Intelligent Speed Adaptation: Slow speed, Slow Implementation?

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Abstract
Every day people in Europe and other parts of the world are confronted with the grim reality of losing loved ones due to traffic accidents. Research shows that one out of three fatal accidents is related to an inappropriate speed. A possible measure for reducing speeding is implementing Intelligent Speed Adaptation (ISA), which supports or enforces a driver to maintain the appropriate speed limit. ISA has been tested around the world and these field tests show that, ISA has the potential to significantly reduce fatal accidents. However, implementing effective ISA seems far away. In this paper we try to explain which factors hamper the implementation of ISA and what needs to be achieved to speed up implementation. Finally we conclude that in order to speed up ISA implementation the government should play the role of change agent, actively promoting ISA creating opportunities for potential adopters to try and observe the use of ISA.

Keywords: ISA implementation, diffusion of innovations, expert opinion.

1. Introduction

Improving road safety is an important transport policy goal, both for the European Union as a supra-national government and for individual member states[1, 2]. In 2004, more than 43,500 people died on European roads. Although the number of traffic fatalities within the EU is declining, the most recent figures show that the current rate of decline is far from sufficient to meet the goals for 2010[2, 3]. The goal for 2010 is to reduce the number of fatalities by 50%, (reference year 2001) but in 2005 only a 17.5% reduction was achieved, by far not the 25% needed for the EU to be on course for meeting their own policy goal of halving road deaths by 2010 [4].

Research indicates that inappropriate speed contributes to one out of three fatal accidents [4]. To address speeding behavior, a wide range of policy options have been considered in the past, these measures are often categorized using the three E's (Engineering (Vehicle and infrastructure), Education and Enforcement). When it comes to speeding related measures, examples of the three E's are plenty for almost all of the three categories, however history shows that one category of measures is structurally underused: vehicle engineering (which is usually focused at making speeding more attractive instead of unattractive). The CEMT recommend, already in 1991 that the appropriate international organizations (UN/ECE, EC) should urgently examine the need to draw up regulations on maximum power-to-weight ratios to tackle speed, high fuel consumption

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and CO_2 emissions, which indicate a change in the vehicle design [5]. Today, a first step can be made in the use of Intelligent Transport Systems (ITS) that contributes in the reduction of speeding behaviour and emissions. Although these techniques would not lead to changes in the vehicle design, and could not probably seen as a solution to counter the problem directly, these ITS devices can have a first positive influence to tackle it.

One of the most promising ITS, specifically aimed at reducing inappropriate speed, is Intelligent Speed Adaptation (ISA). 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. Most ISA-devices can be categorized into three types [6] 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 assisting ISA system will intervene when the speed limit is exceeded. For example, the pressure on the accelerator pedal will increase when the driver attempts to drive faster than the speed limit. A restricting or intervening system will totally prevent the driver from exceeding the limit: the driver cannot overrule the system. ISA has been demonstrated in different trials around the world (e.g. Sweden, The Netherlands, The UK, Australia, etc.) and the conclusions of all these trials are unambiguous regarding the positive effect of ISA on traffic safety [7-11].

The different trials around the world and the implementation of advising ISA as an add-on to current navigation systems (E.g. TomTom®) clearly indicates that the technical realization of ISA is no longer the main issue. The question nowadays has become: If improving road safety is such an important policy goal, why is that ISA implementation is going so slow? In this paper we will answer this question amongst others by applying theory of diffusion of innovation as developed by Rogers [12].

2. Theory and applied methodology

When researching the diffusion of innovations there is one dominant theory that was developed during the last decades, the Diffusion of Innovations Theory (DIT) of Rogers [12]. This theory is extensively criticized [13] and for special domains often adjusted to suit the needs of specific domains (e.g. for IT [14]), but withstood the hands of time and criticism. The diffusion of innovation theory as developed by Rogers shows some similarities with Theory of Planned Behavior as it was developed by Fishbein and Ajzen [15]. Research regarding the diffusion and acceptance of new technologies in ICT often combines the theories [16]. In this paper we combine the two theories, theory of planned behavior and the theory as developed by Rogers. Figure 1 shows the combination of the two theories. Literature regarding the acceptance of IT also mentions the development of a Unified Theory Of Acceptance and Use of Technology, this model however is more abstract and therefore incorporates a lot of the elements from TPB and DIT without making them explicit. For this paper we want to have an evaluation framework that can relatively easy and accurate pinpoint barriers for implementation and possible solutions. Based upon IT related literature and the theories of Rogers and Ajzen we developed the conceptual framework for evaluation of the adoption of ISA as shown in, Figure 1 [12, 15, 16].

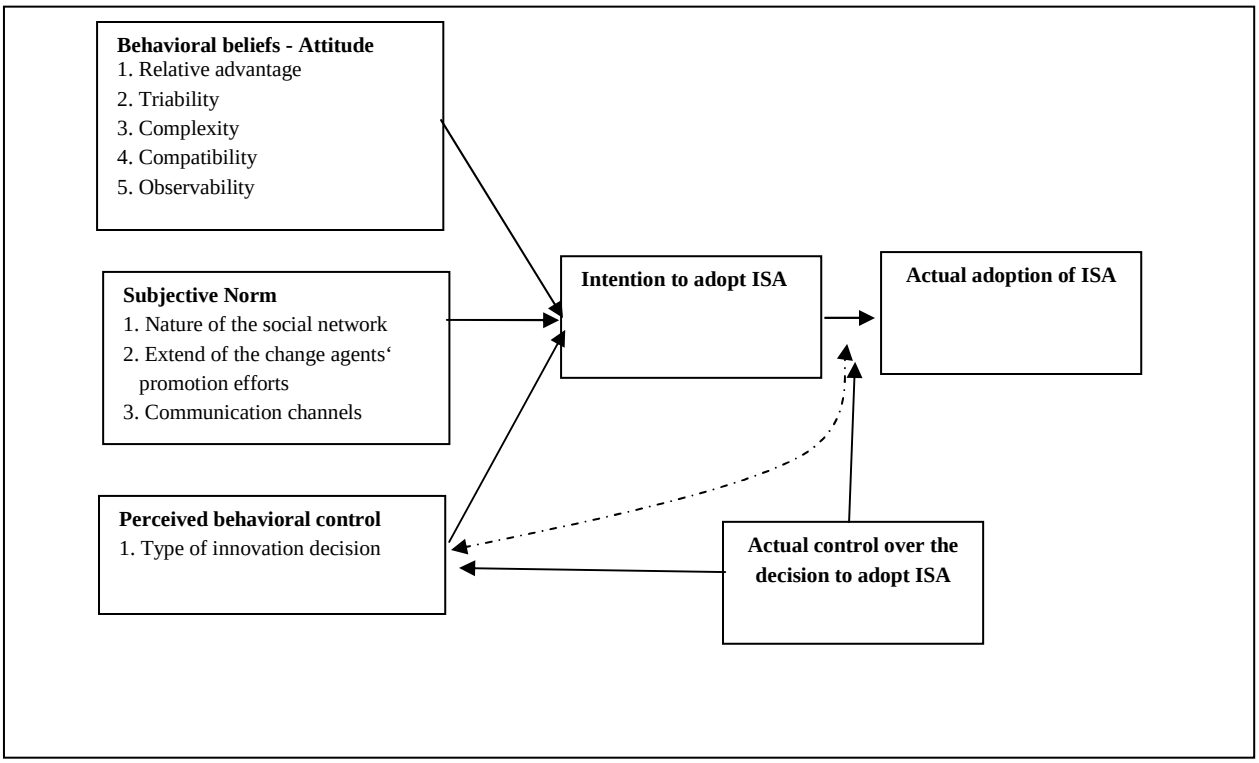

Figure 1 Framework for evaluating the adioption of ISA.

The bases for the model is the Theory of Planned Behavior (TPB). TPB is a theory that explains why people show certain behavior, since the behavior we refer to is the adoption of a technology; we applied the theory of diffusion of innovations to the theory of planned behavior. The behavioral beliefs refer to the attitude towards the behavior (adoption of ISA). The attitude toward a behavior is determined by the total set of accessible behavioral beliefs linking the behavior to various outcomes and other attributes. When the behavior is the acceptance or adoption of a new technology, like in the case of ISA, Rogers, mentions five important attributes that determine the attitude towards the adoption of the technology; relative advantage, compatibility, complexity, triability, observability [12] The subjective norm is the perceived social pressure to adopt ISA. Rogers mentions a number of explaining variables; nature of the social network, communication channels used to diffuse an innovation and the extend of the change agents' promotion efforts. The perceived behavioral control refers to the perception of the adopter regarding his/her ability to adopt ISA an explaining variable is the type of innovation decision (is it optional or forced by authority) [12].

The explaining variables for the rate of diffusion of ISA are determined using literature of different held ISA-trials and the data from a previously performed expert elicitation study called Future of Advanced Driver Assistance Systems Study (FADAS) [For more information regarding FADAS see: 9, 10].

3. Attitude towards ISA adoption

Rogers mentions five important attributes that determine the attitude towards the adoption of the technology; relative advantage, compatibility, complexity, triability, observability [12]. The relative advantage of ISA is still unclear. As a part of the FADAS research 35 international

experts were asked what they perceive to be the most important barriers for the diffusion of ISA. The experts indicated that the major barrier for implementation of ISA is the perceived relative advantage of the technology. According to the experts, consumers in the innovation diffusion process are negative about the expected utility vs. cost. (See Table 1) For the informtaive ISA, the relative advantage is more clear to the adopters, it is currently sold as an add-on to navigation systems, which means relatively low cost and relatively high benefits. More intervening or restricting types of ISA bring the relative advantage of using the technology down. An interesting case is made by Rogers for so-called preventive innovations. He argues that sometimes there is a conflict between what is best for the system, say a city or a nation, and what an individual prefers to do. ISA implementation is an example of such a case, where some people might prefer to drive faster than the speed limit, but for traffic safety in the region that person drives in, it is better that he or she doesn't. Rogers mentions mandates for adoption in these cases to be a mechanism through which the system exerts pressure on the individual to recognize the relative advantage of the innovation.

However, experts seem convinced of the relative advantage of ISA, the contribution to policy goals like safety and environment and road capacity is no barrier for implementation. (See Table 1) In the past many different types of studies have been performed, researching the benefits of the use of ISA. Driving simulation studies, [17, 18], instrumented vehicle studies [19, 20] and field trials in The Netherlands [7], Belgium [8], Sweden [9], Denmark [10] and France [11]. These different trials showed that ISA systems can potentially achieve high reductions in the incidence and severity of road crashes. In 2005 Carsten & Tate presented a cost benefit study comparing the costs and benefits of various ISA systems. Subsequently the accident savings were estimated/calculated, assuming a 100% equipment rate of the systems. In Table 2 an overview of the results is given. The table shows considerable effects for all types of ISA systems. There is a large variation though; informative systems appear to have a much smaller effect than mandatory automatic control systems, and the effect of static and variable speed limits is smaller than dynamic speed limits. According to the SARTRE survey around a quarter of the European drivers are of the opinion that it is 'very useful' to have a device in the car that restrains you from exceeding the speed limits [21]. This is a little bit lower than for devices preventing drink-driving and driving when fatigued.

Table 1, Group opinion on barriers for implementation (indicated by mean): 1= very important, 2= important, 3 = neutral, 4= unimportant, 5 is very unimportant

Barrier	**Score**
Reliability of the system	2.1
Accuracy of the system	2.2
Parameter trade-off	2.8
Riskier driving behaviour when using system	2.9
Riskier driving behaviour when not using system	2.9
Human-machine interface	2.1
Contribution to accident reduction	3.3
Improvement in road capacity	3.3
Uncertainty about the reduction of fuel consumption/pollution	3.7
Liability allocation	**1.9**
Consumers perception of system utility vs. Costs	**1.8**
Stakeholders perception of system utility vs. costs	2.1
Lack of international standardization	2.6

Table 2traffic safety results of ISA implementation (Source:[6])

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
Informative	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%

The practical experiments in the trials have shown that the willingness to adopt ISA increases if concrete experience with it has been gained, triability clearly influences the intention to use ISA[8]. The scale of the pilots held in the past does not allow a huge mass of people to try out ISA, accept for informative ISA, ISA is still not available yet. A method that was used to measure the acceptance in different trials was the procedure of Van Der Laan, Heino and De Waard [22]. 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. As an example the results of acceptance in the Belgian trial are described, see Figure 2.[8].

Figure 2, influence of trialability on the acceptance of ISA. (Source [8])

All drivers (total) accepted the active accelerator pedal. 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 was not satisfying, although useful, they declared it was more satisfying and useful after the trial. Assisting and mandatory ISA are not on the market and can only be tried

during field tests, demonstrations and pilots, which also results in the fact that important stakeholders like policymakers have limited to no opportunity to try ISA. In Belgium (Ghent) five policymakers were convinced to participate in the trial. It is important to note that this had significant results. These role-models in the Ghent trial and the given demonstrations have led to more publicity in the media, a better known concept by the general public and a higher topic within policy. This more positive image and the better knowledge of ISA as a possible measure in road-safety led to several voted resolutions in the Belgian federal parliament and senate (Source www.isaweb.eu).

Complexity of the system is the degree in which ISA is perceived to be relatively difficult to use. Experts indicate that the Human Machine Interface (HMI) is a considered to be an important to neutral barrier for ISA implementation (Table 1). The complexity of the HMI basically determines how difficult it is to use the system. In the Belgian trial it was noted that the drivers did not experienced ISA as a difficult device to use, although drivers did indicate that minor technical issues are annoying (like the accuracy of the speed map). Furthermore several studies indicated that "overinformation" could lead to a rejection of the use of an ITS-device, therefore the information must be given clearly and simple [23]. Overall it can be assumed that complexity is not a negative factor influencing the speed of diffusion of ISA.

Compatibility of ISA with values and beliefs, with previously introduces ideas or the potential users' need for ISA. Research indicates that most people do not feel that driving fast is fun or creates a feeling of freedom[8]. Furthermore, when asked, people have a negative attitude towards speeding; they think it is dangerous, reckless and not sportive. This indicates that ISA is compatible with the values and beliefs of most drivers [8, 24]. Whether it is compatible with the needs of the drivers is uncertain. Research indicates that voluntary usage of a ISA leads to around 30% engagement (depending on the type of ISA) [8, 25]. The voluntary use of ISA indicates a need for the use of ISA, problem is however that those who really need ISA, are least willing to use it voluntary [25]. Rogers mentions a couple of possible measures of you want to improve the perception of the compatibility: naming the innovation and a proper positioning strategy. Over the years, ISA has been called numerous different names (e.g. External Vehicle Speed Control, Speed alert Systems, Speed Warning Systems, Intelligent Speed Assistant etc.), fact is that this didn't speed-up the implementation. Positioning the technology should be done by the problem owner, in this case governments. In depth research should indicate niches for the technology (e.g. ISA around schools, or ISA for known offenders but also opportunities).

Observability of ISA is still a major problem. Accept from the relatively small media coverage during trials ISA is still not on the market. To increase the observability of ISA during the ISA-trial in Belgium, some drivers were especially selected to be role-models in ISA-driving. These drivers had a delegating - public function at the council of Ghent, an institution or company. The need for these role-models is because it was assumed that ISA could have an 'image-problem.' The use of role-models could take some prepossessions away: policy-makers and the manager of a car manufactory were using the system and were giving 'an example in road-safety.' The use of ISA by decision-makers also made it more debatable within the public opinion. Also, policy-makers were using it first, before they would implement it [26].

4. Subjective norm regarding ISA adoption

Subjective norm towards ISA implementation is the perceived social pressure to engage or not to engage in imlpementing ISA. With respect to the subjective norm, Rogers identifies the nature of the social network as an important variable. This refers to the norms of the social system and the interconnectivity of the communication network. As indicated before ISA matches the current public opinion regarding speeding [8].

Second Rogers mentions the important role of the change agent. The change agent is an individual (or organization) that influences the potential adopters. Rogers identifies seven roles for a change agent in the process of implementing an innovation. 1) develop a need for change, 2) establish an information-exchange relationship, 3) diagnose problems, 4) translate an intent to actions, to stabilize adoption and prevent discontinuance and to achieve a terminal relationship. When it comes to ISA implementation the change agent are not very powerful persons or organizations (e.g. the ETSC European Transport Safety Council can be seen as a change agent). When it comes to implementing ISA, the more powerful and higher social economic status a change agent has the more successful he will be [12]. The ISA change agents are still in the first phase of their implementation roles (developing a need for change, establish an information exchange relationship and identifying problems). For ISA implementation it can be considered important that exchange agents 1) become more powerful, an interesting step towards this process was taken in Belgium where five policymakers where selected to take part in a pilot in order to try to make them change agents. 2) change agents make clear why ISA is needed, so to communicate the social norm and the ISA in relation to this norm.

The subjective norm and information regarding the innovation is communicated trough communication channels. The type of communication channel that is applied to communicate the innovation is also important for the rate of diffusion. Since ISA is not a real complex to use innovation mass media can be used to inform potential adopters. In this first phase of large scale implementation the first priority is knowledge supply. People need to understand what ISA is and why ISA is an appropriate measure for increasing traffic safety. Only later, in the persuasion phase it is interesting to use interpersonal communication channels.

5. Perceived control over ISA adoption

The perceived control over ISA adoption is influenced amongst others by what Rogers calls the type of innovation decision. He defines three types of decisions to innovate, optional, collective or authority. In case of this will depend largely on either the policymakers and/or the automobile industry. The policymakers can decide to implement ISA mandatory (authority innovation decision), leaving no room for the decision to adopt for the other stakeholders. Experts in different researches indicate different expectation regarding the way ISA will be implemented, but in most cases ISA or ISA-like devices are expected to be implemented mandatory [27]. The FADAS experts indicated to expect mandatory implementation, for the assisting types of ISA, to take place in 2025, for the automatic ISA this was expected to be 2050 [27]. Up until now only voluntary ISA implementation is taking place (Optional innovation decision) and currently only of the assisting system, we can assume that currently the adopters have the perception that they have full control over adopting assisting types of ISA. The second type of stakeholders that has influence over the control of ISA adoption is the automotive industry, if they would decide to implement ISA in their cars or certain types of cars this would influence the perceived control of the adopter over the adaptation behavior. Currently the industry indicates they are not willing to

implement ISA in their cars because of liability issues. Table 1, shows that experts indicated that this is a barrier for ISA implementation. There seems to be uncertainty regarding the liability allocation in case of an accident, which seems to keep industry form implementing it. Research indicates that liability issues not necessarily have to be a barrier for ISA implementation [28, 29].

For ISA to be effective there are two reasons to assume that a limited control over adoption (so an authority-innovation-decision is best for traffic safety. First a certain percentage of road vehicles should be equipped with ISA, a so-called critical mass, in order to sort an effect. Research indicates that this should be around 60% of the vehicles [6], to reach these penetration levels in relatively few years mandatory implementation seem logical. Second research indicates that drivers who need ISA most (un-safe drivers) are the least willing to adopt ISA on a voluntary basis [25].

6. Policy recommendation to support ISA implementation

Policymakers have not sat still the last years. Although implementation went slow they did recognize 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 researched and developed a framework to harmonise 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 [23]. In the research of ActMap (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 [30]. Besides these European projects, many national initiatives were made: In Sweden [31], and Finland [32] the speed limit database is a part of the national road database, which contain different kind of road information. In Denmark [33] 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 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. We can generally conclude that on European level the major technical guidelines and protocols were developed. Within the national initiatives the focus was more on an operational level, concluding legislations, national protocols, basic tools and field practice. 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 among policymakers can be noted [34] which still are the key-figures in conducting implementation of ITS.

Based upon the applied framework (see Figure 1), we can give a number of policy recommendations. Experts are aware of the relative advantage of ISA. This does not necessarily means that all stakeholders have the same perception regarding the relative advantage, or that they are aware of the advantages of using ISA. Throughout the studies on ISA it is noted that the more intervening a system is, the less accepted it will be. Also because of the experimental setup, some technical issues like malfunctions of the system or not having a reliable speed map are

noted as show stoppers for ISA. Not just the type of the system but also the characteristics of the driver are important for the acceptance of the ISA systems. It seems that drivers, whose speed behaviour would benefit most from ISA, are accepting ISA the least [25].

Policymakers that intend to implement assisting or mandatory ISA, have to take measures that increase the relative advantage of ISA. Rogers (1995) mentions different ways to do this but an important measure is giving incentives. Incentives have the effect that the quantity of adoption goes up but also that the quality goes down. In ISA this comes down to a higher penetration level but a lower level of compliance. This means that giving incentives for assisting ISA will probably lead to high adoption rates and limited people using the system (relatively high percentage of users overriding the system) (also see e.g. [23, 25]). For mandatory ISA it will probably lead to higher levels of adoption, and since the system is mandatory the level of compliance will be higher.

Governments should adopt the role of change agent [34]. Policymakers can be seen as important problem owners. As a change agent they can fulfill this role with much decisive and communicative power. As in SARTRE it was noted that a large public can be in favor of ISA. Throughout policy perspectives implementation of ITS will indicate other policies and decision-making processes than for traditional enforcement methods. A main issue within implementation strategies is to gather support for the measures. public support for road safety (measures) can be described as a positive valuation of road safety and of measures that evidently increase road safety. This positive valuation leads, under favorable conditions, to an increased willingness to accept a measure and even to actively support it. The growing interest in getting public support must be seen in the increased notion that policymaking acts must be considered as a two-way direction wherein interaction, transaction and communication with the public are the key-elements. This leads, in terms of road safety policy, to the precondition that the effectiveness of a measure will increase if there is support. A better support can be done by developing good communication strategies. To enforce the communication about the ISA-trial in Belgium, some drivers were especially selected to be role-models in ISA-driving (increasing observability and functioning as change agents). These drivers had a delegating - public function at the council of Ghent, an institution or company. The need for these role-models is because it was assumed that ISA could have an ‘image-problem.’ The use of role-models could take some prepossessions away: policy-makers and the manager of a car manufactory were using the system and were giving ‘an example in road-safety.’ The use of ISA by decision-makers also made it more debatable within the public opinion. Also, policy-makers were using it first, before they would implement it.

7. Conclusion

Since technical realization of ISA no longer seems to be the problem (proving the large number or pilots and the implementation of informative ISA), the time has come to start thinking about the implementation of ISA. We applied a combination of the Theory of Planned Behavior and the Diffusion of Innovations Theory to account for the slow implementation of ISA to today and to give practical recommendations to policymakers in order to speed-up implementation. The conceptual framework, as shown in Figure 1, proves itself useful, and allows us to come up with the following policy recommendations to speed up ISA implementation:

- Policymakers should see them selves as problem owners

- Policymakers should adopt the role of change agent, because they are the problem owners and current change agents lack the power to make a change. As a change agent the government should influence potential adopters by:
    - The use of mass communication channels. (increasing observability and explaining the relative advantage)
    - Creating and assigning role models, like was done in Ghent (Increasing observability and political awareness)
    - Look for niches, and implement ISA there where it can be successful (increasing trialability and observability)
    - Make a case for mandatory implementation, because:
        - ISA is a preventive innovation
        - The ones who need ISA most will never voluntary adopt ISA
        - Penetration levels that have to be reached in order for ISA to be effective is 60%, if we want to make the 2020 goals you need policy intervention.
        - The effect of giving monetary incentives are questionable

Based upon the elements in the theory of planned behavior we can pinpoint a number of elements that are, at least in theory, account for the slow speed of adoption, these are displayed in Table 3.

Further research will comprehend the use of data from pilots and simulation research in order to establish the relationships and their impacts in the conceptual model.

Table 3 ISA and the explaining variables of the rate of ISA adoption

Explaining variables for rate of diffusion		**Type of ISA**		
		Advising	**Assisting**	**Restricting**
I	Perceived attributes			
	1. Relative advantage	Clear to potential adopters	Unclear to potential adopters	Unclear to potential adopters
	2. Compatibility	Compatible with values and beliefs but also with existing technology. (navigation systems) → those who don't want to use it can easily ignore it.	In general it can be assumed that it is compatible. Only for the ones who need this type of ISA it can be assumed that it is not compatible with values and beliefs.	n general it can be assumed that it is compatible. Only for the ones who need this type of ISA it can be assumed that it is not compatible with values and beliefs
	3. Complexity	Not complex	Not complex	Not complex
	4. Triability	Very triable (it is an add-on on existing technology)	Not triable for the large public	Not triable for the large public
	5. Observability	Observable, it is on the market	Little observable	Little observable
II	Type of Innovation-Decision	Optional	? (not on the market yet)	? (not on the market yet)
III	Communication Channels	Limited advertising (mass media)) but mostly interpersonal through salespersons in stores.	Very limited communication only in times of pilots and some on the internet (request based).	Very limited communication only in times of pilots and some on the internet (request based).
IV	Nature of Social network	No indication for a negative impact on rate of ISA adoption	No indication for a negative impact on rate of ISA adoption	No indication for a negative impact on rate of ISA adoption

V	Extent of "Change agents "Promotion Efforts	A lot and powerful change agents; sales persons in stores and representatives of the industry.	Little change agents that have very limited power	Little change agents that are less power

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