a measure, and acceptability as the prospective judgement before such future introduction. In this case, the respondents will not have experienced any of the measures or devices in practice, which makes acceptability a construction of attitudes. In the present study the focus will be on the acceptability of ISA.

A main goal in our (overall) research is to find out which factors are mainly used to define acceptability and which of these factors could predict acceptability the best.

Previously an in-depth analysis was conducted on different user acceptance models, acceptability theories and researches that was used in the field of ISA and ITS. This analysis resulted in 14 factors or indicators that could possibly influence acceptability the most. For a more in-depth discussion we refer to Vlassenroot et al. (2010). These 14 found factors could be categorized in three main groups:

1. Indicators related with the characteristics of the device (device specific factors).
2. Indicators related to the context wherein ISA is used (speeding & traffic safety). These indicators can influence the specific factors and acceptability.
3. The third group are more general issues like personal information (age, gender, education) and driving information (mileage, experience, accident involvement). These background factors will influence the contextual and device specific indicators.

The next step in our research was to measure these factors, which has been done in 2009 in a large-scale survey among Belgian and Dutch car-drivers (Vlassenroot et al., 2011). This paper will focus on how the 14 found indicators would directly and indirectly influence the level of acceptability by using a structural equation modelling (SEM) approach. Section 2 describes the method. The results on the direct and total effects are given in section 3. In section 4 the results are discussed in the context of ISA implementation policies.

7.2 Method

7.2.1 The conceptual model

In a previous in-depth study on the factors that influence the acceptability on ISA (Vlassenroot et al., 2010), the following conceptual model was constructed (see Figure 7-1).

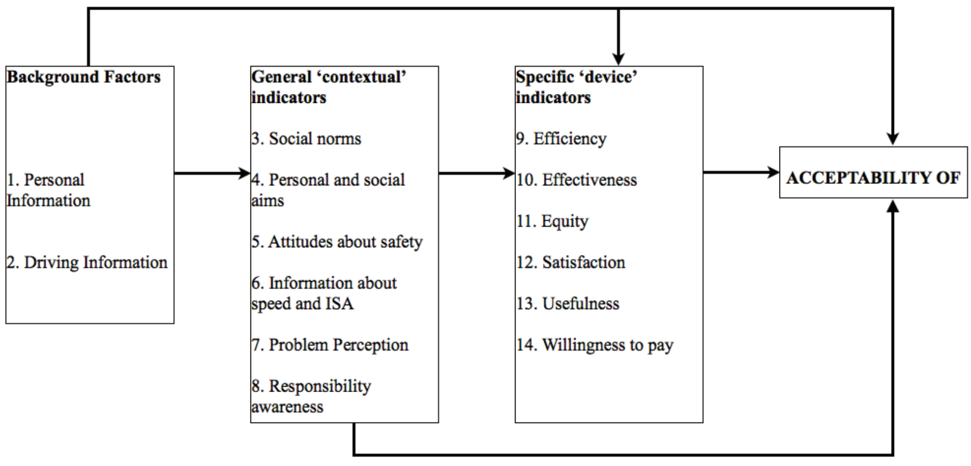

Figure 7-1. Hypothetical model of the found indicators that define acceptability

In Figure 7-1, the three main blocks are described that would influence acceptability. The background factors and the general contextual indicators would determine the specific device factors while the general indicators are only influenced by the background factors. It can be stated that these 14 factors may either directly or indirectly affect the acceptability of ISA and so they would influence each other as well. In the next paragraphs, the causal order between the factors is described; including the relationships between every factor would make Figure 1 too complicated and incomprehensive. More detailed information of the issues included in the factors is also given in Annex 7-1. A casual order is assumed, going from the highest ranked item (1) to the lowest (15). This ranking is based on our previous developed theory that is described in Vlassenroot et al. (2010). All selected variables are assumed to directly or indirectly influence ISA acceptability.

The personal information factors (*age, gender, family situation and education*) are considered to be exogenous variables in the model, hence, not influenced by any other variables. The driving information factors (*type of car. i.e. company car, private vehicle etc., accident involvement, mileage and driving experience*) are the next variables in causal rank order, only influenced by the socio-demographic variables. Both of these factors (personal and driving information) may affect any other remaining variable in the model: for example, gender and age are noted as relevant determinants in the performance of speeding behaviour; i.e. speed is associated with young male drivers (Shinar et al., 2001).

The third factor, *social norms* related to speed and speeding behaviour, may influence every contextual and device specific factor in the model. In many models and theories (like theory of planned behaviour (Azjen, 2002), technology acceptance model (Davis et al., 1989), it is stated that peers or co-workers will influence the attitudes and behaviour of individuals. Silcock et al. (2000) noted that immediate peer pressure is an important factor in speeding for some groups. The choice to speed or not can depend on the *personal and social aims* of people when driving. This fourth variable refers to the dilemma between social or personal aims and benefits (Schade & Schlag, 2003) to consider speeding or not: the hypothesis is that people who want to drive as fast as possible according to their own preferences could be less aware of the *speeding problem* and other issues that causes accidents. *Attitudes on safety* will be measured by defining which issues could causes accidents: most of the time, people will also compare the speeding problem in relation with other road safety issues (Corbett, 2001), like intoxication, experience or infrastructure. Therefore the *attitudes concerning road safety* could influence the level of *problem awareness* but also the *information and knowledge* about the consequences of excessive speed. The factor *information and knowledge* refers to the assumption that people who are better informed are possible more aware of the problem and the alternatives to tackle it. One of the main context variables is the *problem perception:* in many trials (Vlassenroot et al., 2010) it was noted that the acceptability of ISA would depend on the *awareness that speeding is a problem*. The last context indicator is *responsibility awareness* (Schade & Schlag, 2003): if the individual is considered at least partly responsible to solve the problem, a higher acceptability may occur. But if he/she only indicated that the external parties (governments) are considered the problem owners, a negative affect can occur in the acceptability of ISA.

All the context factors could possibly influence the device specific indicators. The determination of the order of the device specific indicators was rather difficult because most of these variables were not investigated in one and the same model. Some theories and approaches used in ISA trials formed the base to determine the causal order (Adell, 2007; Agerholm, 2008; Biding & Lind, 2002; Driscoll, 2007; Harms et al., 2007; Regan et al., 2006; Várhelyi, 2004; Vlassenroot et al., 2007).

Perceived efficiency of ISA related to other speed management systems (e.g. speed cameras, police enforcement) can be considered as a ‘gate’ between the context factors and the device specific factors: it is assumed that people would compare the suggested new solution to counter the problem (speeding) with other existing measures. Defining the efficiency already implies how the respondents would recognise that speeding is a problem, also compared with other road safety issues; concern who is responsible to solve the problem; have information about the solutions; compare these instruments related to their own or social aims and; would possibly be influenced by their peers. If ISA is rated efficient compared to the other measures a next step can be to define how effective ISA is rated by the potential drivers: *perceived effectiveness* is first related to other ITS devices that supports the driver: it is assumed that the effectiveness and acceptability of ISA will depend on how the effectiveness of other ITS is rated (Regan et al., 2006). Secondly the effectiveness of ISA is defined by rating the effectiveness of ISA to maintain the speed in different speed zones (Agerholm, 2008; Biding & Lind, 2002). Thirdly some secondary effects are given like ISA can reduce speeding tickets, ISA is better for the environment. A causal order is assumed between the effectiveness factors going from ITS *effectiveness* to ISA *effectiveness* to *secondary effects* of ISA. These 3 items could possibly influence the other device specific factors and the acceptability of ISA. The third device specific factor is equity: *Equity* refers to perceived justice and integrity (Schade & Schlag, 2003). The respondents were asked to indicate when they would (*penetration level*) use a certain type of ISA and *for whom* a certain type of ISA would be the most beneficial. The assumption is made that the level of penetration would also influence for whom the system should be beneficial. Both of these factors are assumed to be influenced by the efficiency and the effectiveness parameters. The fourth and fifth device specific factors are *satisfaction*, i.e. when a certain ISA would be used, and usefulness of ISA to support the drivers’ behaviour. *Perceived usefulness* and *satisfaction* are two parameters from the method of Van der Laan et al. (1997) and considered to be important variables to determine the level of acceptability: the technique consists of nine rating-scale items. These items are mapped on two scales, the one denoting the usefulness of the system, and the other satisfaction. *Satisfaction* will be mainly influenced by *effectiveness* and combined with *effectiveness* define the level of *usefulness*. The final parameter in our model is the *willingness* *to pay for a certain system* that is influenced by all the parameters. *Willingness to pay* is a frequent used predictor to define the acceptability of ISA in trials (Biding & Lind, 2002).

To determine *the acceptability* of ISA by the drivers, the respondents had to indicate which system they preferred on a 5-point scale going from no ISA, informative, warning, supportive to restrictive.

7.2.2 Constructing the survey

In a first phase, a web-survey was constructed using the open source program Limesurvey and distributed among a few colleagues to test it. The questions were categorized into questions about: (1) personality characteristics or background information (2) questions about problem recognition related to traffic accidents, speed and speeding (3) questions about the use of the new technology (ISA) to counter speed and speeding.

Using their comments, especially about user-friendliness, a pilot test-survey was conducted and distributed by mail and the popular network-website ‘Facebook’. Based on the answers of these respondents some modifications were made to improve the survey and some first data were processed to find out whether the questions would cover the described determinants of acceptability.

In a second phase only the questions that were relevant to define the indicators were used. Around 60 questions were found to be relevant. A new version of the survey was made, based on these questions. A reduction to 36 main questions was made based on stakeholders (in the field of transport psychology) values and user-friendliness.

Finally the definitive web-survey was put online at the end of September 2009. The web-address of the survey was published by the Flemish and Dutch car-users organisations. In Flanders an email newsletter was sent to the VAB members. In the Netherlands, the link to the survey was first announced on the ANWB website. Because of the low response rate in the Netherlands an additional email newsletter was sent, only to the subset of ‘active members.’ It is also possible to subscribe (for free) to different kind of newsletters of ANWB products and services. Active members are members that pay a fee to ANWB for several kinds of services.

In total 6370 individuals (see Table 7-1) responded to the web-survey in Belgium and 1158 persons in the Netherlands. Of these 7528 respondents 5599 responses of car drivers were considered useful for further analysis.

Most respondents were male (79%), because most VAB and ANWB members are male. Only 2% of the respondents were younger than 25 years, while 27% were between 25 and 45 years, and 71% of the respondents were older than 45 years.

Table 7-1. Individual factors of the Belgian and Dutch respondents

	Belgian Flemish	Owner of drivers' license* (2007)	Z-test	Dutch	Owner of drivers' license** (2008)	Z-test	All Resp.
Response							
Response	6370	7621		1158	10321996		7528
N (withheld)	4641	7621		958	10321996		5599
Gender (in %)							
Male	77.3	53.6	P<0.01	89.4	53	P<0.01	79.4
Female	22.6	46.4	P<0.01	10.6	47	P<0.01	20.6
Age (in %)							
17-24	1.4	10.0	P<0.01	2.5	7.9	P<0.01	1.6
25-34	9.0	15.6	P<0.01	6.5	17.7	P<0.01	8.6
35-44	19.0	18.9	n.s.	13.7	20.9	P<0.01	18.1
45-54	30.0	18.3	P<0.01	25.0	21.8	P<0.05	29.1
55-64	26.9	14.9	P<0.01	34.4	16.9	P<0.01	28.2
65 +	13.4	22.2	P<0.01	17.8	14.8	P<0.01	14.1
Education (in %)							
Higher education	58.2	28.5	P<0.01	53.9	-	-	57.4
Secondary education	39.2	54.5	P<0.01	44.9	-	-	40.2
Primary education	1.8	15.4	P<0.01	0.8	-	-	1.7
No education	0.7	1.6	P<0.01	0.3	-	-	0.6
Family-situation (in %)							
No children	48.5	-	-	58.7	-	-	49.1
Oldest child < 12 y.	19.2	-	-	14.3	-	-	18.4
Oldest child > 12 y.	13.3	-	-	12.7	-	-	13.2
Oldest child > 18 y.	19.0	-	-	14.3	-	-	18.2

A Z-test was used and indicated that our sample of responses differs significant from drivers' license owners in Belgium and the Netherlands. Only for the Belgian drivers between the ages of 35 and 44 our sample would be representative. For the respondents in the Netherlands it was possible to compare with the national figures (SWOV, 2010) In Belgium it was only possible to compare with the results collected from a large-scale travel behaviour survey (Vlaamse Gewest, 2010). Compared with the population of drivers' license owners in Belgian and the Netherlands, drivers younger than the age of 34 are underrepresented and the age group 45 – 64 is overrepresented. More male and elder drivers have participated. Although our sample was not representative for the whole population of drivers' license owners in the Netherlands and Flanders, both motorist organisations indicated that our results were relevant compared to their member-databases, although exact data of every parameter (e.g. education level) was not available. This can partly be explained by the fact that predominantly elderly people have a membership of the motorist organisations. In the sample, one out of two drivers had a "higher education" (university). This was expected since using a web-survey specifically stimulates people with a higher education to participate. 49% of the drivers have no children living at home. Our research goal is mainly to define how the different acceptability predictors are related to each other instead of to determine the acceptability of a certain population.

7.2.3 Data analyses

Annex 7-1 specifies the topics asked in the survey, the range of the response scales and sub-questions. Five-point scales have been used as a response format for most questions. Some elements were further described in the survey, which can be found in the most right column. Instead of the name of a certain ITS or ISA system, a description of its functionality was presented to the respondents.

It was assumed that every indicator is defined by the set of sub-questions. Factor analysis was applied to examine the structure and the dimensionality of the responses. Also the Cronbach's alpha was calculated to determine the reliability of a summed scale (see Table 7-2).

Not all the items of the different indicators loaded on a single factor like *problem perception, ISA effectiveness* and *equity*. The reliability of some indicators was improved by dropping one of the selected items. The variable *intoxication of speed or alcohol* as cause of an accident to define the *attitudes about safety* was left out. Compared to the other variables to define the *attitudes* this one seemed to be of a different order. This was also the only variable that loaded high on a second factor. On *the effectiveness of ITS*, the item of *black box* was left out which increased the reliability: most of the other systems that were described in the survey would interact when driving, while the black box is only a monitoring system. This could explain why *black box* loaded on a second factor. The reliability of *efficiency* was improved by leaving *campaigns* out. It is assumed that for drivers the efficiency of campaigns is difficult to predict. Also campaigns are not a 'hard measures' to reduce speeding compared with the other presented items to the respondents. On *information about ISA* the items regarding the *information about the trials in Ghent or Tilburg* was left out. We assumed that this was too long ago to remember for the respondents.

Table 7-2. Cronbach's alpha & explained variances (%)

Indicators	% variance explained	Cronbach's alpha
Attitudes about safety	50%	.748
Problem perception		
Speed and speeding in high speed zones	75%	.884
Speed and speeding in low speed zones	65%	.884
Responsibility awareness	66%	.692
Social Norms	58%	.794
Personal & social aims	57%	.844
Information about ISA	59%	.776
Efficiency	49%	.694
ITS Effectiveness	69%	.836
ISA Effectiveness		
ISA speed effectiveness	78%	.931
ISA secondary effects	72%	.868
Equity		
Equity for different groups of drivers	66%	.908
Equity depending on penetration level	59%	.760
Affordability	55%	.725
Usefulness	64%	.860
Satisfaction	72%	.870

Regarding the *problem awareness*, a main distinction could be made between *low speed zones* like home zones, 30 kph area and urban area, and *higher speed zones*, like outside urban area and highways. In our model we allowed these items to correlate.

The scale to define acceptability consists of 5 items between no intervening systems to high intervening systems (closed ISA). Therefore it can be assumed that the acceptability of high intervening types of ISA has been measured in this model.

Cronbach's alphas of the intended scales were above .70, except for responsibility awareness and efficiency. It was concluded that the reliability of these scales was reasonable (e.g. Molin and Brookhuis. 2007). The scale scores were constructed by summing the scores on the constituting indicator variables, equally weighing each variable.

Structural equation modelling (SEM) was used for the data-analyses. SEM is a modelling approach enabling simultaneous estimation of a series of linked regression equations. SEM can handle a large number of endogenous and exogenous variables, as well as latent (unobserved) variables specified as linear combinations (weighted averages) of the observed variables (Golob, 2003). SEM contains a family of advanced modelling approaches, among which is path modeling (e.g. Molin & Brookhuis. 2007; Van Acker et al. 2007; Ullman, 2007).

7.3 The estimated model

An initial model was estimated based on the causal order presented in Figure 7-1. Initially, all possible paths were drawn from factors earlier in the causal order towards all factors later in the causal order. The exogenous variables were allowed to correlate and the two variables related to speeding. The model was estimated with the program AMOS 7.

Only the variables of which the effects were found significant ($p < 0.05$) were further used in the model. Paths that were not significant were left out the model, which lead to a total number of 139 distinct parameters in our final model to be estimated (df = 186). The probability level is .091 and Chi-square is 212, 27. The goodness of fit (GFT) is 0.99. The probability level and the GFT indicate a good overall fit of the model. Another indication, especially when a large amount of data or cases are used, to define the model fit is the ratio between the chi-square and the degrees of freedom: if the figure is lower than 2 a good fit of the model is indicated (Wijnen et al., 2002). In our estimated model the ratio is 1.141, which also indicate an acceptable fit.

7.3.1 Direct effects

The estimated standardised direct effects are presented in Table 3. The effects are briefly discussed with respect to the plausibility of the significant relationships. The strength of the relationships between the variables is given between brackets. Only the most remarkable effects are described. Not every class related to age, having children, car use and mileage were kept in the model because they had no significant influence on the other variables. The different levels of education seemed to have no significant influence.

This model explains 56% of the variance in acceptability. *Acceptability of ISA* is directly influenced by *effectiveness of ISA on speed* (.37), *equity on ISA equipment for different groups* (.31). *Usefulness* (.13) and *equity of ISA depending on level of penetration* (.11): drivers who find ISA effective and useful will accept ISA more. Also the lower the penetration level has to be before installing ISA and if more intervening types of ISA are chosen for the different groups, the higher the acceptability is. Remarkably is that the *willingness to pay* has a very small direct effect (.02) on the acceptability. Drivers who like *higher speed limits and speeding* will accept ISA less (-.09 in high speed zones; -.08 in low speed zones). Respondents who rather choose *social aims* (.04) in driving and drivers who use the *car as main transport mode to work* (.07) are more willing to accept ISA. *Drivers between 25 and 45 years old* (-.04) will less prefer ISA.

Willingness to pay is directly influenced by *equity related to the level of penetration* (.49) and to *ISA equipment for different groups of drivers* (.10): Drivers who like to pay for ISA will already do this at a low penetration level and if they are convinced that ISA is beneficial for all types of drivers.

Usefulness is directly influenced by *satisfaction* (.68) and *personal & social aims* (.14). *Satisfaction* will increase by the influence of *personal & social* aims (.12) and *equity on penetration level* (.19).

Both *equity* variables are highly influenced by the *effectiveness of ISA on speed* (.32 and .38). *Personal and social aims* (.13), *information about ISA* (.10) and *effectiveness of ITS* will also influence the *equity related to the ISA penetration level*.

The *effectiveness of ISA* on speed is influenced by *efficiency* (.14), *effectiveness of ITS* (.34) and *personal and social aims* (.16). Drivers who valuated social aims highly, are aware that ISA can be efficient to reduce speeding related to other measures, and think that ITS or ADAS can be effective in driving, will find ISA more effective. The *effectiveness of ISA on secondary effects* (like reducing speeding tickets etc.) will depend on how *effective ISA is rated to reduce speeding* (.44) and the *equity related to the group of drivers* (.20).

The valuation of *efficiency* will decrease by both *age groups* (-.11 and -.16) but increase if they *have children younger than 12 years old*. *Personal & social aims* (.10), *responsibility awareness* (.14) and the *effectiveness of ITS* (.19) will also influence efficiency.

Attitudes on safety (.15) and *responsibility awareness* (.13) will directly influence the *effectiveness of ITS*. Drivers, who are convinced that the proposed items could cause an accident, found ITS more effective. *Female drivers* (-.09) and *drivers between 25 and 45* (-.08) years old are less convinced of the *ITS effectiveness.*

Female drivers have less *knowledge of ISA* (-.13). *Mileage 1* (.12) and the *attitudes on safety* (.09) influence *the knowledge on ISA.*

Young drivers (<25 years; -.11) and *drivers who like to speed in high speed zones* (-.10) have less *responsibility awareness*. *Personal & social aims* (.18) and *attitudes on safety* (.22) will increase *responsibility awareness.*

Speeding in both zones is influenced by *personal & social aims* (-.24 and -.21). Respondents who valuate personal aims higher are more likely to speed.

Drivers younger than 25 years are less influenced by the *attitudes on safety* (-.12) or the risks certain driving behaviour can have on road safety.

Personal & social aims are directly influenced by *social norms* (.19) and *the age group 25 to 45 years* (.13). *Social norms* are influenced by both age groups (.15 and .13) that were significant relevant in the model.

Table 7-3. Direct standardized effects

	Gender	Age < 25y	Age between 25-45y	Having children <12y	Mileage < 25 000 km	Mileage <45 000 km	Having Company car	Car as transport mode to work	Social Norms	Personal & Social Aims	Attitudes on Safety	Speeding in High speed zones	Speeding in low speed zones	Responsibility Awareness	Information & Knowledge about	Effectiveness of ITS	Efficiency	Effectiveness of ISA on speed	Equity on level of ISA penetration	Satisfaction	Equity on equipment of	Usefulness	Effectiveness of ISA on secondary effects	Willingness to pay
Background factors																								
Age between 25-45y	.14*																							
Having children <12y	.07*		.47*																					
Mileage < 25 000 km	-0.23		0.08	0.04																				
Mileage < 45 000 km	-0.17		0.08																					
Having Company car					0.25	0.16																		
Car as transport mode to work	-0.05				-0.16	-0.09	-0.10																	
Context indicators																								
Social Norms	-0.10	0.15	0.13					-0.05																
Personal & Social Aims	-0.07	0.05	0.13			0.12		-0.07	0.19															
Attitudes on Safety	0.07	-0.12	-0.08							0.09														
Speeding in High speed zones	-0.09					0.04				-0.24			.68*											
Speeding in low speed zones		0.05		-0.05						-0.21		.68*												
Responsibility Awareness		-0.09								0.18	0.22	-0.10												
Information & Knowledge about ISA	-0.13				0.12			-0.06			0.09													
Device specific indicators																								
Effectiveness of ITS	-0.09		-0.08							0.08	0.15			0.13										
Efficiency	0.07	-0.11	-0.16	0.10	-0.06				0.06	0.10				0.14	-0.09	0.19								
Effectiveness of ISA on speed								0.05	0.06	0.16		-0.05		0.05		0.24	0.14							
Equity on level of ISA penetration			-0.05				0.08			0.13	-0.05				0.10	0.18	0.07	0.32						
Satisfaction										0.12				0.05					0.19					
Equity on equipment of groups		-0.05	-0.05		-0.06						0.07			0.04		0.05	0.06	0.58	0.09					
Usefulness			0.05							0.14									0.06	0.68				
Effectiveness of ISA on secondary effects												-0.09	0.06				0.07	0.44	0.08		0.20			
Willingness to pay/affordability			-0.06		-0.04									0.07		0.09			0.49		0.10	0.05		
Acceptability of ISA			-0.04					0.07		0.04		-0.09	-0.08					0.37	0.11		0.31	0.13	0.04	0.02

* Correlations

Table 7-4. Total standardized effects

	Gender	Age < 25y	Age between 25-45y	Having children <12y	Mileage < 25 000 km	Mileage <45 000 km	Having Company car	Car as transport mode to work	Social Norms	Personal & Social Aims	Attitudes on Safety	Speeding in High speed zones	Speeding in low speed zones	Responsibility Awareness	Information & Knowledge about ISA	Effectiveness of ITS	Efficiency	Effectiveness of ISA on speed	Equity on level of ISA penetration	Satisfaction	Equity on equipment of	Usefulness	Effectiveness of ISA on secondary effects	Willingness to pay
Background factors																								
Age between 25-45y	.14*																							
Having children <12y	.07*		.47*																					
Mileage < 25 000 km	-0.21		0.10	0.04																				
Mileage < 45 000 km	-0.16		0.08																					
Having Company car	-0.08		0.04	0.01	0.25	0.16																		
Car as transport mode to work	0.00		-0.03	-0.01	-0.19	-0.11	-0.10																	
Context indicators																								
Social Norms	-0.08	0.15	0.13		0.01	0.01	0.01	-0.05																
Personal & Social Aims	-0.08	0.08	0.17	0.00	0.02	0.13	0.01	-0.08	0.19															
Attitudes on Safety	0.07	-0.12	-0.10		0.00	-0.01	0.00	0.01	-0.02	0.09														
Speeding in High speed zones	-0.12	0.02	0.04		0.00	0.07	0.00	-0.02	0.05	-0.24			.68*											
Speeding in low speed zones	-0.02	0.07	0.01	-0.05	0.00	0.03	0.00	-0.02	0.04	-0.21		.68*												
Responsibility Awareness	0.04	-0.13	-0.05		0.00	-0.03	0.00	0.02	-0.04	0.22	0.22	-0.10												
Information & Knowledge about ISA	-0.15	-0.01	0.01	0.01	0.13	0.01	0.01	-0.06	0.00	0.01	0.09													
Device specific indicators																								
Effectiveness of ITS	-0.08	-0.04	-0.11		0.00	-0.02	0.00	0.01	-0.02	0.12	0.18	-0.01		0.13										
Efficiency	0.08	-0.13	-0.15	0.09	-0.07	-0.02	0.00	0.01	0.03	0.15	0.06	-0.02		0.17	-0.09	0.19								
Effectiveness of ISA on speed	0.01	-0.04	-0.08	0.01	-0.02	-0.04	-0.01	0.07	0.02	0.24	0.06	-0.06		0.11	-0.01	0.27	0.14							
Equity on level of ISA penetration	-0.03	-0.04	-0.12	0.01	0.02	-0.02	0.08	0.03	-0.02	0.24	0.01	-0.02		0.07	0.09	0.28	0.12	0.32						
Satisfaction	0.01	-0.02	-0.05	0.00	0.00	-0.02	0.01	0.02	-0.03	0.18	0.02	-0.01		0.07	0.02	0.05	0.02	0.06	0.19					
Equity on equipment of groups	0.02	-0.10	-0.13	0.01	-0.07	-0.03	0.00	0.05	0.01	0.19	0.12	-0.05		0.13	-0.01	0.24	0.15	0.61	0.09					
Usefulness	0.00	-0.01	0.03	0.00	0.00	0.00	0.02	0.00	0.01	0.00	0.01	-0.01		0.05	0.02	0.05	0.02	0.06	0.19	0.68				
Effectiveness of ISA on secondary effects	0.02	-0.05	-0.08	0.01	-0.03	-0.03	0.00	0.04	0.01	0.18	0.06	-0.13	0.06	0.09	-0.01	0.20	0.17	0.59	0.10		0.20			
Willingness to pay/affordability	-0.02	-0.04	-0.15	0.01	-0.04	-0.02	0.04	0.02	-0.01	0.16	0.05	-0.02		0.13	0.05	0.25	0.07	0.22	0.51	0.03	0.10	0.05		
Acceptability of ISA	0.01	-0.05	-0.14	0.01	-0.04	-0.04	0.00	0.11	0.00	0.23	0.07	-0.14	-.08	0.09	0.00	0.21	0.12	0.62	0.12	0.09	0.32	0.13	0.04	0.02

* Correlations

7.3.2 Total effects

The total effects are given in Table 7-4. A brief description of the most relevant findings is given.

Finding *ISA effective to reduce speeding* (.62) will have a very high influence on the *acceptability of ISA*. This was also expected. Also being convinced that other *ITS systems are effective* (.21) will highly influence acceptability. In this way we can assume that drivers who are convinced that technology can help to support their driving behaviour will accept ISA better. Also being convinced that ISA is *beneficial for most of the groups of certain type of drivers (equity)* (.32) will increase the acceptability. The lower the *ISA penetration level* has to be the higher (.12) the acceptability can become. Believing that ISA can be *useful* and *satisfying* will increase the level of acceptability. These two items were already proven as relative good predictors of ITS and ISA acceptance (Várhelyi et al., 2004; Vlassenroot et al, 2007). *Satisfaction* (.68) will highly influence *usefulness*. Drivers who *like to speed in high-speed zone*s (-.14) will less accept ISA. Rating ISA *efficient* (.12) related to other speed reducing measures will also increase the acceptability. Drivers between the age of *25 and 45 years* (-.14) will accept ISA less. A higher value for *social aims* (.23) will increase the acceptability. While in many trials *willingness to pay* has been stated as a good predictor for acceptance, this was not found in our model. Also the *secondary effects of ISA* will not have a high influence on the level of acceptability.

Drivers who are not influenced by the *equity level of penetration of ISA* are more *satisfied* (.19) and will rate ISA more *useful* (.19). Also these drivers are highly *willing to pay* for ISA (.51). *Effectiveness of ISA* (between .22 and .59) on speed and speeding seems to be a good predictor for all of the system related indicators except for usefulness and satisfaction. *Efficiency* (between .07 and .17) will also influence all the other system related indicators, except *usefulness* and *satisfaction*. The same can be found for the total effects on *effectiveness of ITS*.

A high valuation of the *responsibility* of the different actors to counter speed will influence the *efficiency* of ISA (.17) related to other measures. Being aware of *responsibility* can also lead to find ITS and ISA more *effective* (.11 and .13) and a higher *willingness to pay* (.13). People who *like to speed* will *accept* ISA (-.14 in high speed zones and -.08 in low speed zones) less and will find it less effective (-.06 and -.13). Being convinced that certain driving behaviour and contextual issues (items from the *attitudes on safety*) can cause accidents could lead to a higher *responsibility awareness* (.22), higher valuation on the *effectiveness of ITS* (.18) and finding ISA *beneficial for different groups of drivers* (.12). Personal and social aims would have a high influence (higher than .10) on many of the variables (except on *usefulness* and *knowledge about ISA*). *Social norms* will mostly influence personal and *social aims* (.19).

Going by *car to work* can also increase the *acceptability* of ISA (.11). *Mileage* will decrease the use of a car as *transport to work* (-.11 and -.19): people who drive less than 25000 km on yearly base will use the car less as transport mode to work. *Having children* would mainly influence the *efficiency of ISA* (.09) but would slightly lead to *speeding in low speed zones* (-.05). Two age groups were kept in the model as the only groups that have significant influence on the other variables. *Drivers between 25 and 45 years* will less *accept ISA* (-.14). This is also the group with the most children younger than 12 years old (.47). Social norms (.13) and personal & social aims (.17) will be highly effect by this age group of drivers. Age between 25 and 45 will have mainly a negative effect on most of the 'device specific indicators' (between -.08 and -.15). *Younger drivers* (<25 years) are less convinced that certain behaviour or accidents could cause accidents (*attitudes on safety: -.12*); these drivers will also valuate *responsibility awareness* (-.13) and *efficiency* (-.13) lower. *Female* drivers will less speed in *high-speed zones* (-.15) and are less *informed about ISA* (-.15).

7.4 Discussion and conclusion

In this paper, a model has been estimated, by using SEM, to find out which predefined indicators would be relevant to define the acceptability of ISA. Background factors, contextual issues, and ISA-device related factors were used as indicators to predict the level of acceptability. The factors that were used in the model were based on the methods used in past ISA trials, acceptance and acceptability theories and models.

The effectiveness of ISA (1), equity (2), effectiveness of ITS (3) and personal and social aims (4), were the four variables that had the largest total effect on the acceptability of ISA. Effectiveness was found a relevant predictor for acceptance in many trials (Morsink et al, 2006). The model showed that the willingness of drivers to adopt ISA increases if they experience the system in practice: if people are convinced that ISA will assist to maintain the legal speed in different speed zones, the acceptance will be higher (Van der Pas et al., 2008). Hence, trials seem a good way to demonstrate the effectiveness of ISA. However, trials typically do not allow many people to try out ISA. Therefore, communication strategies that focus on the ISA-effectiveness would be helpful to convince people about the benefits of using such a system.

Often when new driver support technologies are introduced – especially when it could restrict certain freedom in driving – a majority of the population is reluctant when it comes to ‘buy or use’ the system. In the Ghent ISA trial (Vlassenroot et al., 2007) it was noted that most of the drivers were convinced of the effectiveness and were highly in favour of the supportive system but they stated that they would only use ISA further when more or certain groups of drivers would (also) use the system (equity on level of penetration). In the development of implementation strategies this is a very important issue. Therefore policymakers should be aware that if they would introduce certain types of ISA, the penetration level should be sufficient from the start to convince others to accept ISA. Promoting ISA by certain groups of drivers, for instance professional drivers (bus-, taxi-, van-, truck-drivers) or younger drivers, may be helpful to introduce certain systems (equity related to the equipment of certain groups).

In some studies (see Morsink et al., 2006; Marchau et al., 2010) the willingness to pay was reported to be a good predictor for acceptability. However, in the present study the effect of willingness to pay was very low or even absent; hence it may be assumed that better indicators are put in the model than the willingness to pay.

With respect to context indicators, ‘personal and social aims’ seemed to be the variable with the highest influence on acceptability. Drivers, who rate social aims above personal aims with respect to speed and speeding, will accept ISA more. Personal and social aims had also a high influence on most of the device specific indicators. Furthermore, drivers who speed for their personal benefit were found to rather speed more often.

Drivers who speed in high-speed zones would also be less inclined to accept ISA. This is in line with previous findings (e.g. Jamson et al., 2006), frequent speeders would support ISA less; those drivers who would benefit most of ISA would be less likely to use it. This is an important finding when considering the strategies for implementing ISA. Some studies (e.g. Morsink et al., 2006) indicated that to increase the acceptability, implementation strategies and campaigns could focus on other benefits of ISA (like reducing speeding tickets, emissions etc.). According to our study these secondary effects have rather small effects to increase acceptability. Drivers who like to speed would even care less for these secondary benefits of ISA.

The youngest group of drivers (<25 years old) would influence responsibility awareness negatively. These younger drivers are also less convinced that certain behaviour or circumstances could cause accidents. Many studies indicated that young drivers overestimate their own driving skills, drive faster and are less aware of accident causes (Shinar et al., 2001). For the implementation of ISA – although there is no direct relationship between younger age and acceptability – a different strategy is needed to convince this group of drivers. Awareness campaigns and communication should be deployed during their education, however, road safety education and training stops during secondary school or higher education (OECD, 2006).

Drivers between 25 and 45 years old would also be less inclined to accept ISA, mainly considered out of indirect effects in the estimated model. This group of drivers may be labeled as one of the most active groups of drivers. Another aspect is that both of the significant found age groups were influenced by social norms. This may be very important in implementation strategies. For instance, role models could be used in ISA driving. This strategy was also used in the Belgian trial to gain more publicity and attention. The positive image and the improved information communication of ISA as a possible measure in road-safety have led to several voted resolutions in the Belgian federal parliament and senate (Vlassenroot et al. 2007).

Our study had some limitations as well. The groups of respondents were not representative compared to the average drivers' license owners in Belgium and the Netherlands. However, the involvement of two major motor vehicle organizations and the participation of their members, indicates that a relevant group of drivers has been covered in this survey. It may be presumed that these groups of respondents are more auto-minded than average. Motor organizations will largely defend the positions and opinions of their members. Therefore these organizations can be highly influential in future policy actions.

Additionally, some of the chosen topics to define the indicators could be improved, especially to determine responsibility awareness and efficiency. Also the scale that was used for acceptability of ISA could be better: the range from no intervening to complete intervening could possibly be interpreted in such a way that in our research the acceptability of restrictive ISA is determined. Future research should make a better distinction between the acceptability of the different systems.

One of the main ambitions was to come to a more simplified model to define acceptability with respect to ADAS. However, taking into account a large variety of different indicators left this model yet rather complex. This may be a striking indication that defining acceptance and/or acceptability is rather complex. Many different items would directly or indirectly influence acceptability, which is important for the development of implementation strategies: increasing the support of ISA has to be established at different levels.

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Annex 7 - 1. Topics in the survey for the different indicators

Content Indicator/question	Scale	Specified for
Gender	Male/female	
Age	<25 years; 26 – 45 years; 46 – 65 years; >65 years	
Having children	No children; < 12 years old; <18y. >12y.; <18 years	
Education	No education, primary, secondary, higher education	
Mileage	<25 000 km/y: 25001-45000; >45000	
Company car	Yes/No	
Car use	Transport to work/transport for work/transport shopping/transport leisure	
Attitudes about safety	1-5 Low to high influence	
Less driving experience		
Inappropriate speed		
Other less exper. drivers		
Bad weather conditions		
Mobile phone use		
Bad infrastructure		
Risk seeking behaviour		
Fatigue		
No distance keeping		
Problem Perception		
Attitudes on own speeding behaviour	1-5 never speeding to always	For every speed zone
Mistakenly speeding	Range from posted speed limit until 50 kph above	For every speed zone
Irresponsible speeding	Range from posted speed limit until 50 kph above	For every speed zone
Best posted speed limit	Range from posted speed limit until 50 kph above	For every speed zone
Responsibility awareness	1-5 no responsibility to high	
Road administrators		
Police		
You (Yourself)		
Other drivers		
Politicians		
Social norms	1-5 maintain speed to drive faster	
To impress others		
To get along with drivers		
If they push to drive faster		
If I have pass. of same age		
If I have passengers		

To compete w. traffic flow		
Per. & soc. aims		***Speed zones** Home zones (20 kph) 30 kph area Urban area (50 kph) Out urb. area (70-90 kph) Highways (120 kph)
Normal conditions	1-5 slow down to drive faster	
During the night		
In a hurry		
Knowing the road		
Alone on the road		
No control		
You can endanger others		
Inf. on ISA	1-5 no information to well informed	
Speed informative systems		
Speed warning systems		
Haptic throttle		****ISA system** Informative ISA Warning ISA Supportive ISA Restrictive ISA
Information about ISA		
Speed warning in GPS		
Speed Alert		
Efficiency	1-5 no to high efficiency	
Speed camera's		
Police control		
Infrastructure measures		
ISA		
ITS Effectiveness	1-5 not to high effective	
FDW		
ACC		
Collision Warning systems		
Seat belt rem.: Type 1		
Seat belt rem.: Type 2		
Alcohol-warning		
Alcohol-lock		
ISA Effectiveness	1-5 not to high effective	Every speed zone and ISA**
Reduce fuel consumption	1-5 no to high effective	For every ISA system
To reduce emissions		
To increase traffic safety		
To reduce speeding tickets		
Equity for different type drivers (1)		
Young drivers	1-5 not beneficial to high beneficial	For every system
Elder drivers	1-5 not beneficial to high beneficial	
Vans	1-5 not beneficial to high beneficial	
Trucks	1-5 not beneficial to high beneficial	

Motorcyclist	1-5 not beneficial to high beneficial	
Bus drivers	1-5 not beneficial to high beneficial	
Taxi drivers	1-5 not beneficial to high beneficial	
Problem drivers	1-5 not beneficial to high beneficial	
Equity depending on penetration level	1-5 from high level of penetration to low level	For every ISA system
Willingness to pay	1-5 from no willingness to pay to high willingness	For every ISA system
Usefulness		
Useful	1-5 not useful to useful	For every ISA system
Good	1-5 bad to good	For every ISA system
Effective	1-5 not effective to effective	For every ISA system
Assisting	1-5 not assisting to assisting	For every ISA system
Alertness	1-5 less alertness to high alertness	For every ISA system
Satisfaction		
Pleasant	1-5 not pleasant to pleasant	For every ISA system
Nice	1-5 not nice to nice	For every ISA system
Likeable	1-5 unlikeable to likeable	For every ISA system
Desirable	1-5 undesirable to desirable	For every ISA system
Acceptability	1-5 from no ISA to high intervening ISA	

8 Conclusions

The general objective of this dissertation was to *analyse and understand the acceptability of Intelligent Transport Systems (ITS) within the context of speed management in order to achieve a better-accepted implementation of in-vehicle speed controlling technologies.* First, a literature overview was conducted regarding the most common effects of speed and speeding on road safety, the environment, and the quality of life, and how the negative effects of speed can be tackled by the use of environmental, behavioural, and technological measures. Second, a meta-analysis was performed to describe the research on ISA, the development of ISA related technologies, the actors involved in the deployment of ISA, and the status of the implementation of ISA. Third, a field operational trial was conducted in which drivers could use an intervening type of ISA. Data logging was used to analyse the driving behaviour of the test drivers and a survey was conducted to define the attitudes and opinions regarding. Fourth, different theories, methods, and studies were analysed to define acceptability. A conceptual framework was described and tested by the use of a large-scale survey. This resulted in a model that may be used for policymaking actions.

8.1 Overview of results

Speed is related to safety on our roads, speeding may make cities or neighbourhoods unliveable, and speeding affects the environment. Therefore measures need to be taken to reduce speed and speeding. No single measure will solve all of the problems related to speed and speeding. Rather it takes a combination of measures including comprehensive infrastructure, credible speed limits, education, information, enforcement, vehicles, and vehicle technologies. Speed management measures rest on three pillars (the driver, the environment, and the vehicles) to intervene and to improve road safety. Through speed management, actions can be taken within three pillars, allowing for an effective ‘policy mix’ approach. Speed management policies can only be successful if people are willing to support or to accept these measures. One of the technological measures to reduce speeding or to help to maintain the speed is Intelligent Speed Assistance (ISA).

During the last two decades a lot of research on ISA has been carried out. Several trials with different types of ISA have shown that ISA can be an efficient and effective way to reduce speed and speeding and therefore, to have a positive effect on traffic safety. ISA is also expected to have a positive effect on fuel consumption, emissions, dust, and noise.

A trial with a supportive intervening ISA, installed in 34 cars & 3 buses, was conducted in the city of Ghent, Belgium. Comparison of logged speed data during the activation period and speed data after this period showed that ISA had a lasting effect on speeding. Effects were highest in the 90 kph zone, where speeding decreased by almost 10%. At lower speed limits the effects were smaller although speeding was more frequent. In the 30 kph zone, speeding decreased from 45.9% to 42.8%. This means that the counter pressure on the gas pedal was overridden in a vast amount of distance. Differences between drivers were, however, large. Speeding with the system varied between 3% and 50%. For most drivers, speeding was reduced with the system.

When questioning basic attitudes using surveys, most of the drivers did not report that driving fast is fun, liberating or exciting, before, during, or after the project. Most drivers stated that speeding is dangerous, reckless, and not sportive. Driving with ISA changed their behaviour on speeding: during the project, most of the drivers reported that they never drove faster on highways, outside urban areas, in urban areas, and in 30-zones. The drivers used the system voluntarily on highways and outside urban areas, which gave a first indication of their acceptance of the active accelerator pedal. They also experienced the pedal as satisfying and useful.

It was reported that ISA could have benefits in road safety and may even open new debates about speed policies. Still, one of the main questions was how the general public would evaluate these new devices and how they could be convinced to accept new legislation in relation to ITS and ISA. These questions led us to the major topic of this dissertation: the acceptability of ISA.

It was recognized that knowledge concerning the level of acceptance or acceptability of a measure is important for future implementation of in-vehicle technologies. Debates are continuing, but ironically, a clear definition of what acceptance and acceptability imply and how they should be measured is still lacking. We made a distinction between acceptance and acceptability based on the amount of time and the amount of experience the individual had with the system. While acceptance follows from beliefs and attitudes based on behavioural reactions after the introduction of a measure, acceptability is a prospective judgement, based on attitudes and beliefs about a measure before its introduction.

Based on different socio-psychological theories and data derived from ISA trials, we arrived at 14 relevant indicators that were divided into general indicators (related to persons' psyches, social values, and norms at that time, etc.) and device-specific indications (factors that are directly related to the device itself). These 14 indicators were presented to randomly selected respondents (through Internet media) in a test survey. The main goal of this survey was to find out whether the distilled indications and the questions were indeed relevant, and whether some relationships could be found between the indicators. Through the use of factor analysis, we found out that our questions were relevant for every item, and some correlations were found between the items. It was also noted that some indicators would directly influence the acceptability of ISA, while some would influence others indirectly. This first step in our research enabled us to conduct a large-scale survey among the general public in the Netherlands and Belgium regarding the acceptance and acceptability of ISA.

In total, 7528 drivers responded to the questionnaire call by the two main interest groups in both countries; 5599 responses were found sufficiently complete to take into account for further analyses. The average respondent was male between 45 and 54 years old with a relatively high education and no children living at home. Their vehicle was the main mode of transport and on average they drove between 10 000 and 25 000 km/year. 76% of the drivers had been involved in an accident at least once, 11% of them had had an accident with injuries, 4% had had a severe accidents and 1% had been in an accident with casualties.

The resulting general indicators in the survey showed that the drivers had positive opinions concerning the current posted speed limits. The drivers would generally drive within the speed limit in urban areas. However, in 30 kph-zones they would speed more often. These results are in line with the Belgian, Dutch, and Swedish ISA-trials.

The respondents stated that behavioural aspects are a greater cause of accidents than contextual issues. The drivers were relatively positive about the use of ITS to support their driving behaviour. Already in 2004, the SARTRE research project indicated that drivers rated the use of certain ITS applications as positive, although they had only a few systems to choose from (GPS, ISA, alcohol-lock, driving monitor). In our study, the ratings for these systems were even higher. This might be an indication that drivers would like to have even more support when driving.

Almost 95% of the respondents in our survey stated that they are in favour of some type of ISA-system. In many studies, effectiveness was found as a relevant criterion to determine acceptability. However there is a difference in peoples' opinion about the effectiveness and the effectiveness results found in trials. In our study, open systems were considered the most effective ones, although from a safety point of view (semi)-closed systems are considered better.

Closed ISA was more preferred (i.e. was found more satisfying and useful) than supportive ISA. This remarkable result might be explained by the fact that it was more difficult for the respondents to understand how the supportive systems actually worked in practice.

Although the support for ISA is relatively high, the respondents indicated that it was not unconditional. The more the implemented system would be perceived to intervene in their control of the driving experience, the higher the penetration level should be. The respondents of our study felt that young and professional drivers (especially trucks and buses) should have a more intervening system. This was also stated in other trial reports; however, in our survey many respondents also stated that ISA would be beneficial for all drivers. As in many ISA-studies the implementation of restrictive ISA was considered a good solution to stop frequent speeders. Our study also indicated that incentives would increase the support for more intervening systems. However, it would still be difficult to get people to accept restrictive ISA.

Finally, a model was estimated by using structural equation modelling (SEM) to find out which predefined indicators would be relevant to define the acceptability of ISA. Background factors, contextual issues and ISA-device related factors were used as indicators to predict the level of acceptability. The factors that were used in the model were based on the methods used in past ISA trials, acceptance theories and models.

The four variables that had the largest total effect on the acceptability of ISA were (1) the effectiveness of ISA, (2) equity, (3) effectiveness of ITS, and (4) personal and social aims (4). Effectiveness was found a relevant predictor for acceptance in many trials (Morsink et al, 2006). In some studies the willingness to pay was reported to be a good predictor for acceptability. However, in our model the effect of willingness to pay was very low or even absent. Hence, it may be assumed that our model had better indicators than the willingness to pay.

With respect to context indicators, 'personal and social aims' seemed to be the variable with the highest influence on acceptability. Drivers, who rate social aims over personal aims with respect to speed and speeding, are more inclined to accept ISA. Personal and social aims had a high influence on most of the device specific indicators as well. Furthermore, drivers who speed for their personal benefit were found to rather speed more often. Drivers who speed in high-speed zones would also be less inclined to accept ISA.

8.2 Scientific relevance

The lack of a theory and definitions regarding acceptance and acceptability has resulted in a large number of different attempts to capture or measure ITS acceptance and acceptability, often with quite different results. In our research we tried to make a clear distinction between acceptance and acceptability. Some existing theories like Theory of Planned Behaviour, Technology Acceptance Model, etc. were mostly used. These models were developed in a certain timeframe, place and for specific audiences. Although, these models are frequently used, rarely has anyone questioned whether they are good enough to be used to study the defined problem.

In our research we started from scratch. First we tried to understand what acceptability could be. Second, an inventory was made of all the possible items that could influence the degree of acceptability. Finally, we developed our concept based on existing theories. The advantage of doing it this way was that a lot of items could be brought into the framework that other theories had not taken into account. Also our research was the first time that all of the most important indicators of acceptability were put into a single model.

One of our main ambitions was to come to a more simplified model to define acceptability with respect to ADAS. However, taking into account such a large variety of indicators resulted in a model that is still rather complex. This may confirm that defining acceptance and acceptability is rather complex.

8.3 Social relevance

This research resulted in improved insight into the opinions and attitudes that can or will influence acceptance or acceptability of ISA.

Many different items influence acceptability directly or indirectly. It is important to understand these in order to develop implementation strategies. Increasing the support of ISA has to be established at different levels. We discussed some of our results combined with certain implementation strategies.

Younger drivers are less convinced that certain behaviours or circumstances could cause accidents than older, more experienced drivers. Many studies have indicated that young drivers overestimate their own driving skills, drive faster, and are less aware of accident causes (Shinar et al., 2001, but see also De Craen, 2010). For the implementation of ISA – although there is no direct relationship between younger age and acceptability – a different strategy is needed to convince this group of drivers. Awareness campaigns and communication should be deployed during their education; however, road safety education and training are not common during secondary school and are absent in higher education.

Drivers between 25 and 45 years of age would also be less inclined to accept ISA. This group of drivers may be labelled as one of the most active groups of drivers. We also found that both younger drivers and those between 25 and 45 are influenced by social norms. This may be very important in implementation strategies. For instance, role models could be used to encourage ISA driving. This strategy was used in the Belgian trial to gain publicity and attention. The positive image and the improved information communication of ISA as a possible measure in road-safety have led to several approved resolutions in the Belgian Federal Parliament and Senate (Vlassenroot et al. 2007).

Not surprisingly, drivers who claim to speed for their personal benefit were found to speed more often than other drivers, regardless of ISA. Drivers who speed in high-speed zones were also found less inclined to accept ISA. This is in line with previous findings (e.g. Jamson et al., 2006) i.e., frequent speeders would support ISA less; those drivers who would benefit most of ISA would be less likely to use it. This is an important finding when considering strategies for implementing ISA.

Our model showed that the willingness of drivers to adopt ISA increases if they experience the system in practice; if people are convinced that ISA does what it is designed to do, acceptance will be higher. Hence, (large scale) trials seem a good way to demonstrate the effectiveness of ISA (Van der Pas, 2008). However, trials typically do not allow a lot of people to experience ISA. Therefore, communication strategies that focus on ISA-effectiveness, supported by demonstrations, would be helpful to convince people about the benefits of using such a system.

The issue of ‘equity’ has rarely been investigated in other trials or ISA studies. However, in other types of traffic and transport studies (e.g. tolling) equity has been investigated. These gave a good indication for future implementation actions. Often when a new driver support technology is introduced – especially when it could restrict certain freedom in driving – a majority of the population is reluctant to ‘buy or use’ the system. In the Ghent ISA trial, it was noted that most of the drivers were convinced of the effectiveness and were highly in favour of the supportive system but they stated that they would only use ISA further when more or certain groups of drivers would (also / be forced to) use the system (equity on level of penetration). In the development of implementation strategies this is a very important issue. Therefore policymakers should be aware that if they would like to introduce certain types of ISA, the penetration level should be sufficient from the start to convince others to adopt ISA. Promoting ISA by implementing in certain groups of vehicles, for instance introduction to professionals (bus-, taxi-, van-, truck-drivers) or younger drivers may be helpful to introduce certain systems (equity related to the equipment of certain groups). It is assumed that implementing ISA in the fleet of professional vehicles would be very effective to increase acceptability rates. The companies and vehicles concerned could be considered as role models in road safety. Previous studies and trials already stated that role models are effective to gain awareness of ISA.

Our model showed that willingness to pay was not a major indicator influencing acceptability. However, others have reported that price-policy, subsidies, etc. could be good instruments to increase the level of acceptability for a policy measure (Walta, 2011).

Some studies (Van der Pas, 2011) have indicated that to increase support, implementation strategies and campaigns could focus on other benefits of ISA (e.g. reducing speeding tickets, emissions, etc.). According to our study, these secondary effects have a rather small influence on increasing acceptability. Drivers who like to speed would care little about these secondary benefits of ISA.

8.4 Further research

This section discusses some directions for further research related to issues that surfaced during our research.

Regarding the trial, the drivers' perceptions about the effects of the system were evaluated to be more significant than the results from the logged speed data. Data logging problems could have influenced these results. The logged data were fully analyzed without making any distinction in road characteristics. In this trial, the logged data was analyzed in total. In similar trials, only stretches of roads were examined. The benefits are that the research environment is controlled. However, total analyses, as in this trial, make it possible to have a full picture of all the driving behaviour in the test-area. Better tracking technologies can help to conduct better analysable trials with ADAS.

In our large-scale survey, the groups of respondents were not representative compared to the average drivers' license owners in Belgium and the Netherlands. However, the involvement of two major motor vehicle organizations and the participation of their members ensured that a relevant group of drivers has been covered in this survey. It may be presumed that these groups of respondents are more auto-minded than average. Motor organizations will largely defend the positions and opinions of their members. Therefore, these organizations can be highly influential in future policy actions. Future research may also focus on other road users (e.g. pedestrians), different groups of drivers (e.g. professional drivers), or different stakeholders (e.g. policy makers).

Some of the selected topics to define the indicators could also be improved; especially the ones to determine responsibility awareness and efficiency. Also the scale that was used for acceptability of ISA could be better; the range from no intervening to complete intervening could possibly be interpreted in such a way that in our research only the acceptability of restrictive ISA is determined. Future research should make a better distinction between the acceptability of the different systems.

In our study, Dutch and Belgian drivers were interrogated. A new study may focus on other driver groups across Europe in order to have more information on the cultural differences in choosing ISA.

8.5 Discussion

ISA is one of those systems for which acceptance increases if the driver can test the system. Frequently it was said that you could talk about ISA as long as you want, but the best way to convince somebody of the benefits is to let him or her drive with ISA.

All in all, we are inclined to conclude that the test-phase of ISA is over and that implementation strategies should be developed, although there are still some barriers. One of the major issues is the development of a valid and reliable speed limit database. National and regional initiatives are currently made and on the European level – with the action plan on ITS – governments will be stimulated to develop national digital road database. Some stakeholders also indicated that some legal issues still need to be resolved, especially when ISA would malfunction (certainly if a restrictive ISA is used). These issues are not of such an order that it would make the introduction of ISA difficult; it seems that some problems are more connected with organizational difficulties and challenges than with legal risks and constraints.

The study by Walta (2011) supports our conviction that, if ISA has to be introduced, it would be beneficial if governments would be involved in the implementation strategies. This could be done by supporting or creating a (technical) framework that would enable the use of ISA, and actively promote ISA by giving subsidies or alternative positive (financial) actions.

The high level of acceptability of ISA that is found should also be useful in stimulating further development of a feasibility framework for ISA and other ITS by governments. Many ITS, like ISA, will need detailed digital road information such as speed limits; most of these (speed limit) databases are already being developed but not ready yet for large-scale use.

One of the key issues is how the public will react if ISA or ITS are implemented. AN understanding of the indicators associated with acceptability and acceptance may support decision-makers in developing an appropriate implementation strategy. Through the construction of a feasibility framework, we want to provide decision-makers with methods and procedures that are easy to use and understand, based on well-accepted socio-psychological models.

Still, we would like to state that ISA is one of the many speed management solutions. Only in combination with other speed management measures (e.g. credible speed limits, infrastructure, enforcement) the introduction of ISA can be successful.

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Samenvatting

De acceptatie van in-voertuig intelligente snelheidsassistentie (ISA): van een proeftuin draagvlak naar een publiek draagvlak

Snelheid, maar vooral overdreven of onaangepaste snelheid wordt aanzien als één van de belangrijkste oorzaken bij verkeersongevallen. Naast de invloed op de ernst van ongevallen heeft snelheid een effect op de uitstoot van schadelijke stoffen, veroorzaakt het geluidsoverlast, verhoogt het brandstofverbruik, en beïnvloedt het de (subjectieve) leefbaarheid. Hoge snelheden, grote snelheidsverschillen tussen voertuigen en een hoge mate van snelheidsvariatie (optrekken/afremmen) hebben een negatief effect op elk van deze genoemde factoren. De laatste jaren gaan er meer en meer stemmen op om maatregelen voor snelheidsbeheersing coherent aan te pakken. Hiermee wordt bedoeld dat niet één enkel instrument voldoende is maar dat een integrale aanpak moet gebeuren. Dit heet snelheidsmanagement.

Algemeen wordt gesteld dat snelheidsmanagement het verhogen van de verkeersveiligheid, het verbeteren van de leefomgeving (milieuaspecten) en het verzekeren van de levenskwaliteit of welzijn van iedereen beoogt. Wanneer men een snelheidsmanagement wil toepassen dan is het nodig dat alle beleidsaspecten (ook buiten verkeer en mobiliteit) in rekening worden gebracht. Het aandeel van elk aspect zal verschillen naargelang de situatie of context. Snelheidsmanagement wil een kader bieden voor overheden waarin elke overheid kan zoeken naar een juiste balans tussen bepaalde beleidsobjectieven in relatie met veiligheid, mobiliteit, leefmilieu en welzijn.

Binnen dit kader van snelheidsmanagement werd het gebruik van technologie in deze scriptie verder onderzocht. Een van de meest veelbelovende Intelligente Transport Systemen (ITS) gericht op het verminderen van snelheidsoverschrijdingen, is Intelligente Snelheid Assistentie

(ISA). ISA kan worden onderverdeeld in verschillende types, afhankelijk van hoe deze systemen ingrijpen: (i) een informatieve of adviserende systeem toont enkel de geldende snelheidslimiet op een scherm. (ii) Een waarschuwend systeem geeft een visueel of auditief signaal aan de bestuurder wanneer de toegestane snelheidslimiet wordt overschreden. (iii) Een ondersteunend of halfopen systeem geeft tegendruk op het gaspedaal indien de bestuurder sneller rijdt dan de maximale snelheid. (iv) Een limiterend of gesloten systeem voorkomt dat de bestuurder de maximale snelheid overschrijdt.

Allerhande initiatieven werden opgestart in Europa om de effecten van ISA te onderzoeken Sinds de jaren 80 werd al onderzoek verricht naar ISA. Naast simulatorstudies werden er in heel wat landen trials gehouden om deze systemen te testen.

Zo heeft ook in Gent (België) gedurende een jaar een ISA-trial plaatsgevonden met 37 voertuigen. Om de effecten van ISA op het snelheidsgedrag te onderzoeken is zowel een subjectief onderzoek, waarbij de perceptie van de bestuurders getest werd door middel van enquêtes, als een objectief onderzoek, waarbij geregistreerde snelheidsgegevens werden geanalyseerd, uitgevoerd. In het subjectieve onderzoek bevestigen de bestuurders dat door het gebruik van ISA het aantal snelheidsovertredingen aanzienlijk vermindert. Bovendien stellen de bestuurders dat de effecten groter zijn op wegen met een hogere snelheidslimiet zoals autosnelwegen dan op wegen met een lagere snelheidslimiet zoals een zone 30. Deze stelling wordt bevestigd door de objectieve analyse van de rijdata. Wel zijn de effecten veel minder uitgesproken dan wordt aangegeven in de enquêtes. Ook wordt het aantal gemaakte snelheidsovertredingen in de enquêtes aanzienlijk onderschat.

Verschillende studies en proefprojecten hebben aangetoond dat ISA de snelheidsoverschrijding vermindert; ISA de verkeersveiligheid verhoogt; ISA gunstig is voor het milieu (als gevolg van lagere en homogenere snelheden); ISA kan leiden tot meer homogene verkeersstromen.

Tot nu toe is er nog geen grootschalige ISA implementatie, hoewel er veelbelovende initiatieven op Europees en nationaal niveau zijn, zoals de ontwikkeling van geografische snelheidslimietdatabases, interfaces, etc. Naast de technische haalbaarheid van ISA is de aanvaardbaarheid van het systeem door de bestuurder een belangrijk aspect: hoe denken bestuurders erover als ISA wordt geïmplementeerd? Bestaat er een draagvlak voor ISA? Met de acceptatie staat of valt de toepasbaarheid van een maatregel. Daarom is het belangrijk om enigszins inzicht te hebben over wat de acceptatie van een maatregel kan bepalen.

Een onderzoek naar de aanvaardbaarheid van ISA bij bestuurders werd uitgevoerd. Hiervoor werd een grootschalige survey gehouden in Vlaanderen en Nederland bij leden van de automobielvereniging VAB (Vlaanderen) en ANWB (Nederland).

Eén van de hoofdproblemen was dat er omtrent aanvaardings- of acceptatieonderzoek geen duidelijke definities bestaan. Ook werden in verschillende ISA onderzoeken, de graad van acceptatie op diverse manieren geëvalueerd. Dit gaf enerzijds aanleiding bij tegenstanders van ISA om de effecten harder te bekritiseren en anderzijds maakte deze verschillen het moeilijk om resultaten met elkaar te vergelijken.

In ons onderzoek werden diverse ISA, mobiliteits- en acceptatiestudies geanalyseerd. Op basis van deze analyse werden die factoren weerhouden die het vaakst gehanteerd werden in acceptatieonderzoek. Dit leidde tot 14 indicatoren die kunnen opgedeeld worden in enerzijds factoren die betrekking hebben op de context, met name hoe kijkt men naar snelheid en het snelheidsprobleem (kenmerken van het individu; rijgedrag; houdingen ten opzichte van het rijgedrag en de snelheid / verkeersveiligheid; persoonlijke en sociale doelstellingen bij snel rijden; waargenomen sociale normen en waargenomen sociale druk; probleemerkenning; verantwoordelijkheidsbesef; en informatie en kennis over het probleem). Anderzijds zijn er die factoren die betrekking hebben op de karakteristieken van het systeem zoals efficiëntie van het systeem; effectiviteit; gebruiksvriendelijkheid; waargenomen nut; tevredenheid; billijkheid; bereidheid tot betalen. Dit conceptueel model werd verder gehanteerd in de survey.

In Vlaanderen en Nederland werd einde 2009 de grootschalige survey gehouden waarbij 6370 personen reageerden in België en 1158 in Nederland De hoge responsgraad maakt het huidige onderzoek tot een waardevolle survey over de acceptatie van ISA.

Uit de perceptie over snelheidsgedrag en het snelheidsprobleem kan men vaststellen dat de respondenten het huidig beleid van snelheidslimieten goed vinden maar toch nog moeite hebben om zich aan de snelheid te houden in lagere snelheidszones. Tevens zijn ze van mening dat vooral eigen rijgedrag eerder invloed heeft op ongevallen dan contextuele factoren. Dit opent perspectief voor gedragsondersteunende ITS. Dit blijkt ook uit de antwoorden over het potentieel gebruik van verschillende systemen: haast 1 op 2 bestuurders is te vinden voor het gebruik van een gedragsondersteunend systeem.

95% geeft de voorkeur aan ISA. Hiervan wil 30% informatieve, 38% waarschuwende, 12% ondersteunende en 15% limiterende ISA. Meer open systemen worden aanzien als effectiever dan de andere systemen alhoewel deze vanuit veiligheidsoogpunt minst effectief zijn. Dit kan verklaard worden doordat individuen kiezen voor die systemen die hun eigen gedrag het minst beperken. Men stelt dit ook als de ‘acceptatie versus effectiviteit paradox’: hoe ingrijpender ISA is op het snelheidsgedrag hoe beter dit is voor de veiligheid en milieu. Echter blijken deze systemen het minst aanvaardbaar voor bestuurders.

Limiterende ISA had een grotere voorkeur dan ondersteunende ISA. Dit is een opmerkelijk resultaat te noemen aangezien in de meeste gehouden ISA trials, ondersteunende ISA toch de voorkeur kreeg. Dit kan mogelijk verklaard worden doordat het moeilijk is om de werking van ondersteunende ISA in te schatten indien men het niet heeft kunnen testen.

Een groep bestuurders die volgens de respondenten zeker mogen worden uitgerust met meer ingrijpende ISA zijn de professionele bestuurders. ISA blijkt wel gunstig bevonden voor alle bestuurders. Limiterende ISA zou vooral een oplossing zijn voor frequente snelheidsovertreders.

Een volgende stap in het onderzoek was na te gaan hoe elk van deze indicatoren elkaar en de acceptatiegraad van ISA kunnen bepalen. Structural Equation Modeling (SEM) werd gebruikt om de directe en indirecte effecten van deze indicatoren op de acceptatie te bepalen.

ISA en ITS effectief vinden, de mate van een billijke introductie van ISA, persoonlijke en sociale doelstellingen bij het rijden bepalen in grote mate de acceptatie van ISA. Effectiviteit wordt in het algemeen aanzien als een goede voorspeller voor acceptatie. Daarom zijn demonstratieprojecten die kunnen aantonen hoe deze systemen werken en blijken te werken een goede manier om het draagvalk te verhogen mits er een goede communicatiestrategie wordt opgezet. Het is namelijk ook zo dat de acceptatie van ISA vergroot naarmate men deze systemen kon gebruiken en dit is zeker het geval bij ondersteunende ISA. Indien men wil overgaan naar de implementatie van meer ingrijpende ISA dan moet men acties voorzien die kunnen zorgen voor een voldoende penetratiegraad op een billijke manier. Hierbij kunnen subsidies en voordelen in verzekeringspremies helpen maar de weerstand voor deze systemen zal groter zijn. De implementatie van informatieve en waarschuwende ISA (meer open systemen) kan mogelijk worden overgelaten aan de markt (zonder inmenging van de overheid) aangezien bestuurders bereid zijn om dit vrij snel aan te schaffen en hiervoor zelfs willen betalen.

Uit ons model bleek de bereidheid tot betalen weinig effect te hebben op de acceptatiegraad van ISA. Dit kan verklaard worden dat er mogelijk andere indicatoren in het model werden gestopt die betere voorspellers zijn dan prijsbeleid. Men mag ook niet ontkennen dat een prijspolitiek van subsidies of tussenkomsten een relevante bijdrage kunnen leveren bij het introduceren van diverse systemen.

De context-indicator ‘persoonlijke en sociale doelstellingen met betrekking tot het rijgedrag,’ bleek de meeste invloed te hebben op de andere variabelen die werden meegenomen in het model. Wie vooral eerder socialere doelstellingen hoog inschat (bijv. veiligheid) zal ISA ook beter aanvaarden. Personen die vooral handelen vanuit individueel belang (bijv. sneller rijden indien gehaast voor een afspraak) hechten minder belang aan het gebruik van ISA.

Bestuurders die graag sneller reden in hogere snelheidszones wensen ook minder gebruik te maken van ISA. Dit is in lijn met andere onderzoeken. Een vaak gestelde vraag is of de hardrijders of frequente snelheidsovertreders wel gebruik willen maken van deze systemen terwijl men het meeste voordeel kan hebben om deze personen uit te rusten met snelheid limiterende systemen. Sommige studies stellen dat mogelijk andere voordelen die het systeem kan bieden (zoals bijv. verminderen van boetes) deze groep van bestuurders wel kan overtuigen. Uit onze studie bleek dat bijkomende voordelen van ISA weinig effect hebben op het draagvlak.

Jonge bestuurders (jonger dan 25 jaar) zijn minder bewust van het effect van bepaald onveilig gedrag op ongevallen en wensen het gebruik van ISA minder. Nogal vaak merkt men dat jongeren zich minder bewust zijn van onveilig rijgedrag en overschatten deze ook vaak hun kunde. Betere bewustmaking bij deze jongeren zou (nog steeds) een prioriteit moeten zijn voor het beleid. Bestuurders tussen 25 en 45 jaar zijn ook minder geneigd in het aanvaarden van ISA, vooral op basis van een analyse van de indirecte effecten op de aanvaardbaarheid. Nochtans kan deze groep gekenmerkt worden als één van de meest actieve bestuurders. Wel blijkt dat deze groep bestuurders belang hechten aan de opinies en meningen van peers (familie, vrienden) en belangwekkende personen. Een mogelijkheid om bij deze groep het draagvlak te verhogen is gebruik maken van rolmodellen.

Dit onderzoek toonde aan dat ISA potentieel aanvaardbaar is voor bestuurders en dus zeker een veelbelovende weg is om te bewandelen indien men de verkeersveiligheid wil verhogen. Deze studie toont ook aan dat het verder investeren in ISA technologie zoals betere kaarten, betere systemen enz. de moeite waard zijn. ISA blijkt ook één van de systemen te zijn waar het meeste baat bij te vinden is als het komt tot het verhogen van de veiligheid. Een vaak aangehaalde reden om ISA niet verder te implementeren is dat beleidsmakers stellen dat ‘het publiek’ dit niet wil. Deze studie toont aan dat de aanvaardbaarheid voor ISA zeer groot is maar dat een gericht beleid, afhankelijk van het type systeem noodzakelijk is.

Summary

The Acceptability of In-vehicle Intelligent Speed Assistance (ISA) Systems: From Trial Support to Public Support

Speeding is a widespread social problem. It affects road safety, higher vehicle speeds also contribute to increased greenhouse gas emissions, fuel consumption and noise and to adverse impacts on quality of life. Different researchers, organizations and road safety visions noted that co-ordinated actions taken by the responsible authorities can bring about an immediate and durable response to the problem of speeding and so can reduce rapidly the number of fatalities and injuries, and to reduce environmental pollution and energy consumption.

Speed management can help achieve appropriate speeds, taking into account mobility and economic needs as well as safety and environmental requirements. A coherent consistent policy will produce better results than a series of isolated measures.

Within this concept the use of technology has been further investigated. One of the most promising ADAS, aimed at reducing inappropriate speed, is Intelligent Speed Assistance (ISA). ISA is an intelligent in-vehicle device that warns the driver about speeding, discourages the driver from speeding, and/or prevents the driver from exceeding the speed limit. Most ISA uses the Global Positioning System (GPS) and a digital speed limit database; the position of the vehicle is determined using a GPS receiver. The position is used to retrieve the speed limit or other information from a database. The information is then reported to the driver. ISA can use three types of limits: static speed limits (posted speed signs), variable speed limits (information about speed limits depending on the location), and dynamic speed limits (information based on actual road and traffic conditions). ISA devices can be divided depending on how intervening they are. An informative or advisory system displays the speed to remind the driver of the changes in speed levels. A warning or open system

cautions the driver if the posted speed limit at a given location is exceeded; the driver then decides whether to use or ignore this information. An intervening, supportive, or half-open system gives a force feedback through the gas pedal if the driver tries to exceed the speed limit (like the active accelerator pedal). It is however still possible for the driver to overrule the counter-pressure initiated by the accelerator pedal. A mandatory, automatic control, restricted, or closed system will fully prevent the driver from exceeding the limit; hence, the driver cannot overrule the system.

Several studies and field trials have indicated that ISA reduces speed and speeding that ISA is effective for traffic safety that ISA is expected to be beneficial for the environment because of the estimated reduction in speed and speed variance and thus that ISA can lead to a more homogeneous traffic flow.

In October 2002 an ISA-trial in Belgium was started in Ghent. Thirty-four cars and three buses were equipped with the "active accelerator pedal". In this system a resistance in the accelerator is activated when the driver attempts to exceed the speed limit. If necessary, the driver can overrule the system. The main research goals of the trial in Ghent were to evaluate the effects of ISA on speed-change, traffic safety, drivers' attitude, behaviour and drivers' acceptance. To study these effects of the ISA-system both surveys and logged speed data were analysed. In the surveys drivers noticed that the pedal assisted them well in upholding the speed limits and that the system increased driving comfort. Most important drawbacks were technical issues. Data analysis shows a reduction in the amount of speeding due to the ISA-system. There is however still a large remaining percentage of distance speeding, especially in low speed zones. Differences between drivers are large. For some drivers speeding even increases despite activation of the system. For less frequent speeders average driving speed almost always increases and for more frequent speeders average speed tends to decrease. With the system, less frequent speeders tend to accelerate faster towards the speed limit and drive exactly at the speed limit instead of safely below, which causes average speeds to go up.

Although there has been no large-scale implementation of ISA yet, there have been promising initiatives in recent decades at European and national levels with respect to the development of technical feasibility frameworks (like geographical information storage, GPS-accuracy, vehicle communication, etc.) and speed limit databases (Vlassenroot et al., 2008). It could be generally concluded that, at the European level the major technical guidelines and protocols for the feasibility and deployment of in-vehicle ITS have been developed. Within the national initiatives the focus has shifted towards a more operational level, including legislation, national protocols, basic tools and field practices. Another important factor for future implementation of ISA is understanding how users will experience and respond to these devices and to what extent drivers are willing to accept ISA. The interest in defining acceptance or acceptability lies in the precondition that the effectiveness and success of ISA will increase if there is public/social support for it. Under favourable conditions a positive assessment leads to an increased willingness to accept ISA and even to support it actively.

Although several studies have examined acceptance and/or acceptability of ADAS there is little consistency on what is understood by acceptance or acceptability and, equally important, how these factors can be measured. This study aims to define acceptance and acceptability, and to determine which indicators should be considered relevant for their measurement.

Based on different socio-psychological theories and data derived from ISA trials, we arrived at 14 relevant indicators that were divided into general indicators (related to persons' psyches, social values, and norms at that time, etc.) and device-specific indications (factors that are directly related to the device itself). These 14 indicators were presented to randomly selected respondents (through Internet media) in a test survey. The main goal of this survey was to find out whether the distilled indications and the questions were indeed relevant, and whether some relationships could be found between the indicators. Through the use of factor analysis, we found out that our questions were relevant for every item, and some correlations were found between the items. It was also noted that some indicators would directly influence the acceptability of ISA, while some would influence others indirectly. This first step in our research enabled us to conduct a large-scale survey among the general public in the Netherlands and Belgium regarding the acceptance and acceptability of ISA.

In total, 7528 drivers responded to the questionnaire call by the two main interest groups in both countries; 5599 responses were found sufficiently complete to take into account for further analyses. The average respondent was male between 45 and 54 years old with a relatively high education and no children living at home. Their vehicle was the main mode of transport and on average they drove between 10 000 and 25 000 km/year. 76% of the drivers had been involved in an accident at least once, 11% of them had had an accident with injuries, 4% had had a severe accidents and 1% had been in an accident with casualties.

The resulting general indicators in the survey showed that the drivers had positive opinions concerning the current posted speed limits. The drivers would generally drive within the speed limit in urban areas. However, in 30 kph-zones they would speed more often. These results are in line with the Belgian, Dutch, and Swedish ISA-trials.

The respondents stated that behavioural aspects are a greater cause of accidents than contextual issues. The drivers were relatively positive about the use of ITS to support their driving behaviour. Already in 2004, the SARTRE research project indicated that drivers rated the use of certain ITS applications as positive, although they had only a few systems to choose from (GPS, ISA, alcohol-lock, driving monitor). In our study, the ratings for these systems were even higher. This might be an indication that drivers would like to have even more support when driving.

Almost 95% of the respondents in our survey stated that they are in favour of some type of ISA-system. In many studies, effectiveness was found as a relevant criterion to determine acceptability. However there is a difference in peoples' opinion about the effectiveness and the effectiveness results found in trials. In our study, open systems were considered the most effective ones, although from a safety point of view (semi)-closed systems are considered better.

Closed ISA was more preferred (i.e. was found more satisfying and useful) than supportive ISA. This remarkable result might be explained by the fact that it was more difficult for the respondents to understand how the supportive systems actually worked in practice.

Although the support for ISA is relatively high, the respondents indicated that it was not unconditional. The more the implemented system would be perceived to intervene in their control of the driving experience, the higher the penetration level should be. The respondents of our study felt that young and professional drivers (especially trucks and buses) should have a more intervening system. This was also stated in other trial reports; however, in our survey many respondents also stated that ISA would be beneficial for all drivers. As in many ISA-studies the implementation of restrictive ISA was considered a good solution to stop frequent speeders. Our study also indicated that incentives would increase the support for more intervening systems. However, it would still be difficult to get people to accept restrictive ISA.

Finally, a model was estimated by using structural equation modelling (SEM) to find out which predefined indicators would be relevant to define the acceptability of ISA. Background factors, contextual issues and ISA-device related factors were used as indicators to predict the level of acceptability. The factors that were used in the model were based on the methods used in past ISA trials, acceptance theories and models.

This research resulted in improved insight into the opinions and attitudes that can or will influence acceptance or acceptability of ISA.

The four variables that had the largest total effect on the acceptability of ISA were (1) the effectiveness of ISA, (2) equity, (3) effectiveness of ITS, and (4) personal and social aims (4). Effectiveness was found a relevant predictor for acceptance in many trials. In some studies the willingness to pay was reported to be a good predictor for acceptability. However, in our model the effect of willingness to pay was very low or even absent. Hence, it may be assumed that our model had better indicators than the willingness to pay.

Many different items influence acceptability directly or indirectly. It is important to understand these in order to develop implementation strategies. Increasing the support of ISA has to be established at different levels.

Younger drivers are less convinced that certain behaviours or circumstances could cause accidents than older, more experienced drivers. Many studies have indicated that young drivers overestimate their own driving skills, drive faster, and are less aware of accident causes (Shinar et al., 2001, but see also De Craen, 2010). For the implementation of ISA – although there is no direct relationship between younger age and acceptability – a different strategy is needed to convince this group of drivers. Awareness campaigns and communication should be deployed during their education; however, road safety education and training are not common during secondary school and are absent in higher education.

Drivers between 25 and 45 years of age would also be less inclined to accept ISA. This group of drivers may be labelled as one of the most active groups of drivers. We also found that both younger drivers and those between 25 and 45 are influenced by social norms. This may be very important in implementation strategies.

Not surprisingly, drivers who claim to speed for their personal benefit were found to speed more often than other drivers, regardless of ISA. Drivers who speed in high-speed zones were also found less inclined to accept ISA. This is in line with previous findings i.e., frequent speeders would support ISA less; those drivers who would benefit most of ISA would be less likely to use it. This is an important finding when considering strategies for implementing ISA.

Our model showed that the willingness of drivers to adopt ISA increases if they experience the system in practice; if people are convinced that ISA does what it is designed to do, acceptance will be higher. Hence, (large scale) trials seem a good way to demonstrate the effectiveness of ISA, However, trials typically do not allow a lot of people to experience ISA. Therefore, communication strategies that focus on ISA-effectiveness, supported by demonstrations, would be helpful to convince people about the benefits of using such a system.

The issue of ‘equity’ has rarely been investigated in other trials or ISA studies. However, in other types of traffic and transport studies (e.g. tolling) equity has been investigated. These gave a good indication for future implementation actions. Often when a new driver support technology is introduced – especially when it could restrict certain freedom in driving – a majority of the population is reluctant to ‘buy or use’ the system. In the Ghent ISA trial, it was noted that most of the drivers were convinced of the effectiveness and were highly in favour of the supportive system but they stated that they would only use ISA further when more or certain groups of drivers would (also / be forced to) use the system (equity on level of penetration). In the development of implementation strategies this is a very important issue. Therefore policymakers should be aware that if they would like to introduce certain types of ISA, the penetration level should be sufficient from the start to convince others to adopt ISA. Promoting ISA by implementing in certain groups of vehicles, for instance introduction to professionals (bus-, taxi-, van-, truck-drivers) or younger drivers may be helpful to introduce certain systems (equity related to the equipment of certain groups). It is assumed that implementing ISA in the fleet of professional vehicles would be very effective to increase acceptability rates. The companies and vehicles concerned could be considered as role models in road safety. Previous studies and trials already stated that role models are effective to gain awareness of ISA.

Our model showed that willingness to pay was not a major indicator influencing acceptability. However, others have reported that price-policy, subsidies, etc. could be good instruments to increase the level of acceptability for a policy measure.

Some studies have indicated that to increase support, implementation strategies and campaigns could focus on other benefits of ISA (e.g. reducing speeding tickets, emissions, etc.). According to our study, these secondary effects have a rather small influence on increasing acceptability. Drivers who like to speed would care little about these secondary benefits of ISA.

All in all, we are inclined to conclude that the test-phase of ISA is over and that implementation strategies should be developed, although there are still some barriers.

Curriculum Vitae

Sven Vlassenroot (°1977, Dendermonde, Belgium) graduated as a Master in the Psychological and Educational Sciences in 1999 at the Vrije Universiteit Brussel.

Since 2001 he has worked at Ghent University (UGent), specialising in sustainable mobility, road safety, and traffic behaviour. He coordinated the ISA trial (Intelligent Speed Assistance) in Ghent and, carried out research on drivers' attitudes and behaviour with ISA. At UGent he also focused his research on policy aspects regarding the implementation of ITS.

In 2007 he joined the Delft University of Technology to work on his PhD about acceptability of in-vehicle speed assistance systems.

Currently he is working on an implementation project about the collection and use of crowd-behaviour data with mobile communication technologies at Ghent University and on the early-stage adoption of electrical vehicles at Delft University of Technology.

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Summary

Speed management is a set of measures to limit negative effects of speed in a transport system. One of the solutions to solve speeding is making the road transport system more intelligent by implementing intelligent speed assistance (ISA). This thesis provides more insight in the factors that can determine the acceptability of ISA by (potential) drivers, which can be beneficial in the construction of better implementation strategies.

About the Author

Sven Vlassenroot performed his PhD research at the Transport and Logistics section of the Faculty of Technology, Policy, and Management, Delft University of Technology (the Netherlands) in cooperation with Ghent University (Belgium). Currently he works at Ghent University in the field of intelligent transport & monitoring systems.

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