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Chapter 11 Easy Going – the ISA case as an example

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Abstract

Intelligent Speed Adaptation (ISA) involves an in-vehicle system, which 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 (research indicates that in Europe 1/3 of all fatal accidents is caused by inappropriate speed). 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 has been conducted across Europe. This research involved different ISA systems, ranging from simple information provision to keeping the car to 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. By discussion and evaluation of some ISA studies and ISA developments, two main questions will be answered: what do we know and what is still to be done? This will result in an overview of barriers and issues that have been resolved and that still have to be resolved, to enable large-scale implementation.

1. Introduction

Speeding is a widespread problem and is a major source of road traffic externalities. Speeding affects road safety; it not only increases 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 the problem of speeding is making the road transport system more intelligent by implementing Intelligent Transport Systems (ITS). In-vehicle ITS 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 Advanced Driving Assistance System (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.

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).

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 upon how intervening (or permissive) they are (Morsink et al., 2006):

Table 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 can not 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 to 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.

2. Research on ISA

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 behavior 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. 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 behavioral 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 behavior. 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 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 (Päätaalo 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 system 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 was, 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 (Varhelyi 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 kilometers 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 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 behavior (long term being considered as more than a year's period). A study in Sweden (Börlänge) showed that for the Assisting (half open) ISA the effect of ISA decreased year after year (Warner & Aberg, 2008), between 1999-2003.

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.

2.2.1 Safety effects

The most detailed prediction of overall network savings with ISA is provided by Carsten and Tate (2005). Table 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 2. Best estimates of crash savings by ISA type and crash severity, assuming a penetration rate of (nearly) 100% (Carsten & Tate, 2005)

System type	Speed limit type	Best estimate of injury crash reduction	Best estimate of fatal and serious crash reduction	Best estimate 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 slip-

pery roads, around major incidents, etc. Thus, with a Dynamic system, speed limits are current in terms of time.

2.2.2 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, Varhelyi 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 CO₂ 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 CO₂ 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, NO_x and HCs varied by only +/- 2% for all ISA penetration rates.

2.2.3 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 (Varhelyi and Makinen, 2001).

2.2.4 Side Effects

Different studies indicated that the vehicle following gap reduced (Persson, 1993, Comte 2000), this lead to closer car following behavior. Varhelyi et al.

(1998) conclude that safer car following behavior (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 behavior). Vahelyi et al. (2004) found no evidence that the behavior of ISA drivers towards other road users improved. The assumed effect of ISA on give-way behavior varies. Early research by Persson et al. (1993) indicated a slight increase in incorrect give way behavior at intersections. Others found no negative effects (Varhelyi et al. 1998, 2004) or even a slightly positive effect (Almquist & Nygard, 1997 source Varhelyi et al., 1998). It is concluded that overtaking behavior did not change (Comte, 2000; Varhelyi & Makinen, 2001) also no loss in vigilance was found (Comte, 2000).

Different trials indicated an increase in travel time. In 1998, Varhelyi 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 (Varhelyi & 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. Varhelyi 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.

2.2.5 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; Argioli & Van der Pas, 2006).

2.2.6 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 favor 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.

2.2.7 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, already 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 argues 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 favor 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. 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 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 behavioral 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 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 behavior 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 on 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.

3.1 Technology developments and speed information databases

Although there is no sign of ISA implementation in the road transport system yet, policymakers have not sat still the last years. They 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 Advanced Driver Assisting Systems (ADAS) was investigated.

Besides these European projects, many national initiatives were undertaken, e.g. 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 must be 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.

3.2 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 that 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 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 ap-

proaches 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 modeling approaches are used (exploratory modeling), 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 seems 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.

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 behavior 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 is 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:

- to communicate about ISA, to create more observability and political awareness of ISA (e.g. like the initiative on ISAwed.eu)
- to look for niches and implement ISA where it can be successful
- to make a case for mandatory implementation because ISA is a preventive innovation and those who need ISA the most would never voluntarily 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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