Clearing the Road for ISA Implementation?

Applying Adaptive Policymaking for the Implementation
of Intelligent Speed Adaptation

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Clearing the Road for ISA Implementation?

Applying Adaptive Policymaking for the Implementation of Intelligent Speed Adaptation

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Preface

In 2004 I graduated from the Eindhoven University of Technology (TU/e). My final placement was with Siemens Netherlands, while writing my Master's thesis. It was the first time I had to design, conduct and report on a research project completely independently. It turned out to be an experience that suited me very well! Towards the end of the course I came in contact with Prof. Dr. Ir. Marjolein van Asselt. She invited me to come over to Maastricht to discuss my project and findings. It was Marjolein who opened my eyes to the idea of doing doctoral research. She offered me the opportunity to experience conducting scientific research by hiring me for a research project at the University of Maastricht. Together we performed a study for the Ministry of Homeland Affairs. I want to thank Marjolein for our many interesting discussions. We always stayed in touch and Marjolein has always thought along with me when we would occasionally discuss my research or options for my professional future.

After my time at the University of Maastricht I took a post of PhD researcher at the Technical University of Delft. The research was supported by the Next Generation Infrastructure Foundation and my promoters were Prof. dr. Warren Walker and Prof. dr. Bert van Wee, with Dr. ir. Vincent Marchau acting as co-promoter. The subject of research captivated me from the start: "dealing with uncertainty in implementing Advanced Driver Assistance Systems". Vincent, Warren, Bert, and I have had many interesting discussions for which I am very grateful. I would like to thank Vincent for all his support, supervision and in particular for all the personal talks. I would like to thank Warren for all the substantive discussions and supervision. I owe Warren my apologies for any frustration caused by the much recurring process of language editing. I want to thank Bert for his practical attitude, his scientific contributions, and the fact that he almost always has a positive perspective. Finally, both Bert and Vincent were always available for consultation on practical matters, which for a PhD-candidate is often as important as having a scientific sparring partner.

Over the years at TPM many roommates came and went. My first roommate was Datu Buyung Agusdinata. Buyung I am grateful for the substantive discussions that resulted in several scientific papers, as well as for the nice personal conversations. Memories of certain other roommates will also always remain with me: Kiliaan, Allert, and Randy, thanks for the fun times we had!

This is a dissertation based on scientific journal papers. I want to thank all the co-authors of the various papers for their input, contributions, and discussions. It goes without saying that this applies to all the people I ever published with, but to none more so than Jan Kwakkel, and Sven Vlassenroot.

Welcome distractions from the usually rather monotonous, relatively isolated existence of a PhD-candidate come in the form of congresses. During my PhD-process I was allowed to visit several of these. They often resulted in valuable contacts and new insights for my research. Moreover, they were unforgettable experiences. I have particularly fond memories of conferences with Sven and Raffael. I want to thank both for the great professional and personal conversations in we had in The Netherlands and abroad.

The TLO section is not only a great place to work because of the constructive attitude of colleagues and their academic excellence, but also because of the personal and pleasant atmosphere. I want to thank all TLO colleagues for the pleasant times. I wish to thank Menno, Randy, and Maarten in particular for the interesting talks, but especially for all the fun we had. Hopefully we can continue meeting on a regular basis, with a beer, a bite to eat, and lots of laughter.

I also want to thank everybody who helped me with my research and/or contributed to the dissertation, especially the ladies of TRAIL (Conchita and Esther) and the ladies of the Secretariat of the TLO (Betty, Trudie, Ellen, and Thea).

Next to professional activities there is also a private life. Support from friends and family is important in everything you do in life, including writing a dissertation. I want to thank my family, Marieke's family, and my friends for the moral support and contributions that ranged from reading parts of the dissertation to listening to practice runs for my first conference presentations. I especially want to thank my mother for everything she has done for me. My achievements in life pale in comparison to everything she has achieved. I can only hope that I can give to my daughter Fiene and my son Ties what she has given to me.

I would like to thank Paul van den Bosch for the cover design and my paranymphs Martijn and Randy for their willingness to support me in the final hours of the PhD process.

Marieke, thank you for all your love and support over the past years and for everything you are to me, Fiene, and Ties.

Jan-Willem
Breda, August 2011

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Glossary of Policy Analysis Terms[1]

Decisionmakers[2]	-	The actors in the policy domain that make choices regarding the structure, operations, rules, etc. of a policy domain. In other words the persons responsible for deciding what an organization's or government's policies will be. (In the Netherlands, these are, for example the members of the Dutch Parliament, city councils, etc.)
Decisionmaking	-	The process of making choices regarding a policy domain (e.g. the traffic and transportation system) in order to change the system's outcomes in a desired way (e.g. reduce emissions).
Domain experts	-	Experts with respect to a certain policy domain (e.g. specialists, engineers, behavioral scientists, etc.).
Policy	-	A set of actions taken by a government aimed at making changes in the policy domain, to help solve problems within it or caused by it, or to help obtain benefits from it.
Policy advisors	-	Same as analysts.
Policy analysts	-	The professionals that develop and supply (objective) knowledge to the decisionmaking process. Policy analysts provide support/advice to decisionmakers.
Policy analysis	-	The process aimed at assisting policymakers in choosing a policy from among complex alternatives under uncertain conditions.
Policy design	-	The part of the process of policymaking/decisionmaking that is explicitly focused on the design of policy options.
Policymaking	-	Same as decisionmaking.
Policymakers	-	Same as decisionmakers.
Stakeholders	-	Persons or groups of persons that have an interest in the system being analyzed, but cannot influence it to any great extent.

[1] The aim of this glossary is to reduce the possibility of confusion. Therefore, it does not contain an exhaustive overview of all the terms used in this dissertation (other definitions are provided in the dissertation). In this glossary the author focuses on terms that can be considered ambiguous, because different perspectives on policy analysis apply different terms. The author adopts what Mayer et al. (2004) call the "rational style" of policy analysis. (For an overview of the various styles, see Mayer, I.S., Van Daalen, C.E., Bots, P.W.G. (2004). Perspectives on Policy Analysis: A Framework for Understanding and Design, *International Journal of Technology, Policy, and Management*, Vol. 4, No. 2, pp.169-191.)

[2] We are aware of the fact that there is discussion on whether to write policy-making, policy making, or policymaking. (The same goes for decisionmaker and policymaker.) This is a question of style. There are a variety of style manuals available (e.g. Harvard, University of Chicago, RAND). However, there is one style manual that focuses on policy analysis – the RAND Style Manual. We, therefore, selected this style.

1. Introduction to the Research

In this chapter we provide an introduction to the research. The background of the research is explained, and the research questions that will be answered in this PhD dissertation are presented. Finally, the research approach and a reading guide for this thesis is presented.

1.1 Introduction

In the first chapter of this dissertation, we discuss the background of the research, which leads to the research questions and a first indication of the research approach. This dissertation is basically about uncertainties regarding the implementation of transport policies and the way transport policymakers can deal with these uncertainties. The emphasis of the research is on the implementation of an Advanced Driver Assistance System (ADAS) called Intelligent Speed Adaptation (ISA), and the uncertainties surrounding this implementation. ISA is a system that assists the driver in keeping the appropriate speed (i.e. comply with the legal speed limit at a certain location).

The background of this dissertation is discussed in Section 1.2. Section 1.2 provides an insight into the problem of speeding and policy issues related to speeding. Section 1.3 provides the problem statement, and the direct cause for this research. Section 1.4 explains the objectives of the research. Based upon Sections 1.1 to 1.4, the research questions are formulated in Section 1.5. The relevance of the research is explained in Section 1.6. In Section 1.7, a brief introduction to the research approach is given. Finally, Section 1.8 contains a reading guide for this dissertation.

1.2 Background

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. The World Health Organisation estimated in 2004 that every year 1.2 million people die in traffic accidents, and another 50 million suffer non-fatal injuries (World Health Organization, 2009). This means that each day over 3,000 people die, which comes down to more than 2 every minute. In Europe alone, in the period between 1991 and 2008, a total of over 734,000 European citizens were killed in traffic accidents (in the 15 EU member states). Table 1-1 shows the most recent available statistics for Europe. The numbers show that in 2008, in the EU (with 27 member states), over 38,000 people per year died from traffic accidents. This comes down to over 100 people a day, indicating that traffic in Europe still is a major cause of fatalities and injuries.

Table 1-1 Road traffic fatalities in the EU between 1991 and 2008

	1991	2008	Total (1991-2008)
European Union (27 countries)	75426	38875	1006538
European Union (25 countries)	71254	34753	936940
European Union (15 countries)	56027	25429	724109
Source: Eurostat, February 2011			

Research shows that “Excessive and inappropriate speed is the number one road safety problem in many countries, often contributing as much as one third to the total number of fatal accidents” (Organisation For Economic Co-Operation and Development (OECD), 2006). Speeding not only influences the risk of getting involved in a traffic accident, it also affects the outcome of an accident. For the Netherlands, Oei (2001) estimated that, in case all drivers would comply with the legal speed limit, this would reduce the number accidents resulting in injury by 25% to 30%.

To address speeding behavior, a wide range of policy options have been considered in the past. These measures (speed management measures) are often categorized using the three E’s: Engineering (related to both vehicle and infrastructure), Education, and Enforcement. Examples of infrastructure engineering to reduce speeding are speed bumps, and roundabouts. Replacing crossings with roundabouts have reduced the number of accidents by up to 73% in the built environment (Dijkstra, 2005). In driver education, novice drivers are familiarized with the effects of speed. In the Netherlands, a mandatory educational program for speed offenders is currently being considered. Enforcement has proven to be an effective measure. Stationary speed enforcement alone is estimated to have reduced the number of accidents with 17% (95% confidence interval -31;-2), and speed cameras are estimated to have led to a reduction of 39% in fatal accidents (95% confidence interval (-60;-7)) (Elvik et al., 2009). In addition, a series of effective enforcement measures have been applied in the past, such as trajectory control and undercover surveillance.

So, when it comes to speed management, there are many successful examples of the three E’s for almost all of the three categories. However, history shows that one category of measures is structurally underused: vehicle engineering (vehicle design is usually focused on making the vehicle faster instead of making speeding more difficult). For example, research from Sweden shows that the average top speed of all newly sold passenger vehicles in Sweden increased significantly over the past decades, increasing from 153km/h in 1975, to 172 km/h in 1985, 194 km/h in 1995, and to over 200 km/h in 2002 (Sprei et al., 2008). So, the trend in vehicle engineering is not so much to reduce the possibility of exceeding the speed limit, but to enable the driver to drive faster. In-vehicle systems that assist the driver in the task of driving the vehicle are called Advanced Driver Assistance Systems (ADAS). An example of an ADAS that is designed to assist the driver in choosing the appropriate speed is Intelligent Speed Adaptation (ISA).

ISA is an in-vehicle system that helps the driver to comply with the legal speed limit at a certain location. ISA technology is relatively straightforward and it uses the functionality of systems that are already available in most vehicles (e.g. a GPS device, digital maps, engine management systems, etc.). Most ISA devices can be assigned to one of three categories depending on how intervening (or permissive) they are (Carsten and Tate, 2005). An *informative* or *advisory* ISA system provides the driver feedback using a visual or audio signal. A *supportive* or *assisting* ISA system intervenes when the speed limit is exceeded, for example, by providing increasing counter pressure on the accelerator pedal 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. Since the early 1980s, the effects of ISA have increasingly been studied using different methodologies and data collection techniques, including traffic simulation, driving simulators, and instrumented vehicles. ISA has also been demonstrated in different trials around the world (e.g. Sweden, Netherlands, UK, Australia, etc.). The conclusions from all these trials and research are unambiguous regarding the positive effect of ISA on driving speed, and the calculated effects on traffic safety (AVV, 2001; Lahrmann et al., 2001; Biding et al., 2002; Saad et al., 2007; Vlassenroot et al., 2007). The most advanced ISA is expected to reduce the number of fatalities by 59% (Carsten and Tate, 2005). Recent Australian research shows that, depending on the assumptions underlying the research, the cost-benefit ratio could vary between 0.29 to 4.03 (Doecke and Woolley, 2011).

A rough estimate of the benefits of ISA shows the potential of ISA systems. If we use the assumption that 1/3 of all fatal accidents could have been prevented and the traffic safety numbers for Europe presented in Table 1-1, we can calculate that in the period 1991-2008, 335,513 lives in the EU could have been saved if every car had been equipped with a proper functioning ISA (1/3 × 1006,538 = 335,513).

1.3 Problem statement

In the Netherlands, Europe, and numerous other parts of the world, ever growing mobility comes with a lot of problems and inconveniences. Casualties, noise, (air) pollution, the use of fossil fuels, and negative health effects are all examples of problems and discomfort caused by the increase of mobility (Van Wee and Annema, 2009). The negative effect of mobility on public health is high on the policy agenda in both the EU and the Netherlands, and policymakers set ambitious goals for the reduction in traffic fatalities and injuries. The European White Paper on transport “Time to Decide” puts forward the European transport goals and objectives and sets out an action plan to achieve these. One of the main goals is to reduce the number of people killed on European roads by 50 percent (European Commission, 2001). The latest European White Paper on Transport “Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system”, states the same goal for 2020 and a highly ambitious goal for 2050: “By 2050, move close to zero fatalities in road transport. In line with this goal, the EU aims at halving road casualties by 2020” (European Commission, 2011). For the Netherlands, the objective is to reduce the number of fatalities in 2020 to 500 fatalities, and 10,600 seriously injured people (Ministerie van Verkeer en Waterstaat., 2009). In 2010 traffic accidents caused a total of 640 fatalities in the Netherlands).

So, if speeding is a major internationally recognized policy problem and ISA is a proven technology that has the potential to significantly contribute to traffic safety, the obvious question that remains is: why is it that ISA has not yet been implemented? Literature study reveals two important reasons: First, recent research indicates that ISA has been under the attention of policymakers for a couple of decades (Vlassenroot et al., 2011), and ISA related policies are included in different national (Dutch) and international policy plans (Van der Pas et al., 2006a; Van der Pas et al., 2006b). However, the type of ISA policies that are developed typically will not actually change the transport system. The policies that are developed all focus on doing more research and initiating temporary trials and pilots. Second, literature research also indicates that this is due to the uncertainties surrounding ISA's real world outcomes and the preferences crucial stakeholders (will) have regarding these outcomes (E.g. the expected reduction in fatalities given different penetration rates, the liability in case accidents occur with ISA equipped vehicles, etc.) (Marchau et al., 1998; Van Geenhuizen et al., 2002; Bishop, 2003; Donner et al., 2004). Hence: policymakers are aware of the potential of ISA, but policymaking for ISA seems troublesome. Policies lack the potential to really lead to ISA implementation, and policymakers have troubles designing policies that appropriately deal with uncertainties that surround ISA implementation.

The two reasons mentioned above are closely related to each other. Policymakers confronted with uncertainty regarding a decision problem often intentially or unintentially select a strategy aimed at delaying or postponing. Doing more research is one of the most used policies in such cases. When it comes to ISA, most research performed in the past focused on reducing these uncertainties by initiating trials, and trying to forecast future ISA developments, their costs, their benefits, and ISA acceptance. In some cases, scenario approaches were used. Although useful, these approaches have been shown to be insufficient for guiding ISA policy development, since it appeared to be highly difficult to forecast ISA related developments. For instance, looking at the expected implementation and penetration rates for Advanced Driver Assistance Systems (ADAS) in general, which were mentioned in different publications, shows the difficulties when it comes to assessing future ISA developments (Marchau, 2000; Argiolu et al., 2007; Van der Pas et al., 2007).

Research into the way policymakers handled the uncertainties involved in ADAS and ISA implementation shows that the most common strategy to deal with these uncertainties appears to be supporting more research in order to reduce uncertainty (Van der Pas et al. 2006a). This results logically in delaying real world implementation, but involves little risk. A more rare approach to dealing with uncertainty is to implement a robust policy (or developing scenarios), allowing implementation to take place; but, such a policy is more risky. Both the ADAS and ISA policies analysed above only focussed on reducing uncertainty (e.g. doing more research, performing field trials). Research shows only a few studies regarding external forces or exogenous events that influence implementation and which lead to developing robust policies (e.g. Van Arem et al., 1997; Helmreich and Leiss, 2000; Heyma, 2000; Hanson and Tsao, 1996).

1.4 Research objectives

There are two objectives for this research:

1. to develop, specify, test, and evaluate an approach for dealing with the types of uncertainties involved in ISA implementation.
2. to identify policies that might contribute to ISA implementation.

So, we aim to find and apply an approach that can deal with the uncertainties involved in ISA implementation. As the title suggests, we aim to answer the question, can we find a way "*to clear the road for ISA implementation?*"

1.5 Research questions

A large amount of money has already been invested in ISA research. In the 1980s this research was focused on technical aspects. Later the priority shifted to user acceptance, liability issues, human/machine interface research, and other subjects. All this research has supplied us with a tremendous amount of information (for an overview see e.g. Vlassenroot et al. 2011). But there is still a big gap between this wealth of available information and the application of this knowledge in policy development for ISA.

This leaves us with many questions: How have policymakers dealt with these uncertainties in the past? What approaches are suitable for dealing with the uncertainties regarding ISA? Over the past decades, several new tools and policymaking approaches have been developed for dealing with uncertainties, but they have not been applied to the policy domain for ISA. What policymaking approaches are there? Are they suitable for dealing with the uncertainties related to the implementation of ISA? And what would be the benefits and the disadvantages compared to other policymaking approaches? The preceding raises a broader theoretical question: how can we compare, test, and apply alternative policymaking approaches?
The main research question to be answered in this research is: *What is an appropriate analytic approach for handling the uncertainties involved in the implementation of ISA?*

The main question can be divided into two lines of research, which leads to two lines of research questions. The first line of research concerns ISA, the current state of ISA, and uncertainties concerning ISA implementation. The second line focuses more on policy analysis and approaches for dealing with uncertainty in public policymaking. The two lines of research come together in dealing with uncertainties for ISA implementation and policymaking approaches that can handle these uncertainties. These two lines of research can also be distinguished in the research approach displayed in Figure 1-1. The main research question leads to a number of more specific research questions.

RQ 0: How do we define, and classify the uncertainties involved in analyzing public policies, and what are the approaches for handling them?

RQ 1: What are the main uncertainties regarding the implementation of ISA, and what is an appropriate approach for handling them?

Given the definition of uncertainty, the classification of uncertainty, and the assumption that ISA implementation is hampered by the uncertainties surrounding ISA implementation. Research Question 1 is focused on applying the uncertainty definition to the case of ISA, and classifying the uncertainties involved in ISA implementation. Based on the classification of uncertainty we also want to know what an appropriate approach for handling these uncertainties is.

RQ 2: What decision support tools are suitable for developing a policy for implementing ISA using this approach, and what would decision support information that is generated with this tool look like?

Research Questions 0 and 1 resulted in an uncertainty definition, inventory and classification of the uncertainties that surround ISA implementation, and an approach to deal with these uncertainties in policymaking. Given all these answers, Research Question 2 focuses on the decision support tools that can be used to support decisionmaking regarding ISA implementation using the approach identified as part of Research Question 1.

RQ 3: How can we develop a policy that deals with the ISA-related uncertainties using the identified approach, and what would such a policy look like?

Given the answers to the research questions that were mentioned above, Research Question 3 focuses on using the identified approach to deal with the uncertainties involved in ISA implementation.

RO 4: How can we evaluate the identified approach, and what are the implications of such an evaluation for the identified approach and for the developed ISA implementation policy?

RQ 5: How does the identified approach compare to more traditional policymaking approaches?

After we applied the approach to ISA implementation we want to know what the difference is with policymaking approaches that are currently used for ISA implementation (and policy problems with a similar uncertainty classification). Research Questions 4 and 5 focus on the evaluation of the identified approach, and the developed ISA implementation policy.

1.6 Relevance

1.6.1 Social relevance

The social relevance is highly ambitious and two-fold: This research can contribute to the implementation of ISA systems in the Netherlands and Europe, which has the potential to improve traffic safety and as such make our society a safer and better place in which to live. The research will also contribute to policymaking under uncertainty by developing policymaking tools and approaches that will allow policymakers and policy analysts to make better policies in times of uncertainty (less costly, less dangerous, etc.). When reading this dissertation, (ISA) policymakers will gain knowledge that will enable them to develop and implement strategies that contribute to their policy goals. This will allow policymakers to deal with ISA related developments that are a threat to their goals, but it will also allow policymakers to speed up the implementation of ISA related developments that contribute to their policy goals.

1.6.2 Scientific relevance

From a scientific point of view, it is important to develop and test new tools and methods that can help policymakers to make decisions under conditions of uncertainty. A large part of this research is devoted to developing, specifying, applying, and comparing tools for dealing with uncertainty in public policymaking. Furthermore, it will contribute to the body of knowledge regarding approaches to policymaking under conditions of uncertainty and the body of knowledge regarding transportation technology policies. The scientific importance related to ISA is that we will gain insight into the current uncertainties regarding the future of ISA that obstruct policymaking for ISA implementation. It therefore contributes to the body of knowledge regarding the social aspects and implementation barriers for ISA (and, more generally for ISA-like ADAS).

1.7 Research strategy

1.7.1 Research approach

In this section, we discuss the steps that were taken to answer the main research question, and the methods to be used to answer the specific research questions; furthermore we give overall indications of the sequence of the steps of the research and the relationships among the different steps of the research.

To find an answer to Research Question 0*: How do we define, and classify the uncertainties involved in analyzing public policies?,* and the questions of definition related to this question, we performed a desk/literature study regarding the following topics:

- What is uncertainty?
- Which uncertainty typologies are there?
- What approaches do policymakers have available for handling the various types of uncertainty?
- Under which uncertainty conditions is it best to use which approach?

All these questions are addressed in Chapter 2.

To answer Research Question 1: *What are the main uncertainties regarding the implementation of ISA, and what is an appropriate approach for handling them?,* a literature study was performed. Using the results of the literature study, we defined a framework for assessing uncertainty and assessed the different uncertainties involved in ISA implementation. Using the list of uncertainties that emerged from the literature, we asked experts to assess the level of uncertainty of the uncertainties involved in ISA implementation. Chapter 3 presents the results of both the literature and expert elicitation study.

To answer Research Question 2*: What decision support tools are suitable for developing a policy for implementing ISA using this approach, and what would decision support information that is generated with this tool look like?,* we first researched different decision support tools that can be used under conditions of uncertainty. Based on the types of uncertainty involved in ISA implementation, we will select or develop, and apply a decision support tool that can be used to (1) generate decision support information for ISA implementation, and (2) deal with similar types of uncertainty for other policy problems. Chapter 4 presents the results of applying this decision support tool to assess different ISA implementation strategies.

In addition to using the decision support tool to generate decision support information under conditions of uncertainty, we are also interested in an approach that allows for policymaking under conditions of uncertainty (and, more specifically, for the types of uncertainty involved in policymaking for ISA). To find an answer to Research Question 3*: How can we develop a policy that deals with the ISA-related uncertainties using the identified approach, and what would such a policy look like?*, we first operationalized the approach in terms of tools and methods. The operationalized approach is presented in Chapter 5. Next, we tested and evaluated the operationalized approach using an experiment. The experiment focused on a multi-actor system, and we strived to give it the richness of all actors involved in the policymaking process. The experiment is also presented in Chapter 5.

Based on literature study, we developed an approach for evaluating the policymaking approach. The results of the evaluation is presented in Chapter 6, which provides the answers to Research Questions 4 and 5, respectively: *How can we evaluate the identified approach, and what are the implications of such an evaluation for the identified approach and for the developed ISA implementation policy?*, and, *How does the identified approach compare to more traditional policymaking approaches*

Figure 1-1 shows the relationships among the research questions, the chapters in which each of the questions are addressed, and the research approach.

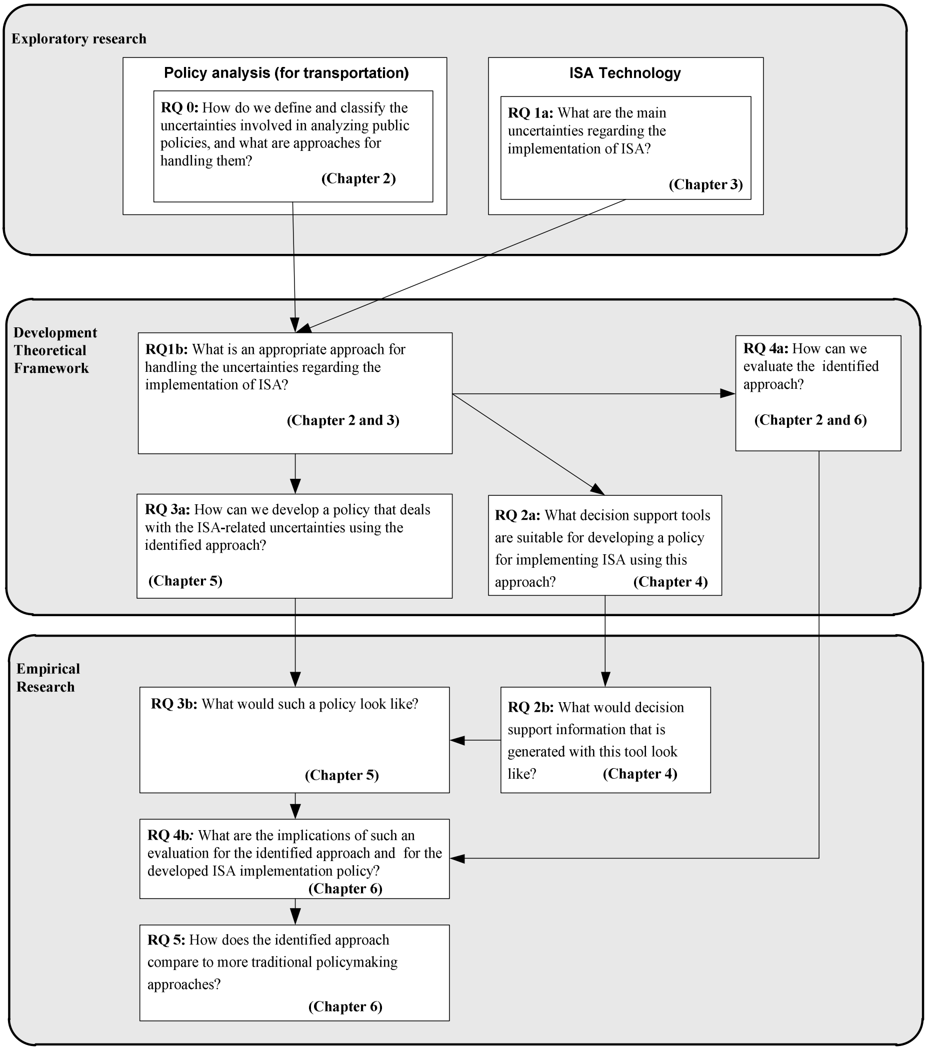

Figure 1-1 Overview of the research

1.7.2 A paper based dissertation

The core of this dissertation (Chapters 3-6), consists of four papers that have been submitted, are forthcoming, or have already been published in scientific peer-reviewed journals. Below, a brief introduction to each of these papers is given:
Chapter 3 was published as Van der Pas et al. (2010a). Figure 1-1 shows which parts of the research are addressed in this chapter. It contains a systematic and representative inventory of the uncertainties based upon the literature. Furthermore, experts in the field of ISA were surveyed and asked which uncertainties are barriers for ISA implementation, and how uncertain these uncertainties are. The chapter reports the results of this survey. It is concluded that the long-term effects and the effects of large-scale implementation of ISA are still uncertain and are the most important barriers for the implementation of the most effective types of ISA. One way to deal with these uncertainties would be to start implementation on a small scale and gradually expand the penetration, in order to learn how ISA influences the transport system over time. To make this type of decision, a decision support tool is needed that is capable of assessing the effects of implementation, despite the deep uncertainties that still exist. Such a tool is presented in Chapter 4.

Chapter 4 was published as Van der Pas et al. (2010b). Figure 1-1 shows which parts of the research are addressed in this chapter. Sometimes experts, decisionmakers, and analysts are confronted with policy problems that involve deep uncertainty. This chapter presents an MCDA approach developed to deal with conditions of deep uncertainty, which is called Exploratory Multi-Criteria Decision Analysis (EMCDA). EMCDA is based on exploratory modelling, which is a modelling approach that allows policy analysts to explore multiple hypotheses about the future world (using different consequence models, different scenarios, and different weights). An example of a policy problem that can benefit from this methodology is decisionmaking on innovations for improving traffic safety. In order to improve traffic safety, much is expected from ISA. However, different MCDA studies on ISA give different results in terms of the estimates of real-world safety benefits of ISA and the willingness of stakeholders (e.g. the automotive industry) to support ISA. The application of EMCDA to the implementation of ISA shows that it is possible to perform an MCDA in situations of deep uncertainty.

Chapter 5 is currently under review as: Van der Pas et al. (forthcoming). Figure 1-1 shows which parts of the research are addressed in this chapter. Adaptive Policymaking (APM) is a policymaking approach that is designed to deal with policy problems that are surrounded with deep uncertainty. However, various open issues of APM still exist: APM lacks thoroughly worked-out examples of adaptive policies; there are few examples of adaptive policies developed by policymakers or domain experts; the concept has very rarely been used in a real world policy setting. More specifically, several research questions remain regarding e.g. the costs and benefits of APM, and the efficacy and performance of adaptive policies compared to more traditional static policies. This chapter addresses these issues by developing adaptive policies with experts, and the use of expert opinions to evaluate the principles of APM.

Chapter 6 was submitted and accepted to *Technology Forecasting and Social Change* as: Van der Pas et al. (2011b). Figure 1-1 shows which parts of the research are addressed in this chapter. Implementation of transport innovations is often hampered by uncertainty. An example of such an innovation is ISA. It has been suggested that APM would allow transport policymakers to deal with these uncertainties. However, this approach has only been described conceptually. Many questions remain regarding how to apply this approach in practice. In this chapter, we operationalize APM and test this operationalization with actors who would normally participate in the policymaking process (e.g. domain experts, policymakers, policy advisors, representatives of interest groups, etc.).

1.8 Outline of this dissertation

Figure 1-1 provides an overview of the research and the chapters in which the various research questions are answered. In Chapter 2 we provide additional methodological and theoretical background for the dissertation. This chapter will also position each of the individual papers that make up this dissertation in the overall research approach.
In Chapters 3 through 6 we will address Research Questions 1 through 5. These chapters were also published separately as journal papers. It is important to mention that journal papers are independent stories. As a result, there is some overlap among the chapters (e.g. definition of uncertainty, the explanation of the Policy Analysis Framework, etc.).

Chapter 7 presents the overall conclusions from the research and a discussion of the results.

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2. Research Framework

In this chapter we provide answers to the questions of definition: what is uncertainty, and what is policymaking? We also provide the necessary methodological and theoretical background information for this dissertation. Furthermore, this chapter addresses Research Question 0: How do we define, and classify the uncertainties involved in analyzing public policies, and what are the approaches for handling them?

2.1 Introduction to this chapter and the rest of this dissertation

As indicated in Chapter 1, this dissertation is a paper-based dissertation. This brings about several implications. First, the information on the applied theory and methodology is scattered throughout this dissertation (each paper, and thus each chapter, contains part of the theory and methodology). A journal paper needs to be short and to the point, also when it comes to methodology. However, for the readers of this dissertation it might be valuable to add some more insights and to address the broader context of the methodology. Finally, papers are often written for a specific audience that has a certain basic level of knowledge. Since this dissertation addresses a multi-disciplinary group of professionals, it might be valuable to give some additional background information and explanation on the various theories and methods addressed in this dissertation. For all these reasons, Chapter 2 is included. In this chapter we present relevant methodological and theoretical background information and a context for the different theories and methodologies that are applied in Chapters 3 through 6.

Figure 1-1 shows in which part of this dissertation Research Question 1 and the related methodological and theoretical background is addressed. In Section 2.2 we address the question: What is policy analysis? This question is also addressed in Chapters 3 and 4, where we explain the policy analysis framework. In Section 2.3 we answer a question of definition: What is uncertainty? Throughout the chapters that are part of this dissertation, different definitions and categorizations of uncertainty are applied. For example in Chapter 4, we link the levels of uncertainty mentioned by Walker et al. (2003) to specific approaches to dealing with uncertainty. In Chapter 5, three ways of dealing with uncertainty are introduced. The three approaches policymakers use to deal with uncertainty are mentioned briefly in almost all chapters in this dissertation and previous publications by the author (e.g. Van der Pas et al. 2006a).

In Section 2.4 we discuss the methods policymakers have available for dealing with uncertainty, and link them to uncertainty characteristics.

Chapter 3 provides an overview of the uncertainties regarding the implementation of ISA. Not an integrated part of this paper but perhaps interesting for the reader is the question: How policymakers dealt with uncertainty in the past? For this we refer to two previously published papers: Van der Pas et al., 2006a, and Van der Pas et al., 2006b.

Section 2.5 addresses the theory and methodological background for assessing different policymaking approaches. In this section we go deeper into the evaluation of policymaking approaches and ways to test and compare these approaches. This subject is also briefly addressed in the third paper of this dissertation (Chapter 5). In this chapter we test and apply an adaptive policymaking approach. The theoretical background of testing and applying different policy design methods is based on the paper published by Kwakkel et al. (2009) and a paper published by Kwakkel and Van der Pas (2011).

2.2 What is policy analysis?

In this section we provide an answer to the question of definition: what is policymaking? First, we briefly introduce policy analysis. This framework is used throughout the dissertation for multiple purposes, but most dominantly to structure thinking about the policymaking process, and to classify the uncertainties (based on their location in the PA framework). Next, the systems view on policy analysis and the Policy Analysis (PA) framework is explained.

The professional field that occupies itself with policy research and advice is called “Policy Analysis”. Mayer et al. (2004) describe Policy Analysis as “a broad and versatile field of applied policy research and advice, where a multitude of perspectives and methods have developed”. Policy Analysis evolved from Operations Research around 1950, through Systems Analysis in the late 50s, to Policy Analysis in the 1960s and 1970s (Walker, 2000). Public Policy Analysis, as described by Walker, is a rational and systematic approach to making policy decisions based on the systems view, as described by Miser and Quade (Miser et al., 1985; Miser et al., 1988; Walker, 2000). The systems view on Policy Analysis can be depicted using the Policy Analysis framework (see Figure 2-1).

Public policy for transport is concerned with intervening at various points in the transport system in a way that takes into account both the interaction among the physical elements of the transport system and the behavioral mechanisms underlying this interaction. In this research, we apply the Systems view on policymaking and apply this to the domain of traffic and transport (See Figure 2-1).

For the purposes of this dissertation, we assume that policymaking, in essence, concerns making choices regarding a system in order to change the system outcomes in a desired way. The analytical framework we use, the Policy Analysis (PA) framework, is shown in Figure 2-1, which is adapted from Walker (2000). Throughout this dissertation we use the PA Framework in different ways (in Chapter 2 to assess past ISA policies, in Chapter 3 as a framework for uncertainty categorisation, and in Chapter 4 as a supportive framework to build a policy assessment model). So it is important to briefly introduce the terminology (for more information, see Walker, 2000).

At the heart of the PA framework is the system representing the policy domain. In the illustration used in this section, the system is a generic national road transport system. The elements in this framework can be assembled in a structure labeled ‘XPIORV’. The center of this structure is the system domain or policy domain. In the case of ISA implementation, the system can be defined as the road transport system. In general, a transport system can be defined by distinguishing physical components of transportation (I) (infrastructure, vehicles, and subjects of transportation) and their mutual interactions (R). Outcomes of interest (O) refers to the characteristics of the system that are considered relevant criteria for the evaluation of policy measures (e.g. the level of emissions by motor vehicles, the number of road casualties, and the level of congestion). The valuation of outcomes (V) refers to the (relative) importance given to the outcomes by crucial stakeholders, including policymakers. Two types of forces act on the system: external forces (X) and policies (P). External forces refer to forces that are not controllable by the policymaker but may influence the transport system significantly, i.e. exogenous influences (i.e. demographic, economic, spatial, social, and technological developments in society). Policies are the set of forces within the control of the policymakers related to the system. General transport policies include the maintenance policies, traffic safety policies, building new infrastructure, emission regulations (e.g. EURO norms), etc.

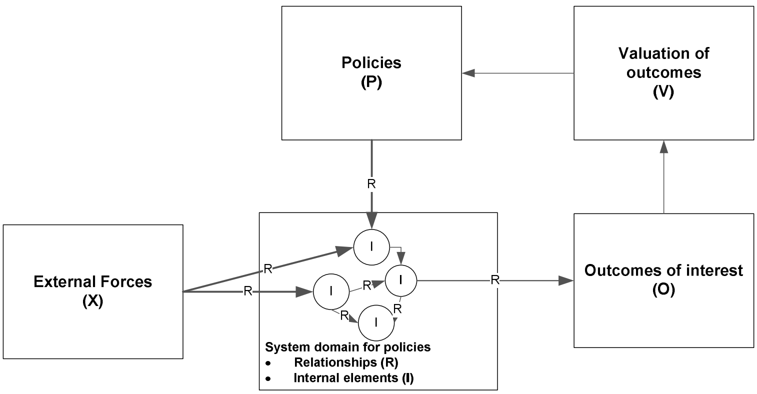

Figure 2-1 The Policy Analysis framework (Walker, 2000)

2.3 What is uncertainty?

In this section we define uncertainty. Throughout this dissertation, uncertainty is defined in almost every chapter. So here we provide a very brief definition of uncertainty. This is important because there are numerous definitions and interpretations of uncertainty, often differing per professional field, and philosophical point of view.

Different authors have provided a large number of definitions and typologies of uncertainty (for an overview see e.g. Walker et al., 2003 and Kwakkel et al., 2010). In 2003, Walker et al. defined a framework for defining and assessing uncertainty for model-based decision support.

They define uncertainty as: ”*any deviation from the unachievable ideal of completely deterministic knowledge of the relevant system”*. To support model-based Policy Analysis, Walker et al. developed a categorization of uncertainty based on three dimensions. First, there is location of uncertainty. The location of uncertainty identifies where the uncertainty manifests itself within the PA Framework. For example based on the PA Framework, locations could be: in the external forces, in the system model, etc. In Chapter 3, we use the location dimension to assess the uncertainties involved in ISA implementation using the literature. The second dimension is level of uncertainty. This refers to where the uncertainty manifests itself along the spectrum between deterministic knowledge and total ignorance. Walker et al. (2003) identify four levels of uncertainty ranging from statistical uncertainty, Scenario uncertainty, recognized ignorance, to total ignorance. In Chapter 3 we use experts to assess the level of the uncertainties involved in ISA implementation. In Chapter 4 we use a slightly adjusted version of these levels of uncertainty to assess the levels of uncertainty involved in the case of ISA implementation. The third dimension of uncertainty is the nature of the uncertainty. The nature indicates whether the uncertainty is due to the imperfection of our knowledge or is due to the inherent variability of the phenomena being described. Throughout this dissertation the nature of uncertainty is not used. We only use the dimensions level and location (see Chapters 3 and 4).

In addition to term ‘uncertainty’ we also use the term ‘*deep uncertainty’*. This dissertation focuses on policymaking under *deep* uncertainty. Deep uncertainty refers to situations in which “decisionmakers, analysts, and experts do not know or cannot agree on: 1) the system models, 2) the prior probability distributions for inputs to the system model(s) and their interdependencies, and/or 3) the value system(s) used to rank alternatives” (Lempert et al., 2006). Deep uncertainty can be considered a special class of uncertainties. Using the three dimensions of uncertainty, and the above mentioned definition of deep uncertainty, we can position deep uncertainty within the uncertainty typology framework of Walker et al. (2003):

- it can occur at any location of the PA framework;
- it can have any nature;
- however, there are only two levels of uncertainty that relate to deep uncertainty (recognized ignorance (the situations in which decisionmakers, analysts, and experts cannot agree, or know that they don’t know), and total ignorance (situations in which decisionmakers, analysts, and experts don’t even know they don’t know)).

An example of a deep uncertainty is the uncertainty regarding the effect of human behavior on the problem of climate change. Experts do not have models that be used to model the complete ecosystem; they even doubt the conceptual model (think of climate skeptic people). The problem concerns long-term global climate change. However, scientists do not have recorded information of the climate of centuries ago. This makes the discussion on the actual change very hard. Finally, there is the value system that can be used to rank the alternatives. Not everybody dislikes the idea that the earth is getting warmer. Also, the problem of climate change is perceived differently by, for example, people that live in a city that floods every other week compared to people that live in a city that does not has these problems.

2.4 Policy Analysis and uncertainty

In this section we link Policy Analysis to uncertainty, and answer the question: “what approaches to policy analysts have available for dealing with uncertainty?” First, we define three approaches that policy analysts apply when dealing with uncertainty. Second, we

indicate which analytical tools (e.g. scenario analysis, sensitivity analysis, etc.) are frequently used as a part each of these approaches. Finally, we give an indication of the circumstances for which each of the approaches is most useful.
Before introducing the three approaches to dealing with uncertainty, there are several underlying assumptions that have to made explicit:

- policies should be as rational and as legitimate as possible;
- the policy analyst dealing with uncertainty has to
  - be explicit about uncertainty;
  - perform an uncertainty analysis (Morgan and Henrion, 1990);
- In the past, several inventories of approaches to dealing with uncertainty have been made (Lipshits et al., 1997; Van Geenhuizen and Thissen, 2002; Morgan, 2003; Walker et al., 2003; Van der Sluijs et al., 2004; Van Asselt, 2005). A literature review regarding dealing and coping with uncertainty reveals two dominant types of categorizations. First, there are the categorizations focusing on what Van Asselt (2005) calls, "methods, approaches and procedures"; the second category is what she describes as, "the logics, strategies and tactics in use". The framework we apply excludes neither of the two categories. However we apply a strong focus on the policy analysis process. (I.e. we don't focus on dealing with uncertainty in decision making but dealing with uncertainty when developing and assessing policies).

Discussing dealing with uncertainty implies that there is an option not to deal with uncertainty. Marchau and Walker (2003) refer to this option as overlooking uncertainty or ignoring uncertainty (a similar category of approaches was mentioned by: Morgan and Henrion, 1990; Davis and Hillestad. 2000; Van Geenhuizen and Thissen, 2002). Although, according to Morgan and Henrion (1990), this option has been most often applied, we do not consider it as actively dealing with uncertainty. Furthermore, ignoring uncertainty is in conflict with the ten commandments of good Policy Analysis. Therefore, we will not elaborate on this option further in this section.

Different authors described different ways that uncertainties are handled in the Policy Analysis process (Lempert et al., 2003; Marchau and Walker, 2003; Lempert et al., 2004; Davis et al., 2000). Based upon the literature, we can distinguish three basic approaches that policy analysts apply when confronted with uncertainty. These are the 'predict-and-act approach', the 'what-if reasoning' approach, and the 'planning for adaptation' approach. They are explained below, and displayed in Table 2-1.

'Predict-and-Act' In this case, it is assumed that the uncertainties can be characterized using probability distributions. The basic paradigm for policy development is that the future can be predicted well enough to select an optimal policy (Lempert et al., 2004). When applying the 'predict-and-act' approach, the policy analyst will deal with the uncertainties by using a single assumption regarding the way the future will be (trend analysis, probability functions, etc.). Probability functions are derived from empirical data and expert elicitation methods (e.g. (Holloway, 1979; Morgan and Henrion, 1990; Cooke, 1991; Kraan, 2002). Ex-ante Policy Analysis is performed in order to select the policy that would perform the best given the assumptions that are made regarding the future.

Lempert et al. (2006) mention three important characteristics of the 'predict-and-act' approach. First, there is a high vulnerability to surprise. Second, it is difficult to find consensus among the involved stakeholders, because there first needs to be agreement on the predictions before there can be agreement on the actions/policies. Third, the approach can encourage analysts and policy analysts to downplay uncertainty. The ‘predict-and-act’ approach has been used very successfully in Policy Analysis and works best in cases where the uncertainty can best be described using single probability distribution, or when the level of uncertainty can be characterized as what Walker et al. (2003) would call statistical uncertainty.

In transportation, the ‘predict-and-act’ approach is used very often. An example is the traffic forecasts that are used for decisions regarding infrastructure projects. In 2006, Flyvbjerg et al. (2006) did a large study into the use of traffic demand forecasts and their accuracy, using data from more than 210 infrastructure projects, located in 14 nations. Flyvbjerg et al. (2006) concluded that highly inaccurate traffic forecasts (the average overestimation of traffic demand was 106%) combined with large standard deviations, translated into large financial and economic risks and eventually losses. Flyvbjerg et al. (2006) reach the same conclusions as Lempert et al. (2006): the ‘predict-and-act’ approach encourages transport planners and decisonmakers to downplay and ignore the uncertainties and risks (Flyvbjerg et al., 2006; Lempert, et al., 2006).

‘What-if reasoning’ The basic uncertainty assumption underlying this approach is that uncertainty cannot be expressed statistically but only as different plausible future states of the system. This is what Walker et al. (2003) call scenario uncertainty. The policymaking paradigm is to perform ‘robustness analysis’. An ex-ante Policy Analysis is performed for a number of different plausible futures, indicating the results of a certain policy for a number of different plausible futures. The best policy would be the policy that performs best across the different futures, i.e. the policy that proves to be most ‘robust’. This approach to dealing with uncertainty originated in the 1950s. RAND developed scenario techniques allowing policy analysts to do “what if” analysis. Different scenarios for the future are sketched and the outcomes are quantified with the help of models (e.g. Schwartz, 1991). Decisionmakers use these scenarios to “probe for weaknesses in proposed plans” (Lempert, et al., 2003). The central assumption of this paradigm is that the future can be predicted well enough to identify policies that will produce favorable outcomes in one or more specific plausible future worlds (Walker, 2000). The objective is to identify policies that prove satisfactory in most of the imagined future worlds (i.e. to identify “robust” policies).

In transport policymaking ‘What-if reasoning’ is commonly applied. Often scenario analysis is used to calculate the effect of different policy measures. In the past, numerous scenarios have been developed and applied to policy plans (E.g. (De Mooij et al., 2003; European Commission Directorate-General for Energy and Transport, 2003; Janssen et al., 2006). For large infrastructure projects, performing a cost-benefit analysis for different scenarios has become standardized; examples of how this should be done are given in the guidelines for the evaluation of large infrastructure projects (Eijgenraam et al., 2000; European Commission, 2003).

‘What-if reasoning’, as we define it, is less broad than the Robust Decisionmaking approach as described by Lempert et al. (2003). It basically does what Lempert et al. (2003) would call creating robust policies without adaptivity by using scenario planning. What-if reasoning sometimes encourages decisionmakers to select a scenario that is than considered to be “the future” and on which they base their policies (This is what Van Asselt, (2005) calls

"Construction of solidity"). This can be considered a "predict and act" way of using decision support information that is meant for What-if reasoning.

'Planning for adaptation' The underlying uncertainty assumption in this third category of approaches is that the future cannot be predicted. More recently, policy analysts have started exploring approaches to building 'Dynamic Adaptive' policies, policies that change over time by assuming that the world will change over time, so new uncertainties arise, and old uncertainties decline and disappear (Holling et al., 1978; Walker et al., 2001; Lempert, et al., 2003; Lempert, et al., 2006). This leads to the third category of approaches for dealing with uncertainty. 'planning for adaptation' approaches allow policy analysts to create policies that change over time as the uncertainties about the future are reduced. Within this paradigm, policy analysts consider the future as intrinsically unknowable, and it is accepted that policy decisions have to be made in a context of deep[3] uncertainty (Krayer von Krauss, 2005). The concept of adaptive strategies to deal with uncertainty is not new. In the early 1980's researchers started to suggest developing adaptive management solutions for dealing with uncertainty (Holling, et al., 1978; Clark, 1979). A study into adaptive management was initiated by a workshop that was held in 1974 by SCOPE (Scientific Committee on Problems of the Environment), and is a result of a two-year participative study of scientists and policy analysts (Holling, et al., 1978). The concept of adaptive management has undergone much theoretical change and practical application, mostly in the environmental sector[4]. Initially, adaptive management policies added to existing policies. Experimental policies were applied in numerous environment-related cases (e.g. management of grasslands, waterfowl, ecosystems, national parks). (For an overview see: (Jacobson, 2003.) More recently, other adaptive approaches to dealing with uncertainty have been developed, providing policy analysts with additional approaches for developing adaptive policies. A different interpretation of adaptive policies is given by Walker et al. (2001). These authors have proposed a new policymaking approach to facilitate the development of adaptive policies (Walker et al., 2001). Walker et al. (2001) propose a number of adjustments to the traditional sequence of policy development to come-up with an adaptive policy.

Until now, adaptive policies, as defined by Walker et al. (2001), have been little used in transport policymaking. Sometimes real-options decisonmaking is used in policymaking to assign monetary value to future options (Leslie et al., 1997; Pichayapan et al., 2003). The result is often a decision that is flexible, but not adaptive. It allows for change, and leaves room for future flexibility, but the policy itself lacks the mechanism to adapt over time. To the author's knowledge, there is only one policymaking approach that incorporates such a mechanism: the Adaptive Policymaking approach (APM). APM is still a concept. A recent overview of the state of the art of APM shows that it needs to be operationalized in terms and of tools and methods that can be used to support the APM process and that can be used to develop adaptive polices (Walker et al., 2010).

An important distinction between the three policy development paradigms is that both the 'predict-and-act' and the 'What-if reasoning' approach require the policymaker to perform an ex-ante evaluation of the available policy options at a certain point in time, and decide to select and implement one of the options. These policies are static (do not change) over time. The APM approach allows a policymaker to take a decision at a certain point in time (also based upon ex-ante evaluation), but also to monitor and adapt the policy according to

[3] Deep uncertainty is defined in Section 2.3
[4] Source: http://student.lincoln ac.nz/am-links/am-intro.html (6-04-2006)

predetermined conditions (so it is dynamic in time). The development of adaptive policies requires a completely different and relatively new way of ex-ante evaluation of policy options. No longer are ex-ante evaluation tools used only to select the optimal or most robust policy option; the tools are now also used to probe for weaknesses in the basic policy and to learn how the system reacts to certain external developments (e.g. search for vulnerabilities and opportunities), which allows policy analysts to develop meaningful actions to take to avoid the policy failing due to future external changes. This is aimed at being prepared for the future and determining in advance when and how to adapt.

Table 2-1 Policy analysis approaches and their characteristics

Approach is best for dealing with this level of uncertainty	**Assumption regarding uncertainty**	**Paradigm regarding the future**	**Decision criteria in use**	**Examples of commonly used tools**	**Type of policy**	**Policy analysis Approach**	**Encourages decisionmakers to**
Statistical	Future can be predicted accurately (or at least probabilistically)	Uncertainty can be expressed in frequencies or subjective probability functions	Optimality (or max expected outcomes)	-sensitivity analysis -statistics and probability	Static 'optimal'policy	**Predict-and-Act**	Downplay uncertainty
Scenario	Several plausible futures can be specified that span the plausibility space	We can't express uncertainty in probabilities, but we can identify several plausible states of the future system in the future	Robustness	-scenario analysis -bouncecasting -backcasting	Static robust policy	**What-if reasoning**	Identify a preferred future and assume they can shape the world to this future's image
Deep uncertainty or recognized ignorance	Future is unpredictable	It is accepted that the future is intrinsically uncertain	Regret Robustness Flexibility Adaptivity	- All above mentioned tools, but used differently - Innovative tools like: exploratory modeling, real options etc.	Planning for adaptation Policy	**Planning for adaptation**	Be explicit about uncertainty, and act consciously in its presence.

As also can be seen in Table 2-1, we have identified three types of approaches for dealing with uncertainty. However, it is also important to assess under what circumstances each is most useful. After the assessment of the uncertainties involved in ISA policymaking (Chapter 3), we need to select an approach to deal with these uncertainties. When to use which approach is hard to determine based solely upon the literature, due to several reasons: First, as explained above, the literature on dealing with uncertainty often contains a mix of approaches, tools, and postures towards uncertainty. This results in the situation that identifying specific criteria regarding when to use which approach is hard to distill from the available literature. Second, there are only a limited number of sources writing on approaches to deal with uncertainty in the process of policymaking, let alone the criteria for selecting an approach. Courtney et al. (1979) distinguish four levels of uncertainty to select appropriate strategies to deal with the uncertainty. Where Courtney et al. (1979) use a single characteristic of uncertainty to determine an appropriate approach, Lempert (2006) indicates three criteria to determine the appropriate way to deal with uncertainty: complexity of the policy problem, level of uncertainty, and hedging possibilities (Lempert, 2006). Lempert indicates a three dimensional space in which problems can be positioned according to these three criteria. Lempert also adds the notion that “further research is needed to understand the precise boundaries and conditions where these different methods are most appropriate”.

To come up with an indication of when to use each of the approaches, we focused on the criteria used in the literature to select an approach to deal with uncertainty (as also indicated in Table 2-2). When it comes to level of uncertainty, the literature is relatively unambiguous; in almost all literature, uncertainty is identified as an important criterion. When it comes to approaches to dealing with uncertainty it can be determined that in cases where the uncertainty is relatively low (situations in which the probability and the effect are known), the ‘predict-and-act’ approach seems to be the preferred approach. In cases where the level of uncertainty is medium (e.g. scenario uncertainty), the most appropriate approaches is ‘What-if reasoning’ approach. In cases of deep uncertainty (e.g. recognized ignorance), the ‘planning for adaptation’ approach seem to be most suitable.

An alternative criterion that is mentioned many times is the complexity of the policy problem. This is, however, a more difficult characteristic to operationalize since uncertainty and complexity are related (Holloway, 1979; Van de Riet, 2003; Khisty et al., 2005). Other criteria mentioned in literature but also not further explored here, are: value ladeness of policy options (RIVM, 2003), decision stakes (Functowicz and Ravetz, 1990), number of hedging opportunities (Lempert et al., 2006), and posture of policy analysts (Courtney et al., 1997).

Based on the literature, we have concluded that there are multiple ways to deal with uncertainty, and we distinguished three commonly used types of approaches: predict-and-Act, what-if reasoning, and planning for adaptation. Based on the literature, we identified the level of uncertainty each of the approaches is capable of dealing with.

2.5 Assessing policymaking approaches

In this section we discuss how policymaking approaches can be assessed and compared to other policymaking or planning approaches. This is extensively addressed in a paper published together with Kwakkel and Cunningham (Kwakkel et al., 2010), and a paper published together with Kwakkel (Kwakkel and Van der Pas, 2011). Here we give a brief introduction; in Chapter 6, some more information is presented.

Designing an approach to come-up with adaptive policies is one thing; evaluation of the design is something else. As indicated by Verschuren and Hartog (2005), and Frey and Dym, (2006), literature on design methodology is plenty; however, this literature contains little on design evaluation (Kwakkel and Van der Pas, 2011). Verschuren and Hartog (2005) identified an approach based on design cycle (the plan on paper, the realization of the plan, and the results of the plan). Based on an analogy derived from medicine, Frey and Dym (2006) identified five ways of validating design. In a recent paper Kwakkel and Van der Pas (2011) applied these five ways to policy design or decision support approaches:

1. Theories. Based on the theory, methods can be validated (e.g. decision science, cognitive science, political science, organizational behavior, Policy Analysis);
2. Animal Models. Using computational experiments of plans across an ensemble of futures, or using a workshop, seminar, or simulation game to develop policies in a simulated environment using students;
3. In Vitro Experiments. Seminar or simulation game to develop policies in a simulated environment using real policy analysts and policymakers;
4. Natural Experiments. Case studies of long-term infrastructure plans;
5. Clinical trials. Controlled field application of planning approaches.

These five approaches are related to the stage of the development of a new approach. First an approach is validated using theory; next, after validation using theory, it is validated using animal models, until in the end it is validated using clinical trials.

2.6 Synthesis and conclusion

In this chapter, we defined uncertainty and deep uncertainty, we explained Policy Analysis and, based on literature, we identified three ways of dealing with uncertainty, each best for different types of uncertainty. Finally, we explained how policymaking approaches can be evaluated, based on a paper of Kwakkel and Van der Pas (2011).

In Chapter 3 we assess the uncertainties involved in ISA implementation. In Chapter 4 we develop decision support information to support decisionmaking on ISA (with the selected approach). We select and apply an approach to deal with the uncertainties that surround ISA implementation in Chapter 5. This results in policies that allow policymakers to handle the uncertainties in ISA implementation. Finally, in Chapter 6 we select and apply a method to evaluate the selected policymaking approach.

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3. ISA Implementation and Uncertainty

In this chapter we answer Research Question 1: What are the main uncertainties regarding the implementation of ISA, and what is an appropriate approach for handling them? First, we provide the methodological framework for assessing uncertainties. Next we present the results of a literature study and an expert elicitation study. Finally we present an overview of uncertainties for ISA implementation and possible directions for finding solutions.

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3.1 Introduction

In 2007, approximately 42,600 people were killed in road traffic accidents in the European Union (EU) and over 1.7 billion people were injured (European Road Safety Observatory (ERSO), 2008). Research shows that roughly one-third of these accidents are caused by speeding. (Organization for Economic Co-Operation and Development (OECD) et al., 2006). Although the number of traffic fatalities within the EU is declining, recent figures show that the current rate of decline is far from sufficient to meet the goals for 2010 (EU press office, 2006; ETSC, 2006).

Speed management policies can be categorized according to the three E's: Enforcement, Education, and Engineering (infrastructure and vehicle engineering). Analysis of speed reducing measures taken in the past shows that most of the three E measures are being used. The success of these measures has clearly been shown in practice, and different studies have made clear the costs and benefits of most of these measures (for an overview, see Elvik and Vaa, 2004). However, despite the fact that in-vehicle technologies might be able to replace

other measures in a more effective and efficient way, vehicle design measures (vehicle engineering) aimed at reducing speed are underused.
A heavily researched and promising speed management measure that qualifies as a vehicle engineering solution is Intelligent Speed Adaptation (ISA). ISA is a system that supports drivers in avoiding speeding by continuously comparing the driving speed to the prevailing speed limit. In case of speeding, the ISA system can warn the driver (e.g. with audio visual signals), assist the driver (e.g. with a haptic throttle, which provides resistance above the speed limit), or even restrict the driver from going faster (e.g. the dead throttle, which makes it impossible to go faster than the local speed limit). In addition to categorization by the level of intervention the system gives, ISA can be categorized by the type of speed limit information it uses (static speed limits or dynamic speed limits), and whether it can be switched off by the driver (overridable vs. non-overridable). In this chapter, we mainly use the level of intervention categorization (Warning ISA, Assisting ISA, and Restricting ISA).
If making traffic safer is such an important policy goal, and ISA-technologies are available to significantly improve traffic safety, why is it that implementation is going so slowly? Different authors have explicitly argued that the uncertainties surrounding ISA implementation are a major cause of slow implementation (e.g. uncertainty about the effects of ISA on road safety and on throughput) (Oei, 2001; Marchau 2000). Others implicitly indicate that the uncertainties are barriers for ISA implementation by indicating the need for future research (Carsten, 2002; Vàrhelyi, 2002). The fact is that, despite decades of ISA research, there are still many uncertainties surrounding ISA implementation, and these uncertainties are considered to be barriers to implementation.

From this, we can conclude that there is a clear need for a systematic identification of the uncertainties surrounding ISA implementation from the policymaker's perspective. In addition to identifying the uncertainties, there is a need for a systematic evaluation of these uncertainties: how large are the uncertainties and to what extent are they are barriers to implementation? This information is crucial input for ISA policy assessment, so it is important for both policy advisors and for policymakers. The main research questions addressed in this chapter are: "What are the uncertainties that still exist regarding the implementation of ISA, how important are these uncertainties and how large are these uncertainties?" To answer these questions, this chapter addresses the following research questions:

1. What uncertainties are associated with ISA implementation?
2. What is the level of each of these uncertainties? (from fully determined to fully uncertain)
3. How important are these uncertainties as barriers for implementing ISA?
4. What are the most important research needs, from the perspective of facilitating the implementation of ISA?

Before beginning, however, it is important to define uncertainty and to present the uncertainty framework used to categorize and identify the uncertainties involved in ISA implementation. Section 3.2 explains the theoretical framework of our study and addresses the methods used to answer the above mentioned research questions. In Section 3.3, the first research question is answered through an extensive literature review of ISA research. In Section 3.4, sub-questions 2 and 3 are addressed by means of an expert elicitation study. Section 3.5 answers the 4th research question by synthesizing the main findings of both the literature review and the expert elicitation. Section 3.6 presents this chapter's main conclusions, including recommendations for policymaking and future research.

3.2 Theory and methodology

3.2.1 A framework for uncertainty categorization

In general, uncertainty can be defined as "*any deviation from the unachievable ideal of completely deterministic knowledge of the relevant system*" (Walker et al., 2003). In our specific case, this comes down to missing knowledge regarding the implementation of ISA. There are many different ways of categorizing uncertainty (see e.g. Van Asselt, 2005; Morgan and Henrion, 1990). We apply the uncertainty framework introduced by Walker et al. (2003), because it was specifically designed to be applied to policy decision problems. Furthermore, it has been applied successfully in the transport policy domain in the past. For the case of ISA implementation, we define the transport policy domain or transport system by distinguishing its physical components (e.g. people, goods, vehicles, and infrastructure) and their mutual interactions (see e.g. Agusdinata et al., 2009; Marchau et al., 2010).

The Walker, et al. uncertainty categorization is based upon the analytical framework used in Policy Analysis (PA) (Walker, 2000). Using the PA framework, a categorization of uncertainties surrounding the choice of a policy using model-based Policy Analysis can be derived (see Figure 3-1). In the context of transport, uncertainty regarding what policy to choose can be split up into (1) uncertainty about the model's estimates of the transport system's outcomes which are related to the objectives of policymakers and stakeholders (e.g. traffic safety, emissions, costs), and (2) uncertainty about the valuation of the outcomes (the relative importance given to the outcomes by crucial stakeholders, including policymakers).

The left branch of the tree of Figure 3-1 shows the uncertainty about the model's outcomes, which can result from uncertainty about external forces and/or uncertainty about system responses to the external forces (resulting from uncertainty regarding the relevance of the external forces or the values for the relevant external forces. External forces are forces outside the transport system that can affect the structure of the transport system and are not controllable by the policymaker but may influence the system significantly (e.g., economic and demographic developments affecting the transportation system). There can also be uncertainty about how the transport system responds to the external forces and to policies. Uncertainty about the system response might be due to uncertainty about the structure of the model and/or uncertainty and/or uncertainty about the model's parameters.

The second category of uncertainty, shown in the right branch of the uncertainty tree (Figure 3-1) refers to the valuation of the model's outcomes. One can distinguish uncertainty about the stakeholder configuration (e.g. uncertainty on who the most important stakeholders are) and uncertainty about how these stakeholders value the various model outcomes. These values may change over time in unpredictable ways, leading to different valuations of future outcomes than those made in the present. Furthermore, new stakeholders can appear on the stage or the importance of stakeholders may change. But, these changes are also uncertain. The framework presented in Figure 3-1 will be used throughout this chapter to identify and structure the uncertainties surrounding the implementation of ISA.

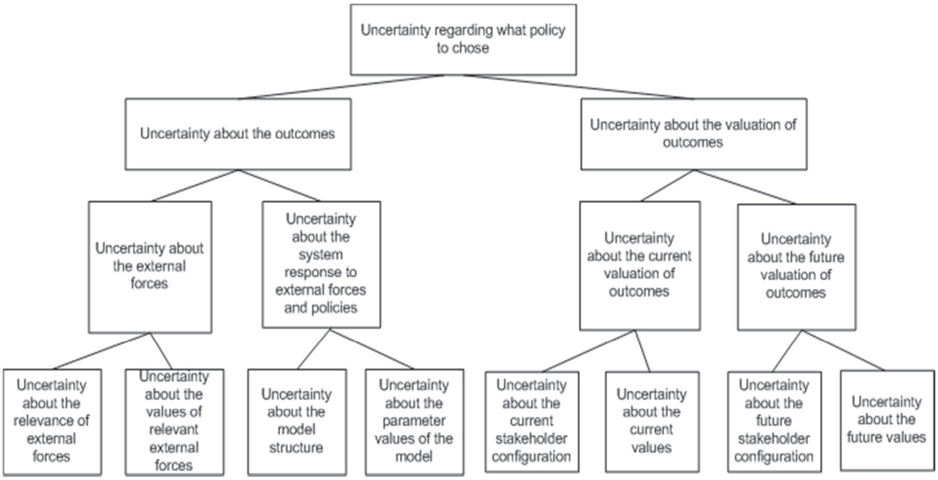

Figure 3-1 Categorization of uncertainty (derived from Marchau and Walker (2002))

3.2.2 Literature review methodology

In order to identify the uncertainties surrounding the implementation of ISA, we performed an extensive literature review. Although very insightful literature studies regarding ISA have been performed (see e.g. Jamson et al., 2006), our review differed in two important ways from the existing studies. First, and most important, we focused on the uncertainties surrounding ISA implementation from the policymaking perspective. Our underlying assumption is that the uncertainties surrounding ISA implementation are major barriers for policymakers and market parties to start implementing ISA. Second, we used results of the literature review to validate and extend the results using expert elicitation that, for each uncertainty, gives insight into the importance of the uncertainty as a barrier to implementation and its level of uncertainty.

The relevant literature was identified by searching different scientific databases (e.g. Scopus, Web of Science) using a list of keywords (e.g. ISA, speed limiter, etc.). In addition, the references of relevant publications were analyzed as well ("snowball" method). This resulted in a list of 187 publications of relevant ISA research.

3.2.3 Expert elicitation methodology

Given the uncertainties that resulted from the literature review, this section discusses sub-questions 2 and 3 (the level and importance of the uncertainties), which could not be answered using literature because the questions are hardly addressed at all in the literature. We designed a Web-based questionnaire and invited experts from all over the world to fill it in. We used a Web-based questionnaire for several reasons: it is an easy way to approach international respondents, a fast way of collecting data, and facilitates data-analyses (Sills and Song, 2002).

To elicit how large the experts thought the uncertainties were (sub-question 2), we used the level of uncertainty as introduced by Walker et al. (2003). The experts were able to choose among five levels of uncertainty, ranging from fully determined to fully uncertain:

1. Fully determined: there is no uncertainty regarding the subject. (I.e. there is perfect understanding of the subject.)
2. Statistical uncertainty: there is a lot of information about things that can happen and their likelihood. (I.e. there is a vast amount of empirical information on the subject.)
3. Scenario uncertainty: it is understood how the main mechanisms work, the range of things that can happen is known, but they cannot be ranked because the likelihood is unknown. (I.e. we have limited information on the subject.)
4. Recognized ignorance: there are some clues regarding the subject; but it is known that there are still things that are unknown. (I.e. there is little information on the subject.)
5. Fully uncertain: There is no clue about the subject and there is no knowledge about what can happen. (I.e. there is no information on the subject.)

In addition to the level of uncertainty, each of the experts was asked about the extent to which they thought the uncertainty was a barrier for implementation of ISA (sub-question 3). We distinguished four barrier levels: no, minor, medium, and major barrier for implementation.

Both these questions were asked for all uncertainties associated with the three ISA categories: (1) Warning ISA (speed alert): ISA that displays the speed limit and warns the driver using an audio/visual feedback in case of speeding, (2) Assisting ISA (haptic throttle): ISA that intervenes with the driving task by limiting the speed in case of speeding but which is still overridable (for instance by providing an overridable counter force on the throttle in case of speeding), and (3) Restricting ISA (speed limiter): ISA that restricts the vehicle speed to the speed limit (non-overridable). In addition, the experts to ask for their opinions on:

- the most important uncertainties;
- the most important barriers;
- what they thought should be added to the list of uncertainties;
- what they thought should be added to the list of barriers.

3.3 Identifying the candidate uncertainties surrounding the implementation of ISA

3.3.1 Results of the literature review

We identified the uncertainties regarding ISA implementation addressed in the literature by applying the uncertainty categorization shown in Figure 3-1. In the remainder of this section, we discuss the most important uncertainties per category. Looking at Figure 3-1, the order of discussion will be from left to right, starting with a discussion of uncertainties regarding external forces and ending with a discussion of uncertainties regarding the evaluation of outcomes.

Uncertainty regarding the relevance and values of external forces

The effects of external forces on the transport system are generally not included as part of ISA research. However, they have been included in other research, and a lot of research has been done on identifying the relationship between external forces (e.g., economy, demography, ecology) and the transport system (see e.g. Button and Hensher (2001)). We found only two studies into uncertainty regarding the relevance and values of external forces for ISA, both by Carsten and Tate (2000 and 2005). In their cost-benefit analyses of ISA, they included assumptions representing two different sets of economic developments.

However, the effect of other external forces, such as technological developments, demographic changes, and policy decisions from ministries besides transport are not considered. This could be essential information needed for policymaking for ISA implementation. Moreover, the research is specific to the United Kingdom, making it hard to use for policy decisions in other countries. (It is difficult to assess which results are ISA system specific, scenario specific, country specific, etc., so application of the results for policy decisions in other countries is difficult.). From the above, we conclude that the relevance and values of external forces for the implementation of ISA are highly uncertain.

Uncertainty regarding the system response to external forces and policies – model structure

Uncertainty regarding the effect of ISA on speed choice behavior

Most of the research related to the system response to external forces and policies has focused on the uncertainties regarding the effect of ISA on driver behavior (and, more specifically, speed choice behavior) and the driver behavior's effect on the outcomes of interest (e.g. number of fatalities, number of accidents, CO_2 emissions). As noted before, it is hard to compare these research results, due to differences in research approach and underlying assumptions. Research into the effect of ISA on speed choice behavior differs according to: (a) the effect of different types of ISA, (b) the effect of different types of roads, (c) the effect of different types of drivers, including non-ISA drivers, (d) short-term versus long-term effects, and (e) the effect after removal of the device, or speed choice behavior in situations in which the system is turned off or does not work.

We found that there is not much uncertainty regarding the effect of ISA on speed choice behavior. All research we found indicates that ISA reduces speeding and inappropriate speed choice behavior, resulting in large reductions in accidents and accident outcomes. Carsten et al. (2005) estimate that, depending on the type of ISA, the reduction in fatal accidents can be as high as 59%. More recent calculations by Carsten et al. (2008) show that, depending on the implementation strategy a reduction in fatal accidents of 42% by 2045 can be achieved in the UK. Uncertainty regarding the effects of different ISA types on speed choice behavior has also been addressed in different publications. In general, it can be concluded that the more permissive the ISA, the less effect on speed choice behavior (Adell, 2008; Comte and Jamson, 2000). Basically, the direction of the effect is known, but the magnitude remains uncertain.

The results with respect to the impact of ISA on speed choice behavior are mixed and, thus, uncertain. For instance, some research concludes that ISA was most effective in reducing the time spent speeding, free flow speed, and mileage spent speeding in 90 km/h zones or rural roads (e.g. Vlassenroot et al., 2007; Agerholm et al., 2008). On the other hand, trials in the Netherlands, Sweden, and Spain indicate just the opposite. ISA reduced the mean speed on urban roads (30km/h-60km/h), but for the rural roads (80-90 km/h) the reduction was not significant. The difference in results is assumed to be caused by the traffic situations in these specific cases (Vàrhelyi and Makinen, 2001). ISA has also proven to be very effective in eliminating momentarily high speeds (Vàrhelyi et al., 1998; Vàrhelyi and Makinen, 2001). Comte (2000) found a decrease of mean speed at specific risk locations. Overall, ISA is very effective in reducing negative speeding behavior; in situations in which speed is already low (due to traffic conditions), results turn out to be insignificant.

Another uncertainty that was researched was the effect of ISA related to different types of drivers. However, the results of these studies show differences, and the effect of ISA on the various driver types is still uncertain, and varies depending on the scope of the research. Danish research (Agerholm, 2008) shows positive effects of ISA on the speed choice behavior of young drivers, who are known to be most likely to speed. A reverse effect was found by Vlassenroot et al. (2007). They conclude that ISA leads to higher mean speed for those drivers who are less frequent speeders. Furthermore, research indicates a decrease in the effect of ISA on speed choice behavior both for the Active Accelerator Pedal (AAP) (Hjamdahl et al., 2002; Vàrhelyi et al, 2004; Vlassenroot et al. 2007) and for the audio visual warning ISA types (Warner et al. 2008).

Research by Adell et al. (2008) shows that ISA only has an effect when it is turned on, not merely by its presence. This research showed that, when ISA was assumed to be turned off, people immediately returned to their old speed choice behavior. This seems to be contradictory to the research by Vàrhelyi et al. (2004), which indicated no compensatory behavior in situations in which the ISA did not work. Moreover, no compensatory behavior in terms of speeding at intersections or higher turning speeds has been found, and test drivers with ISA showed a smoother approach speed to roundabouts and intersections (Vàrhelyi and Makinen, 2001; Vàrhelyi et al. 1998).

The effects of ISA on other driver-related tasks have also been investigated. Uncertainty regarding the effects of ISA on car-following behavior has been researched extensively. Most research has indicated that ISA reduces the vehicle following gap (Persson, 1993; Comte 2000), which leads to closer car following behavior. Vàrhelyi and Makinen (2001) conclude that safer car following behavior occurred on urban roads (30-50 km/h). However, on 70-90 km/h roads, the tendency was the opposite ─ vehicle gaps decreased (meaning riskier car following behavior).

To conclude, the effect of ISA on driver behavior remains uncertain. There are indications of what can happen, but the size of the effects remain uncertain. Here we can also add that comparing the different behavioral studies is difficult ─ even more so when it comes to long-term effects (Saad, 2006). Moreover, the long-term effects and the effects of large scale implementation are unknown, and the uncertainty is compounded when it is considered in relation to the implementation strategy.

No specific research has been done into uncertainty regarding the effect of ISA users on the speed choice behavior of non-ISA using road users. However, trials in Umea (Sweden) showed ISA has a positive effect on surrounding traffic (Biding et al., 2002). Since the implementation of ISA will likely not happen in one day, the effects of ISA in mixed traffic are important to know, but remain uncertain.

Uncertainty regarding the effect of ISA on driver behavior that is not speed choice related.
Vàrhelyi 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 (Vàrhelyi et al. 1998, 2004) or even a slightly positive effect (Almquist and Nygard, 1997, found in Vàrhelyi et al., 1998)). Furthermore, research has concluded that ISA does not change overtaking behavior (Comte, 2000;

Vàrhelyi and Makinen, 2001; Adell et al. 2011) and causes no loss in vigilance (Comte, 2000). Another driving task that belongs belongs to this category, and that takes place at a strategic level is route choice (Michon, 1985). No research has been found that addresses the effect of ISA on route choice, so this remains uncertain.

Uncertainty regarding the effects of ISA on travel time and congestion
Different trials of ISA have indicated an increase in travel time. In 1998, Vàrhelyi et al. concluded that the travel time increase due to ISA was 2.5-2.8%, depending on the country (Netherlands, Spain, or Sweden). Similar effects on travel time were reported by Vàrhelyi and Makinen (2001) and by Liu and Tate (2004). Broekx and Panis (2004) found a small effect, and no effect on travel times was reported by Vàrhelyi et al. (2004). The differences in these research results might be explained by the fact that Vàrhelyi et al. (2004) analyzed the effects of ISA in a network in which speeds were already very low. Despite the increase in travel times, microsimulation has shown that ISA does not lead to increased traffic jams (Liu and Tate, 2004). In this specific case, the result is due to the fact that during peak times, when traffic jams occur, most of the vehicles are already moving below the speed limit, so ISA will not lead to additional traffic jams. To conclude, the effect of ISA on travel time seems to be negative; the size of the effect seems to be small. There is still a large uncertainty when it comes to the effects of the size of the effect for large-scale penetration of ISA.

Uncertainty regarding the effects of ISA on driver workload and comfort
Most research indicates that ISA results in reduced driver comfort. Vàrhelyi and Makinen (2001) report that drivers feel an increased frustration. After trials in the Netherlands, Brookhuis and De Waard (1997, 1999) indicate a slight increase in mental workload based on self-reporting (no increase could be measured using heart monitoring). Rook and Hoogma (2005) looked at the effects of different levels of ISA feedback force (for haptic throttle) on frustration level and workload. They found that a high feedback force leads to more workload and frustration than a low feedback force. However, the workload of driving with the Restricting ISA and with a vibrating pedal does not lead to more workload than driving without ISA. This is in line with other results that indicate that the more intervening ISA is, the less likely it is perceived to be acceptable (see e.g. Comte and Jamson, 2000). Comte and Jamson (2000) found no differences in workload between Advising and Restricting ISA. They also showed that providing the drivers with speed limit information does not necessarily result in a higher workload. To conclude, it seems to be certain that drivers perceive more intervening types of ISA as frustrating (the effect of long-term usage and perfectly working ISA is uncertain). Furthermore, there seems to be little uncertainty about the effect of ISA on workload (no effect or very small effect).

Uncertainty regarding the effects of ISA on emissions and fuel use
A number of studies have looked into the effects of ISA on both fuel use and emissions. Almost all conclude that ISA has a positive effect on fuel use and emissions. Varheyli et al. (2004) find significant reductions in CO_2 and NO_x emissions. Broekx and Panis (2004) mention a reduction in CO_2 and NO_x emissions, together with a decrease in HC and PM emissions. Broekx and Panis (2004) also mention a reduction in fuel use of 2% (between 0.8% and 3.2%, depending on the type of road). Liu and Tate (2004) studied ISA effects on network efficiency, fuel consumption, and emissions through detailed microsimulations. Assessing an ISA penetration level of 100%, they found fuel savings of 8% for urban peak, 8% for urban off-peak, 3% for rural roads, and 1% for motorways. The results for emissions

were mixed. They found that the emissions of CO, NOx, and hydrocarbons varied by only +/-2% for all ISA penetration rates (see also Carsten and Tate, 2005). To conclude, it is fairly certain that ISA will have an effect on fuel use and emissions, and that this effect will be positive; however, the size of the effect is uncertain.

Uncertainty regarding the legal aspects of ISA implementation
Legal aspects are often mentioned as a barrier for ISA implementation (e.g. Marchau et al., 2002; Vàrhelyi et al., 2004; Argiolu et al., 2006; Goodwin et al., 2006). In general, it is argued that those ISA systems that do not intervene more with the driving task than already available systems on the market (e.g. ABB, TC, and ESP) will not encounter product liability problems (Goodwin, 2006; Albrecht, 2005). However, intervening ISA products need to be approved and tested by an approved testing organization before they can be implemented, since it is an offense to modify a vehicle's braking system (Jamson et al., 2006). In addition, in case of intervening ISA malfunctioning, the user can claim that the accident was not caused by the driver but by a technical defect. Such a defense has a high likelihood of succeeding (Van Wees, 2004). To conclude, research indicates that the more intervening a system is the more legal constraints become an issue. Liability issues do not seem to be a barrier for Warning ISA. However, the situation is not completely clear for Assisting ISA. In general, it is assumed that the driver still is responsible for his or her driving, since the system does not interfere with the driving task more than other already implemented systems. Restricting ISA seems to be impossible without legislative changes. Furthermore, there also seems to be a relationship between the legal aspects and the implementation strategy.

Uncertainty regarding the system's response to external forces and policies – parameter values.

Several uncertainties regarding parameter values of system models have been addressed in previous research. In the case of overridable ISA, an important issue for modeling the effects is uncertainty regarding the level of compliance with the ISA system. Research shows that voluntary ISA is likely to be overruled in many cases, depending on a variety of factors (e.g. road and driver characteristics, familiarity with the ISA system, etc.) (Carsten et al. 2008; Jamson, 2006; Comte, 1999). Carsten et al. (2000) indicate that, based upon trials, they estimate the level of compliance to be 50%. To conclude, there is very limited knowledge regarding the levels of compliance with overridable systems that can be expected when ISA is implemented, Hence this is still uncertain.

Another uncertainty in modeling the effects of ISA is the level of penetration that is to be expected when ISA is implemented. Carsten et al. (2008) developed four implementation scenarios that are combinations of type of ISA system and whether adoption is mandatory (government driven) or voluntary (market driven). These implementation scenarios resulted in different penetration levels for different systems in different years. The effect of different penetration levels of ISA-equipped vehicles has been assessed by microsimulation (Xiaoliang et al. (2004, 2005) and Wang et al. (2007)). The results indicate that different ISA penetration levels will have different effects on speed (low penetration levels result in speed waves and higher penetration level result in more stable speeds). Given the very specific focus of the research done (mainly focused on the UK), and the limited number of studies regarding the subject, the effect of ISA implementation policies on penetration rates is considered to be uncertain.

Uncertainty regarding the current valuation of outcomes

Research that addresses the way stakeholders value ISA is mainly focused on potential ISA users and drivers in general, often differentiating among ISA types (e.g. Warning ISA, Restricting ISA, etc.), specific driver groups (e.g. young drivers, aggressive drivers), and road types (e.g. urban roads, 30km/h roads, etc.). ISA research on driver acceptance defines acceptance in different ways (e.g., willingness to buy ISA, willingness to install ISA, willingness to use ISA, willingness to comply with the ISA system).

Literature review regarding the acceptance of ISA shows that the more intervening the system is the less people are willing to accept it (e.g. Comte and Jamson, 2000; Garvill et al, 2003; Rook and Hoogma, 2005). Different groups of drivers are distinguished. Jamson (2006) concludes that those drivers that are most inclined to exhibit speeding behavior are least likely to use ISA. (Garvill (2003) and Rienstra and Rietveld (1996) draw similar conclusions.) Young drivers seem less inclined to accept an ISA system, and older, more experienced drivers tend to like the system (De Waard, 1997; Young 2004). Other researchers conclude that women are more in favor of ISA than men (Rienstra and Rietveld, 1996; Piao et al., 2005), and higher-educated people are more against electronic speed limiters (Rienstra and Rietveld, 1996). Others have looked into the factors that influence the acceptance of ISA. Marchau et al. (2005) indicate that the willingness of drivers to adopt ISA depends on the functionality and the flexibility of the ISA system and the price (ISA should have a rather low price). Others mention technical functioning of the system (Risser, 2002). Molin and Brookhuis (2007) identify three factors that have the most effect on ISA acceptability: (1) the belief that driving too fast is a major cause of accidents, (2) the belief that ISA can contribute to attaining various personal and social goals, and (3) the extent to which one prefers a more limiting ISA. Research indicates uncertainty about whether using ISA influences its acceptance. Vàrhelyi (2002) and Comte (2000) report that the acceptance of ISA increases after people have tried it. However, opposite results were reported by Van Nes et al. (2008). They see a decline in acceptance after drivers use the system. They suggest that this might be due to the characteristics of the specific system they studied. It has to be noted that, in general, the research on user acceptance varied a lot among the different trials (Vlassenroot et al., 2008), and no coherent acceptance indications were described. In general, it could be said that, although the notion that the more intervening the system is the less people are willing to accept it suggests that drivers are unwilling to yield control to anything or anybody, the truth is more complex (see e.g. Vlassenroot at al., 2010). Carsten (2002) noted that the attitudinal research on acceptance of ISA could be criticized for not being sufficiently rigorous. It can be concluded that, although a lot is known about the factors that affect the level of acceptance, the extent to which the individual factors influence acceptance is uncertain. Furthermore, the effects of different implementation strategies on acceptance are unknown, as are the long-term effects of ISA usage on acceptance.

Most research has focused on the opinions of potential ISA users; little research has been done into other stakeholders' opinions. Marchau et al. (2002) researched the actors involved in ISA implementation and their opinions of different ISA systems. Also, a stakeholder analysis was carried out as part of the PROSPER research project (PROSPER, 2004). Reviewing the stakeholder literature for ISA, Walta (2006) concluded that most research has focused on the user, and that none of the studies distinguished preferences among different stakeholders. The preferences of different stakeholders towards ISA, therefore, seems to be uncertain.

Uncertainty regarding the future valuation of outcomes

No research was found that addressed the future valuation of outcomes by different stakeholders or the future stakeholder configuration, resulting in uncertainty regarding these subjects.

3.3.2 Conclusions of the literature review

The literature review resulted in three main products:

- A database containing more than 185 publications.
- An overview and synthesis of the literature regarding the outcomes of research performed in the past addressing important ISA implementation uncertainties (see rest of this section).
- A list of uncertainties regarding ISA implementation that is structured using the uncertainty framework of Figure 3-1.

Policymaking for ISA requires dealing with the uncertainties surrounding ISA policy measures in a transparent and systematic way. Using the uncertainty framework presented in Section 3.2.1 (Figure 3-1), we identified the 24 most important uncertainties surrounding ISA implementation (see Table 3-1). The results show that past research has focused on uncertainty regarding the system's response to external forces and policies (model structure) and uncertainty regarding the current valuation of outcomes (ISA acceptance). Moreover, this current valuation of outcomes is focused on one type of stakeholder – the potential ISA user. Table 3-1 also presents an overview of all the uncertainties addressed in the literature. Several uncertainties that are relevant for ISA implementation have not been researched. These include uncertainties regarding the effect of external forces, current stakeholder valuations (other than the users'), current stakeholder configuration, future stakeholder valuation, and future stakeholder configuration.

Table 3-1 Most important ISA uncertainties derived from the uncertainty framework and literature

Uncertainty category	#*	Uncertainty regarding
The relevance and values of relevant external forces	1	Effect of external developments on the implementation of ISA. (E.g. uncertainties may exist regarding the effect of economic developments, effect of technological developments, effect of demographic developments, etc.)
Uncertainty regarding the system's response to external forces and policies – model structure	2	Effect of ISA on the speed choice behavior of ISA users
	3	Effect of *long-term* ISA use (over 2 years) on ISA users
	4	Effect of ISA on travel behavior (route choice behavior, mode choice behavior, etc.)
	5	Effect of ISA on fuel use and environmental pollution
	6	The cost of ISA implementation.
	7	Effect of ISA implementation on accident and accident outcomes
	8	Effect of ISA on the transport network (e.g. network capacity, network efficiency, network throughput, etc.)
	9	Effect of ISA on driver workload
	10	Effect of ISA on driving comfort
	11	Behavioral adaptation of drivers that use ISA (e.g. delegation of responsibilities, less vigilance driving)
	12	Behavioral adaptation of other road users

	13	Effect of ISA on other (not speed choice related) drive-task related behavior of ISA users. (e.g. car following behavior, give way' behavior, overtaking behavior)
	14	The size and nature of the effect of compensatory behavior of ISA users (e.g. speeding when system is not engaged, more aggressive and rapid acceleration)
	15	Technical reliability of ISA and the effects of a malfunctioning ISA
	16	Technical characteristics and updating of the speed limit database (e.g. what is the best speed limit database format, what is the best way to update the speed limit database, etc.)
	17	Liability allocation in case things go wrong with the functioning of ISA (liability issues)
Uncertainty regarding the system's response to external forces and policies – parameter values	18	Effect of different penetration levels. (E.g. what will be effect of ISA when over 80% of the vehicle fleet is equipped? Or what will be the effect of ISA when 30% of all vehicles are equipped?)
	19	Effect of different ISA implementation strategies on ISA implementation (e.g. voluntary implementation, giving incentives, mandatory implementation).
Uncertainty regarding the stakeholder configuration	20	Which stakeholders are involved in implementing ISA and the importance of each of the stakeholders for ISA implementation
Uncertainty regarding the current valuation of the outcomes of ISA implementation	21	The amount of money people are willing to pay for ISA
	22	Factors that contribute to ISA acceptance of car drivers, and the degree to which each of these factors contributes to the level of acceptance (e.g. driver characteristics, road conditions, level of intervention)
	23	Willingness of people to use ISA (E.g. in which situations are people willing to use ISA? What is the relationship between the way ISA is implemented (voluntary, mandatory) and the willingness use ISA? etc.)
Uncertainty about the future stakeholder configuration	24	Dynamics of stakeholder configuration (e.g. who are the future stakeholders, how important will they be)
Uncertainty about the future valuation of the outcomes of ISA implementation		

3.4 Expert elicitation on the level and importance of the uncertainties

We first identified 130 authors of the papers included in the database as experts. We invited each of these authors to participate in our research, and indicated that we welcomed suggestions for more experts (not necessarily scientists). This resulted in 33 additional experts, who were screened based on their self-reported level of expertise. Seventy-five experts (46% response rate) filled in the questionnaire. Sills and Song (2002) indicate that a non-response of 80% for Web-based questionnaires is not uncommon. Our response rate is, therefore, quite high. Experts were asked to answer only questions within their area of expertise. The response per question varied between 30-36%. The questionnaire consisted of 55 questions about 24 uncertainties. (The uncertainties are listed in Table 3-1.) The average time it took to fill in the questionnaire was 36 minutes.

To have an indication of the expertise of the experts, we asked them to report their current occupation and their area of expertise. A large majority of the experts were university researchers (55%). They represented a very diverse set of areas of expertise (e.g. control theory, transport innovations research, behavioral sciences). The other occupations represented among the experts were: public policymaking (11%), consultancy (16%), automotive industry (4%), and other (14%).

We also asked the experts to indicated their expertise per subject. The subjects were created based upon the uncertainties that resulted from the literature review. The majority of the experts represented themselves as experts (ranging from minor to major). Medium to major expertise was indicated by the majority of respondents for almost all subjects, except for the external factors that influence ISA implementation, implementation and liability issues, and stakeholder opinion and stakeholder configuration issues. Although the experts said that they had little expertise on these subjects, in all cases the expertise that they reported was considered dominantly minor instead of none. All in all, these data indicated that our experts had a sufficient level of expertise to support our research.

Section 3.4.1 discusses the results concerning the experts' opinions on the levels of the various uncertainties. Section 3.4.2 discusses their opinions on the importance of the uncertainties. Section 3.4.3 presents several uncertainties added to the original list by the experts.

3.4.1 Results on the level of uncertainty

Table 3-2, shows, for the three types of ISA (Warning, Assisting, and Restricting), the uncertainties whose uncertainty levels ranked the highest (top 5), based on their mean uncertainty scores. The levels of uncertainty were scored on a 1 to 5 scale (where 1 corresponds to 'fully determined' and 5 corresponds to 'fully uncertain').

Table 3-2 Uncertainties with the highest levels of uncertainty, per ISA type

		Warning			Assisting			Restricting		
# *	Uncertainty	Rank	Mean	s**	Rank	Mean	s**	Rank	Mean	s**
13	Uncertainty regarding behavioral adaptation of other road users.	1	3.15	1.26	2	3.34	1.16	2	3.50	1.11
22	Uncertainty regarding the liability allocation in case things go wrong with the functioning of ISA (liability issues).	2	3.11	1.12	1	3.45	1.02	1	3.61	0.97
4	Uncertainty regarding the effect of ISA on travel behavior	3	2.88	1.32	5	3.16	1.20	3	3.40	1.12
12	Uncertainty regarding behavioral adaptation of drivers that use ISA	4	2.87	1.02	3	3.19	1.00	6	3.29	0.97
17	Uncertainty regarding the effect of different ISA implementation strategies on ISA implementation	5	2.80	1.00	4	3.18	0.96	4	3.36	0.91
24	Uncertainty regarding the dynamics in stakeholder configuration	8	2.74	1.21	6	3.14	1.02	5	3.36	0.99

* Corresponding uncertainty number in Table 1 and Appendix 2
** Standard deviation

As can be seen in Table 3-2, the largest uncertainties surrounding the implementation of ISA all apply to Restricting ISA, although the differences with Assisting ISA are small. Furthermore, the ranking of level of uncertainty seems very consistent across the different types of ISA ─ there are only six uncertainties in the top 5 across the three systems. This indicates that these uncertainties are perceived to be relatively equally uncertain across the types of ISA systems. Most uncertain are the liability allocation aspects in case of a malfunctioning ISA and uncertainties related to behavioral adaptation of other road users (non-ISA drivers). (Most experts labeled the latter uncertainty as 'recognized ignorance'.) This is consistent with the results of the literature review, which found little research regarding the behavioral adaptation of other road users and found that uncertainty regarding liability issues was still uncertain for more restricting types of ISA especially when considered in combination with the implementation strategy (see Section 3.3.1). Uncertainty regarding behavioral adaptation of other road users is indicated to be very uncertain (mostly rated as 'recognized ignorance'). This is consistent with the conclusion of the literature review that little research was found into this subject (see Section 3.2.2). The same can be concluded for the effects of ISA on travel behavior (e.g. mode choice and route choice, which are discussed in Section 3.2.2).

Uncertainty regarding behavioral adaptation of drivers that use ISA was indicated to be a scenario uncertainty. This is consistent with research performed in the past (see Section 3.2.2). Based upon past research, we are aware of the things that *can* happen, but which situation *will* occur remains uncertain ─ hence, scenario uncertainty.

Uncertainty regarding the effect of different ISA implementation strategies is indicated to be very high (most experts rated this to be a scenario uncertainty for Warning and Assisting ISA and recognized ignorance for Restricting ISA). This uncertainty was further specified in the open questions by different experts, who indicated that this uncertainty mainly reflects uncertainty regarding the effect of different implementation strategies on the acceptance of ISA (in terms of willingness to use and to buy), and, related to that, the uncertainty regarding what the preferred strategy is when it comes to implementing the different types of ISA.

As indicated in the literature review in Section 3.3.1, uncertainty regarding the dynamics in stakeholder configuration has not been significantly addressed in literature and research. Despite the fact that it has not been researched in the past, the experts indicated that they consider this to be a scenario uncertainty (for the Assisting and the Restricting ISA). An explanation for this could be that the experts have a good idea of the stakeholders involved in ISA implementation and the stakeholders that could be involved in ISA implementation, and they do not see any unexpected changes in the future stakeholder configuration.

Regarding the level of uncertainty, the experts added that there are synergy effects regarding the uncertainty and the overall level of uncertainty that are relevant for decision making. These interactions lead to complex issues and additional uncertainty.

3.4.2 Results on the importance of the uncertainties

Table 3-3, shows, for the three types of ISA (Warning, Assisting, and Restricting), the uncertainties whose barrier scores ranked the highest (top 5), Based on their mean levels of importance. The levels of uncertainty were scored on a 1 to 4 scale (where 1 corresponds to ‘no barrier’ , 2 corresponds to ‘minor barrier’, 3 corresponds to ‘medium barrier’ and 4 corresponds to ‘major barrier’).

Table 3-3 Uncertainties that are the most important barriers to ISA implementation, per ISA type

		Warning			Assisting			Restricting		
# *	Uncertainty	Rank	Mean	s***	Rank	Mean	s***	Rank	Mean	s***
18	Uncertainty regarding the technical characteristics and updating of the speed limit database	1	2.70	1.05	5	2.83	1.08	7	2.98	1.10
22	Uncertainty regarding the liability allocation in case things go wrong with the functioning of ISA.	2	2.43	1.07	1	3.09	0.96	1	3.36	0.94
20	Uncertainty regarding the factors which contribute to ISA acceptance of car drivers and the degree to which each of these factors contributes to the level of acceptance	3	2.33	0.85	7	2.78	0.97	5	3.08	0.95
19	Uncertainty regarding the willingness of people to use ISA	4	2.29	1.00	2	2.90	0.97	2	3.22	1.05
23	Uncertainty regarding which stakeholders are involved in implementing ISA and the importance of each of the stakeholders for ISA implementation.	5	2.21	1.05	4	2.83	0.94	3	3.19	0.92
17	Uncertainty regarding the effect of different ISA implementation strategies on ISA implementation (e.g. voluntary implementation, giving incentives, mandatory implementation).	6	2.20	0.97	3	2.84	0.82	4	3.24	0.93

* Corresponding uncertainty number in Table 1 and Appendix A

** Standard deviation

For Warning ISA, there seems to be almost no significant barrier left for implementation. The only barrier rated to be between minor and medium is related to the in-vehicle speed limit database characteristics and maintenance. The experts indicate that this is one of the only remaining major technical and organizational challenges left when it comes to implementation. With respect to the speed limit database, there are a number of barriers that are mentioned by the experts: first, the organizational aspects of the development of a speed limit map/database and the accuracy of this speed limit map (who should do this, to what extent is the developer responsible for accuracy, etc.). Second, there is the technical challenge of developing a speed limit database, and even more challenging, the issue of updating the database. Finally, experts indicate that there is no single straightforward standard regarding the technical specification of speed limit databases, and there is a lack of effort to standardize the speed limit database. It is clear that the more intervening the system is, the more this uncertainty becomes a barrier for implementation.

For the more intervening types of ISA (Assisting and Restricting), uncertainties surrounding the liability issues are considered to be the most important barrier for implementation (most experts indicated this as a medium uncertainty for Assisting ISA and a major barrier for Restricting ISA). This is in line with the literature (see Sec. 3.2.2). It also indicates that the institutional settings (e.g. legislation) make it more difficult to implement the more restricting types of ISA.

Uncertainties regarding acceptance were indicated to be an important barrier. This is clearly indicated in Table 3-3, which shows that uncertainty regarding the willingness to use ISA and uncertainty regarding the factors that influence acceptance are considered to be barriers. This was further mentioned in the open questions, where the experts indicated that the lack of knowledge on the willingness to use and install ISA is an important barrier (e.g., the experts said that willingness to use depends on traffic scenarios, driver characteristics, and implementation measures, and on long-term and large-scale usage).

Uncertainty regarding the effect of different implementation strategies was considered to be an important barrier. The experts further specified this barrier in the open question regarding barriers for implementation. They indicated that not only is the uncertainty regarding the effect of different implementation strategies on the level of penetration uncertain, but also uncertain is the effect of the strategy on the usage of ISA (e.g. will mandatory implementation of an advisory ISA lead to more overruling of the system?). The effect of large-scale implementation seems to be very uncertain (e.g. the effects on traffic safety, effects on throughput, etc.). Some of the experts indicated that stakeholders do not want to take the lead in implementation because the effects of large-scale real world implementation of ISA are unknown. On the other hand, the experts also indicated that, in order to make a difference, ISA implementation must reach a certain level of penetration. This is needed both to facilitate further large scale implementation (maturing of technology, people learn about the system) and to harvest safety effects.

Finally, for Restricting and Assisting ISA, a number of additional uncertainties were indicted to be medium to important barriers by most experts. For both Restricting and Assisting ISA, the cost of ISA implementation is a barrier. This can be explained by the fact that experts expect these types of ISA to be required based on public policy. Also indicated to be important barriers are the effects of Assisting ISA and Restricting ISA on the non-speed choice related behavior of ISA users and the counteractive behavior of ISA users. The unknown effect of external developments on the implementation of Restricting ISA is seen as an important barrier for the implementation of Restricting ISA. The willingness to pay for ISA is also an important barrier for implementation of both Assisting and Restricting ISA. With respect to this barrier, the experts indicated that none of the stakeholders seems to be prepared to pay for a system that limits the freedom of the user.

Table 3-3, shows that the more intervening the ISA, the more uncertainty is considered to be a barrier for implementation. However, the magnitude of this relationship differs among the uncertainties. To see which relationships are significant, we tested the relationships in paired sample t-tests.

For most of the uncertainties the relationship between the extent to which an uncertainty is a barrier and the level of intervention proves significant. This is consistent with the notion that the more an ISA is intervening the longer it will take before it is implemented. This is also consistent with the fact that warning devices are currently being implemented (e.g. on navigational devices), and initiatives are being deployed for Assisting ISA to be implemented (e.g. like in London[5]). This is also the likely reason why all the uncertainties mentioned were significantly more a barrier for Warning ISA than for Assisting ISA. However, for six of the 24 uncertainties, the mean values did not differ significantly between the Assisting and Warning variants, which means that, for these cases, this relationship may not exist. These six uncertainties are:

- #2 ─ uncertainty regarding the effect of ISA on the speed choice behavior of ISA users
- #3 ─ uncertainty regarding the effect of long-term ISA use on the ISA users
- #5 ─ uncertainty regarding the effect on fuel use and environmental pollution
- #7 ─ uncertainty regarding the effect of ISA implementation on accidents and accident outcomes
- #8 ─ uncertainty regarding the effect of ISA on the transport network
- #9 ─ uncertainty regarding the effect of IS on driver workload

These six uncertainties appear to be minor barriers for both Assisting and Restricting ISA.

3.4.3 Results on additional uncertainties regarding ISA implementation

Overall, the experts indicated that the list of uncertainties is quite complete. However, some experts added a few uncertainties. Three items were (frequently) added by the experts: (1) uncertainty regarding the long-term effects of ISA implementation (e.g. how will long-term usage of ISA affect user and non-user behavior, and what will be the overall effects on the transport system); (2) uncertainty regarding the effect of large-scale real world implementation of ISA (e.g. what will happen with capacity if the majority of all vehicles are equipped with ISA); and (3) there are synergy effects among the uncertainties. Several experts indicated that each of the uncertainties in itself is not a major barrier, but that the sum total of the uncertainties served as a major barrier to ISA implementation. Uncertainties that were also mentioned more than once, are:

- uncertainties regarding political issues (effects of lobbyists on politicians, political will to take a decision, how can ISA implementation be put on the political agenda?).

[5] See http://www.tfl.gov.uk site visited September 2009

- uncertainties regarding how ISA implementation would perform as a policy option as compared to other policy options. (E.g., would limiting the maximum speeds of cars by design not be more efficient/effective?)

Uncertainties that were included in the survey but which the experts elaborated on further were:

- uncertainties regarding acceptance issues (e.g., how will drivers feel if they are just one of the few ISA drivers on the road?, in what situations are drivers willing to use ISA? and marketing issues, such as how can we “sell” ISA to the users?).
- uncertainties regarding the design and maintenance of the speed limit database.

3.5 What remains to be done?

The final sub-question that is discussed is: what are the most important research needs, from the perspective of facilitating the implementation of ISA? Based upon the literature review, we conclude that, although a lot of research has been done, large uncertainties regarding ISA still remain. These uncertainties still exist for one of two reasons: (1) because past research did not address the subject (e.g. subjects like future valuation of outcomes), or (2) past research did not result in unambiguous results (e.g. like the effect of ISA on the behavior of ISA users towards other road users). Looking at the results of the literature review and the expert opinions, we conclude that the uncertainties regarding ISA fall into three categories, based on the way in which to deal with them:

- Uncertainties that can be dealt with by doing more research (reduce the uncertainty)
- Uncertainties that can be dealt with in an organizational manner (taking leadership and developing policies)
- Uncertainties that can only be dealt with by implementation and subsequent observation

Note that none of these uncertainties will be completely resolved until implementation takes place (e.g. uncertainties regarding ISA implementation; in the real world, on the long-term and on a large scale) and, for the uncertainties related to the long-term effects, the ISA needs to be implemented for a longer period.

Appendix 1 presents graphs for the three types of ISA indicating how interesting the uncertainties are for ISA implementation. The higher the level of uncertainty and the more the uncertainty is a barrier for implementation, the more research is still needed. The graph for Warning ISA shows that there are a large number of uncertainties left, but none of these is a significant barrier for implementation. From the fact that warning types of ISA are currently being implemented, we can conclude that, although experts indicate that there is still uncertainty left, and these are minor barriers for implementation, this is not blocking ISA implementation. However, implementation could be sped up by standardization of speed limit databases and incentives for buying and using warning types of ISA (see for instance the activities by the city of London[3] and the Dutch Ministry of Transport, Public works and Water management[6]). Important in this case is also ex-post evaluation of the implementation of Warning ISA. This could result in important information that can be used when implementing more Restricting types of ISA.

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[6] http://www.maximumsnelheden.info/ Website visited September 2009

The graphs in Appendix 1 show that the implementation of Assisting ISA and Restricting ISA present more of a challenge. In general, there are more serious barriers to implementation, and the overall levels of uncertainty are higher. The results from the literature review and the expert elicitation study suggest that three types of actions can be recommended to facilitate their implementation: additional research, more organizational changes, and beginning implementation (perhaps on a small scale). Based upon the literature and expert opinion, Table 4 shows the category of action that is most appropriate for each of the uncertainties that were indicated to be medium or major barriers by most of the experts or that were mentioned multiple times in the open questions.

Table 3-4 Categorization of actions for uncertainties related to major barriers to implementing Assisting and Restricting ISA

More research	More Organization and policies	Start implementing
- Uncertainty regarding the effect of external developments on the implementation of ISA - Uncertainty regarding behavioral adaptation of drivers that use ISA (counteractive behavior) - Uncertainty regarding the effect of ISA on other (not speed choice related) drive-task related behavior of ISA users - Uncertainty regarding the effect of different ISA implementation strategies on ISA implementation (mainly the effect on acceptance) - Uncertainty regarding which stakeholders are involved in implementing ISA and the importance of each of the stakeholders for ISA implementation. - Uncertainty regarding the dynamics in stakeholder configuration	- Uncertainty regarding the technical characteristics and updating of the speed limit database - Uncertainty regarding the liability allocation in case things go wrong with the functioning of ISA - Acceptance issues (Uncertainty regarding the amount of money people are willing to pay for ISA, Uncertainty regarding the factors which contribute to ISA acceptance of car drivers and the degree to which each of these factors contributes to the level of acceptance, Uncertainty regarding the willingness of people to use ISA) - Uncertainty regarding the cost of ISA implementation - Uncertainty regarding the technical reliability of ISA and the effects of a malfunctioning ISA	- Uncertainty regarding the effect of *long-term* ISA use*. - Uncertainty regarding the large scale effects and the effects of ISA implementation in the real-world*. - Uncertainty regarding the liability allocation in case things go wrong with the functioning of ISA - Synergy effects of all the uncertainties*

*** Added by experts**

The first column of Table 3-4 shows the *research needs* for Assisting and Restricting ISA from the perspective of facilitating the implementation of ISA. This column shows that, because Assisting and Restricting ISA are assumed not to be able to be implemented without policy intervention (this was indicated by the experts), it is important to know what the effect of different strategies will be on implementation (mainly on acceptance), but also who are and who will be involved in future implementation (what are their preferences, goals, and opinions, and how will these evolve over time). For Restricting ISA, fundamental research is still needed on the effects of ISA on driver behavior.

The second column in Table 3-4 shows the *organizational needs* for Assisting and Restricting ISA that would facilitate the implementation of ISA. Uncertainty regarding the technical characteristics of the speed database and the updating of the speed database can best be addressed in an organizational manner. Experts indicated that this is more a matter of standardization and some product development. Hence, this is more an organizational challenge than a technical one Also, liability issues are considered to be an important barrier for ISA implementation. Research shows that this is mainly an organizational problem that can relatively easily be solved by institutional changes (legal changes) and agreements.
As shown in the third column of Table 3-4, the uncertainty about liability issues can only really be resolved by implementing ISA and seeing what happens in the courts. Uncertainty regarding large-scale implementation, real world implementation, long-term effects, and the synergy effects of all the uncertainties can also best be dealt with by starting to implement ISA.

The question is: how can we start implementing ISA despite all these uncertainties? Recently, policymaking approaches that can facilitate ISA implementation despite the remaining uncertainties have been developed. An approach that facilitates dealing with the three categories of actions in an integrated manner is APM as described by Walker et al. (2001). AP allows implementation to start on a small scale to learn the effects of small scale ISA implementation over time. It is also able to incorporate research and organizational aspects, in the form of mitigating and hedging actions. As such, AP is one way to deal with the above mentioned uncertainties. (See Agusdinata et al. (2007) for an example of how AP can be applied to the problem of implementing ISA.) Two other benefits of using AP are (1) stakeholders are actively involved, which allows policymakers to deal with the important acceptance issues surrounding ISA implementation, and (2) actions take place in parallel and not sequentially (which means implementation can start today and not after additional research is done). Other related approaches for facilitating ISA implementation in the face of its many uncertainties are strategic niche management (Rotmans, 2003) and Robust Decision Making (Dewar et al., 1993; Lempert et al., 2003).

3.6 Conclusions & Recommendations

In this section, we first answer the four sub-questions asked in the introduction.

1. What uncertainties are associated with ISA implementation?
The literature review resulted in 24 uncertainties that still surround ISA implementation, which were confirmed by experts (see Table 3-1). Furthermore, there appear to be uncertainties regarding the large-scale real-world implementation (E.g. what will be the effect of large scale implementation on the level of acceptance, traffic safety and network capacity) of ISA and uncertainties regarding the long-term effects of ISA. Less mentioned but also added were uncertainties about political issues surrounding ISA implementation (e.g. effects of lobbyists on politicians, political will to take a decision).

2. What is the level of each of the uncertainties?
Overall, most of the uncertainties are indicated to be scenario uncertainties (i.e., how the main mechanisms work is understood, the range of things that can happen is known, but their likelihood is unknown). Issues that are still very uncertain are: the behavioral adaptation of ISA drivers and of other road users than ISA drivers, the effect of ISA on travel behavior, the

effects of different implementation strategies, and the dynamics in the stakeholder configuration. Experts also mentioned that there are large uncertainties regarding the long-term effects of ISA, the effects of a large-scale real-world implementation of ISA, and the synergy effects of all the uncertainties taken together.

3. How important is each uncertainty as a barrier for implementing ISA?

Few of the deep uncertainties identified in the previous step obstruct the implementation of Warning ISA. In fact, Warning ISA is already available on some navigational devices. An interesting result is that the uncertainties that were considered to be important barriers for Assisting and Restricting ISA were generally not evaluated as the most uncertain. The experts felt that the most important barriers to implementing Assisting and Restricting ISA are: uncertainty regarding liability, uncertainty regarding acceptance (willingness to use, willingness to buy, factors that contribute to acceptance), uncertainty regarding the effects of different implementation strategies, and uncertainty regarding different stakeholders and their importance.

4. What are the most important research needs, from the perspective of facilitating the implementation of ISA?

Since Warning ISA is already being implemented, the most important research needs for Warning ISA should be focused on speeding up ISA implementation. Governments can help by taking action to supply speed limit information and standardizing speed limit databases (which is also important for other types of ISA).

For Assisting and Restricting ISA, we identified the most important research needs based upon both the extent to which an uncertainty was indicated to be a barrier and its level of uncertainty. Fundamental research is needed into:

- the effect of external developments on the implementation of ISA
- behavioral adaptation of drivers that use ISA (counteractive behavior)
- the effect of ISA on other (not speed choice related) drive-task related behavior of ISA users
- the effect of different ISA implementation strategies on ISA implementation (effect on acceptance issues)
- which stakeholders are involved in implementing ISA and the importance of each for ISA implementation
- stakeholder dynamics

To effectively deal with barriers regarding the speed limit database, cost of implementation, malfunctioning of ISA, and liability issues, organizational effort is required and not necessarily more research. On an organizational level, parties have to agree (upon standards), make agreements (on the cost of implementation), and make decisions (legislative changes and implementation decisions). Uncertainties about long-term effects, large-scale implementation effects, and synergy effects can be dealt with only by starting implementation and monitoring the results. This could, for instance, start with the notion that the implementation of Warning ISA is hampered least by uncertainty, and is already being implemented on a voluntary basis. So, an interesting way to move forward would be a phased implementation (moving from Warning ISA to Restricting ISA). Given the urgency of the road safety problem, it would be better to begin implementation of ISA today rather than tomorrow, which can be facilitated through the use of adaptive policies (see e.g. Walker et al. (2003) and Agusdinata et al. (2007)).

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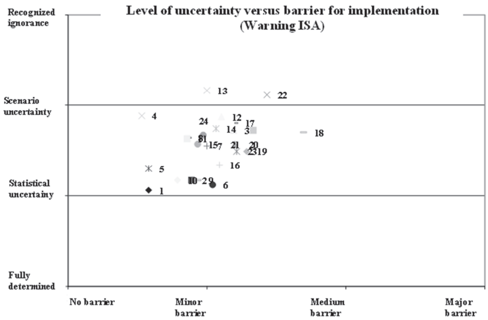
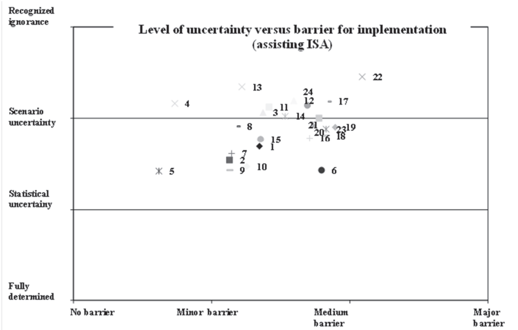
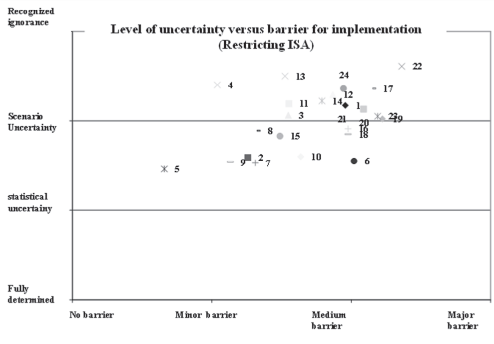
Appendix 1
Level of uncertainty versus barrier for implementation, for three types of ISA

	Uncertainty labels used in figures
1	Uncertainty regarding the effect of external developments on the implementation of ISA
2	Uncertainty regarding the effect of ISA on the speed choice behavior of ISA users
3	Uncertainty regarding the effect of *long-term* ISA use (over 2 years) on the ISA users
4	Uncertainty regarding the effect of ISA on travel behavior
5	Uncertainty regarding the effect of ISA on fuel use and environmental pollution
6	Uncertainty regarding the cost of ISA implementation
7	Uncertainty regarding the effect of ISA implementation on accident and accident outcomes
8	Uncertainty regarding the effect of ISA on the transport network
9	Uncertainty regarding the effect of ISA on driver workload
10	Uncertainty regarding the effect of ISA on the driving comfort
11	Uncertainty regarding the effect of different penetration levels
12	Uncertainty regarding behavioral adaptation of drivers that use ISA
13	Uncertainty regarding behavioral adaptation of other road users
14	Uncertainty regarding the effect of ISA on other (not speed choice related) drive-task related behavior of ISA users
15	Uncertainty regarding the size and nature of the effect of compensatory behavior of ISA users
16	Uncertainty regarding the technical reliability of ISA and the effects of a malfunctioning ISA
17	Uncertainty regarding the effect of different ISA implementation strategies on ISA implementation
18	Uncertainty regarding the technical characteristics and updating of the speed limit database.
19	Uncertainty regarding the willingness of people to use ISA
20	Uncertainty regarding the factors which contribute to ISA acceptance of car drivers and the degree to which each of these factors contributes to the level of acceptance
21	Uncertainty regarding the amount of money people are willing to pay for ISA.
22	Uncertainty regarding the liability allocation in case things go wrong with the functioning of ISA
23	Uncertainty regarding which stakeholders are involved in implementing ISA and the importance of each of the stakeholders for ISA implementation.
24	Uncertainty regarding the dynamics in stakeholder configuration







4. Exploratory MCDA for Handling Deep Uncertainties

The case of Intelligent Speed Adaptation implementation

In this chapter we develop decision support information that is need for designing ISA implementation policies. By doing this we answer Research Question 2: What decision support tools are suitable for developing a policy for implementing ISA using this approach, and what would decision support information that is generated with this tool look like? We first we explain how we developed a new decision support tool, called Exploratory Multi-Criteria Decision Analysis (EMCDA), that allows policy analysts to perform an ex-ante evaluation of different policy options despite massive uncertainty. Next, we apply the EMCDA method to the case of ISA and assess the effect of different policy options. Finally we draw conclusions regarding E\MCDA and ISA implementation.

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4.1 Introduction

Multi-Criteria Decision Analysis (MCDA) is an important method supporting policy assessment. Since policy problems are increasingly confronted with uncertainty, appropriate handling of uncertainty is critical for a successful MCDA. Failure to deal appropriately with uncertainty will lead to a situation in which decisionmakers fail to make a well informed decision, which may result in a costly policy failure.

There are numerous definitions of uncertainty. “At a most fundamental level, uncertainty relates to a state of the human mind, i.e. lack of complete knowledge about something” (Stewart, 2005), or, as Walker et al. (2003) state, uncertainty is “any departure from the unachievable ideal of complete determinism”. In the past, different categorizations of uncertainty have been developed for the contexts of decision making and decision support (see e.g. Walker et al., 2003; French, 1995). Based upon the literature on uncertainty in the context of decision making, Stewart (2005) concludes that there are at least two broad categories of uncertainty that need to be distinguished:

- External uncertainties, which are the uncertainties related to the consequence of our actions, and
- Internal uncertainties, which are the uncertainties related to the decision maker's values and judgements.

In addition to defining the uncertainties by their location (i.e. internal and external), different levels of uncertainty can be distinguished, varying from uncertainty that can be handled probabilistically (e.g. the probability of rolling a six with a die), up to deep uncertainty (Courtney, 2001; Walker et al., 2003). In this chapter (But also throughout this dissertation), we focus on deep uncertainty. Deep uncertainty refers to situations in which decisionmakers, analysts, and experts do not know or cannot agree on:

1) the system model(s) (i.e. what is the appropriate model that should be used to estimate the effects or consequences of the different policy options on the criteria?),
2) the prior probability distributions for inputs to the system model(s) and their interdependencies, and/or
3) the value system(s) used to rank alternatives (i.e. what are the appropriate criteria to assess the effects of different policy options, and what is the relative importance of each of the criteria for the relevant stakeholders?).

Over the years, MCDA researchers and practitioners have developed a wide range of approaches to handle uncertainty. Leaning heavily on Stewart (2005) and Belton and Stewart (2010), we briefly explain different methods to deal with the locations of uncertainty and their applicability to deep uncertainty. Internal uncertainties can be dealt with using approaches like rough sets and fuzzy sets. However, Stewart (2005) argues that "*internal uncertainties should ideally be resolved as far as is possible by better structuring of the problem and/or by appropriate sensitivity and robustness analysis where not resolvable*". It is these irresolvable uncertainties we are interested in for this chapter. However, for deep internal uncertainties, better problem structuring cannot be used to reduce the uncertainties, because deep uncertainties are considered irresolvable. So, sensitivity analysis or robustness analysis should be used. Current sensitivity analysis is done post hoc, using available computer models and to deal with all kinds of uncertainties. Usually, a small part of the uncertainty space is sampled because traditional sensitivity analysis varies the inputs of a model one at a time or a limited number simultaneously. Furthermore, traditional sensitivity analysis uses variations of parameter values within bounds indicated by experts or by assigning probabilities to parameter values to indicate the experts confidence in this value. Under conditions of deep uncertainty assigning meaningful probabilities or indicating parameter bounds is impossible. Instead robustness analysis is used based on the use of robustness as a decision criterion. Implicit assumptions of robustness analysis are that the consequence model is known and that it is possible to determine a representative range of alternative futures (Rosenhead et al. 1972; Rosenhead, 1980). We argue that under conditions of deep uncertainty this is impossible. For external uncertainties, Stewart (2005) identifies three types of approaches:

- probabilistic approaches, which can not be used for deep uncertainty, because it is impossible to assign meaningful probabilities;.
- pairwise comparison approaches, which are designed to deal with the uncertainties regarding the development of a full utility model/function. How to use pairwise

comparisons under conditions of deep uncertainty is not discussed in literature;
- integration of scenario planning and MCDA. The use of scenarios is done from time to time in MCDA (Goodwin and Wright, 2001; Stewart, 2005; Stewart et al., 2010). However, incorporating scenarios in MCDA is not standard practice, and a lot of methodological issues remain (Stewart, 2005). In addition, incorporating scenarios and MCDA also assumes that it is possible to identify possible future states of the world (i.e. scenarios).

In essence, current MCDA is equipped to deal with some conditions of uncertainty. However, under conditions of deep uncertainty these methods have their problems (e.g. how to assign probability functions, how to define utility functions, how to deal with uncertainty regarding the appropriate consequence model, etc.). To deal with conditions of deep uncertainty in decision problems that involve both internal and external uncertainty, we propose to use an integrated set of analysis tools (we call this EMCDA). EMCDA provides a way to deal with all the above mentioned problems and is complementary to the above mentioned approaches. The EMCDA approach involves both an extensive sensitivity analysis, which is called Exploratory Modelling and Analysis (EMA), and the use of scenarios. Sensitivity analysis can be used in many different ways (see e.g. French, 2003). In EMCDA, sensitivity analysis is used to inform and challenge thinking. If one wants to use a sensitivity analysis to inform and challenge thinking under conditions of deep uncertainty, it is important to have a clear overview of all the uncertainties involved in the decision, and as such to have a complete overview of the relevant uncertainty space. Using EMA makes it possible to make huge numbers of computer runs, allowing analysts to sample the complete uncertainty space. EMCDA provides a way to incorporate a relatively large number of scenarios in the analysis, which makes it possible to take into account as many relevant scenarios as needed. The uniqueness of EMCDA is that the uncertainty space can be mapped and explored in a structured and consistent way, which allows for a structured way of reasoning about the system's behaviour and the consequences of different policies given a large uncertainty space. Because the whole uncertainty space can be mapped and explored (by, for instance, varying all uncertain input and model parameters over all plausible consequence models), EMCDA allows for detecting situations in which the outcomes of policy options need further investigation (e.g. situations that can be considered 'unknown unknowns'). EMCDA is explicitly designed to be used to reason about the system's behaviour. It uses simple models that allow for huge numbers of model runs. The fact that EMCDA is explicitly designed for reasoning about the system's behaviour makes it fundamentally different from tools that are currently used for this purpose (e.g. sensitivity analysis using best estimate models).

An example of a policy problem that is surrounded with deep uncertainty is the implementation of Intelligent Speed Adaptation (ISA). ISA is an in-vehicle, technological system that prevents the driver from speeding by providing warnings to the driver, assisting the driver (e.g. with a haptic throttle, which provides resistance above the speed limit), or even restricting the driver from exceeding the speed limit (e.g. the dead throttle, which makes it impossible to drive faster than the speed limit). ISA has the potential to significantly contribute to road traffic safety. Research suggests a reduction of the number of fatalities to up to 59% (e.g. Carsten, 2000). Although, research and pilot projects have shown that ISA is technically feasible and can significantly contribute to traffic safety, large-scale implementation is still far away. An important reason for this is that many aspects relating to ISA implementation are deeply uncertain (e.g. will drivers accept ISA and how to model the traffic safety effects of ISA).

The chapter makes the following two contributions to the current literature on MCDA:

- It specifies an Exploratory MCDA approach that can be used for conditions of deep uncertainty for both external and internal uncertainty, by integrating of EMA and scenario analysis into MCDA.
- It illustrates the approach by applying it to the policy problem of developing future ISA implementation strategies, which is characterized by deep uncertainty.

In Section 4.2, we explain in more detail the EMCDA approach and the underlying concept of Exploratory Modelling and Analysis. Section 4.3 describes the case of ISA and why we have chosen to use it. It also shows how the EMCDA approach can be applied to the ex-ante evaluation of ISA implementation strategies. In Section 4.4, we draw conclusions for both the EMCDA methodology and for ISA implementation.

4.2 EMCDA to deal with the uncertainties in assessing ISA implementation policies

4.2.1 Deep uncertainties

There are numerous ways to categorise, and classify the uncertainties that decisionmakers, analysts and experts can encounter in the process of (model-based) decision support (see e.g. French, 1995; Walker et al., 2003; Stewart, 2005). As explained in the introduction, Stewart (2005) concludes that there are at least tw*o very broad locations of uncertainty: internal and external uncertainty. In addition to distinguishing the location of the uncertainty, it is important to recognise that there are different* levels of uncertainty in both locations. As mentioned above, Courtney (2001) and Walker et al. (2003) have distinguished four levels of uncertainty (Level 1 through Level 4), with two extremes: determinism at one end and total ignorance at the other. Deep uncertainty pertains to Level 3 and Level 4 uncertainties.

Level 1 and 2 uncertainties are the uncertainties that can be dealt with using fairly traditional, straightforward methods. Level 1 uncertainty refers to uncertainty where we know what the consequences of a decision are and we also have a good idea of how likely it is that that these consequences will occur. These situations are dealt with using point estimates, a single forecast (trend analysis), and specifying confidence intervals. For Level 2 uncertainty we know the possible range of consequences of a decision and we know how likely it is that certain consequences will occur (i.e. their probabilities). Level 2 uncertainties are often dealt with using several trend-based scenarios in combination with their relative likelihoods of occurrence (probabilities).

Level 3 uncertainty represents deep uncertainty about the mechanisms and functional relationships being studied. We know neither the functional relationships nor the statistical properties, and there is little scientific basis for placing believable probabilities on scenarios. In the case of uncertainty about the future, Level 3 uncertainty is often captured in the form of a wide range of plausible scenarios.

Level 4 uncertainty implies the deepest level of recognized uncertainty; in this case we only know that we do not know. Recognized ignorance is increasingly becoming a common feature of our existence, because catastrophic, unpredicted, surprising, but painful events seem to be occurring more often. Taleb (2007) calls these events “Black Swans”. He defines a Black Swan event as one that lies outside the realm of regular expectations (i.e., “nothing in the past can convincingly point to its possibility”), carries an extreme impact, and is explainable only after the fact (i.e., through retrospective, not prospective, predictability).

It is a challenge to provide meaningful decision support under conditions of deep uncertainty. Current MCDA researchers and practitioners have dealt extensively with Level 1 and Level 2 uncertainties using probabilistic approaches to deal with external uncertainties, and approaches like fuzzy set, rough set, and possibility theory to deal with internal uncertainties. Level 3 internal uncertainties are often dealt with using sensitivity analysis and using approaches that define an optimal solution amongst an uncertainty range (Stewart, 2005). Level 3 external uncertainties are also dealt with using sensitivity analysis and the integration of MCDA and scenario analysis (e.g. Goodwin and Wright, 2001; Montibeller et al., 2006; Stewart et al, 2010). To our knowledge, there are no examples of a MCDA approach that explicitly deals with Level 4 uncertainties. In this chapter, we deal with Level 3 and Level 4 uncertainties by applying an approach that incorporates scenario analysis to deal with deep external uncertainties related to uncertainty that arises from uncertainty about the external world (basically, these are factors that are not controllable by the decisionmaker but may influence the outcomes of his decision significantly (i.e. exogenous influences)). An extensive sensitivity analysis (called Exploratory Modelling and Analysis) is incorporated in EMCDA to deal with the irresolvable deep internal and external uncertainties.

4.2.2 Exploratory Modelling and Analysis

The core of the EMCDA approach is a method called Exploratory Modelling and Analysis (EMA). The traditional approach to (consequence) modelling is to develop a 'best estimate' consequence model that can be validated by comparison with real world outcomes. This consequence model can then be used as a surrogate for the real world system (i.e. the description of the policy field), using it either to predict the consequences of certain policies or to inform and challenge thinking among decisionmakers. In cases in which there is little uncertainty about the correct consequence model (i.e. the model can be fairly well specified and validated, and probabilities can be assigned to variables), this approach can be successfully used for predicting outcomes, and therefore for supporting decisions. Under conditions of deep uncertainty, however, it is very hard to build a consequence model, and it is impossible to validate it. In situations with deep uncertainty, relying on a 'best estimate' model to predict system behaviour can result in the choice of a very poor policy, even when this model is used to reason about the system's behaviour. Therefore, rather than attempting to predict system behaviour, EMA aims to analyze and reason about the system's behaviour by using a large ensemble of consequence models (Bankes, 1993). This is closely related to the "building understanding" purpose of sensitivity analysis, as suggested by French (2003), and using the model to inform and challenge thinking, as indicated by Belton and Stewart (2010).

How can EMA be used to reason about a system? Under conditions of deep uncertainty, even a model that cannot be validated can still be useful (Hodges, 1991). One use is as a hypothesis generator, to understand the behaviour of a system. A combination of input and system variables can be established as a hypothesis about the system. One can then ask what the system behaviour and its outputs would be if this hypothesis were correct. By constructing a large number of these sets, one may get insights into how the system would behave under a large variety of assumptions, provided that the rationales of the argument from premises to conclusions are clear and correct. In particular, EMA involves exploring a wide variety of scenarios, alternative models, different states of the system, and alternative value sets. The exploration is carried out using computational experiments. A single computational experiment is a computer run for one set of assumptions (a plausible hypothesis) about the external scenario, the consequence model, and the set of weights. EMA aims to "cover the space of possibilities", which is the space created by the uncertainty surrounding the many variables.

Where traditional sensitivity analysis varies the inputs of a model one at a time or simultaneously (see e.g. French et al. 2009), EMA not only varies the input parameters of the consequence models but also the consequence models themselves, allowing for completely different consequence models with different model structures. Traditional sensitivity analysis either varies the input by deterministic variation (a variation of parameter values within bounds indicated by experts) or by stochastic variation (the analyst assigns probabilities to parameter values to indicate his confidence in this value) (French et al., 2009). However, in cases of deep uncertainty, stochastic variation can not be carried out, since assigning probabilities is (by definition) impossible. EMA uses "fast and simple" models (i.e. models with a relatively low resolution (Bankes, 1993), which allows for huge numbers of model runs. The inputs can be varied, in different ways (using e.g. a full factorial design, Latin Hypercube sampling, etc.), allowing for all plausible combinations of parameter values to be tried over a large number of structurally different consequence models.

Figure 4-1, summarizes the EMCDA process. As shown in the figure the uncertainty regarding the external world on the system of interest is explored by using different scenarios. In addition different policy options and different strategies (which are combinations of policy options) can be simulated. Different system structures can be explored by varying the relationships among the system's elements (i.e. by assuming different consequence models). For example, alternative functional relationships can be considered; also alternative parametric values, behavioural rules, or even theories. In addition, EMCDA can provide insights into the interactions among uncertainties in the variables within the model. EMCDA also allows for including different criteria weights in the analysis. So, the current preferences of both decisionmakers and parties involved in the decision (i.e. stakeholders) can be included in the analysis, as well as guesses about their future preferences, by using multiple sets of weights. These weights are integrated in the analysis by using assumptions regarding different current and future weights and combining them with the outcomes of the hypotheses about the system.

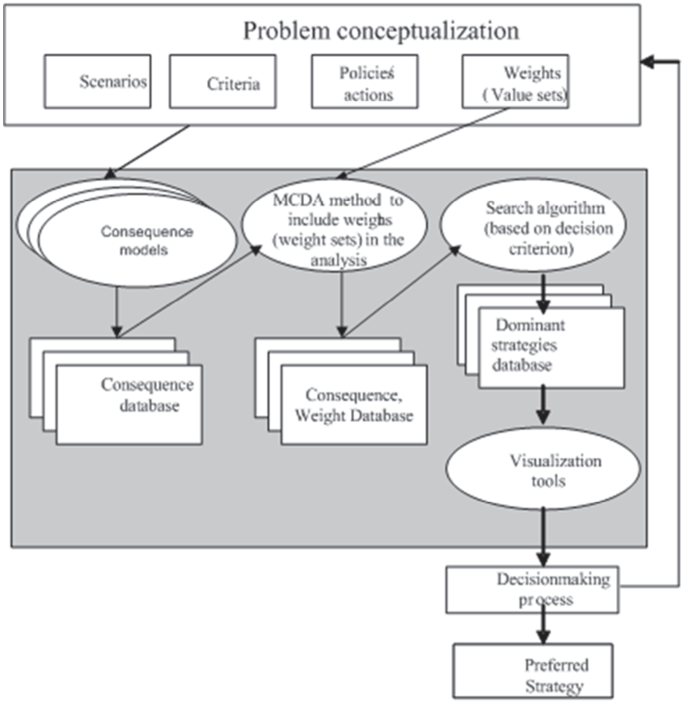


Figure 4-1 The EMCDA process (based on Agusdinata et al., 2009)

To summarize, EMCDA integrates the principles of EMA and MCDA. The conditions of deep uncertainty require the use of a model not as a predictor but as a hypotheses generator. The use of "fast and simple models" allows us to make large numbers of runs. With EMA, the uncertainty space can be mapped and explored, which allows for a structured way of reasoning about the system's behaviour and the consequences of different policies. Each run is treated as a hypothesis about what would happen if the underlying assumptions were correct. Thus, any statements about likelihood are avoided. They can be added later in the analysis.

4.2.3 Steps in EMCDA

The EMCDA approach consists of a number of steps that are derived from Policy Analysis, EMA, and MCDA (Based upon: Walker, 2000; Majone, 1985; Hellendoorn, 2001; De Brucker, 2004). They are summarised in Figure 4-1, and are explained below.

1. *Conceptualise and analyse the policy problem*: the first step in Policy Analysis is perhaps also the most crucial task for analysts and involves identifying the right problem. More often, decision failures are caused *not* by getting wrong solutions but by solving the wrong problem (Ackoff, 1974). In addition to identifying the policy problem, this step can involve: identifying stakeholders, determining alternative actions (i.e. policy options), analysing the external environment, determining constraints, specifying goals and objectives, defining policy success and criteria to measure the extent to which goals and objectives are met.

2. *Uncertainty analysis:* often this step is handled as part of Step 1, but for problems that are surrounded with deep uncertainties the uncertainty analysis is made explicit in a separate step (in Figure 4-1, this is implicitly incorporated in the problem conceptualisation)
    a. Specify the uncertainties relevant for consequence modelling (these are the external uncertainties as mentioned by Stewart (2005)).
    b. Specify the uncertainties regarding the criteria weights (these are the internal uncertainties as mentioned by Stewart (2005)).
3. *Impact assessment*
    a. Build consequence models (reflecting the external uncertainties)
    b. Carry out computational experiments to produce the consequences for each of the alternatives (expressed as a value for each of the criteria defined in step 1) for each of the models. This results in a consequence database.
    c. Determine the ranking of alternative policies across the uncertainty space, assuming the criteria are equally important.
4. *Include the weights in the analysis:* determine alternative weight sets for the criteria and apply a method to integrate the weights in the analysis (this step results in an overall performance database).
5. *Select and apply a decision criterion (or a set of criteria) for selecting the best policy:* define a criterion that can be used to select the best policy. Here a decision criterion is selected which will be used to select the best policy. (E.g optimality, robustness, etc.). After this step we end up with a database containing the dominant strategies (e.g. the most optimal, most robust, etc.) (also see Figure 4-1).
6. *Display the results of the EMCDA in a useful way for policymaking:* here the analyst applies visualisation tools (e.g. scorecards, tables, etc.) to present the results to decisionmakers and other stakeholders.

How do these steps relate to the current process of MCDA as described by Belton and Stewart (2010)? The EMCDA steps can be allocated to the MCDA process as follows: Steps 1 and 2 are part of the 'problem structuring' phase. A variety of methods and tools can be used in this phase (see e.g. Franco, et al. 2006; Franco, et al. 2007). Steps 3 and 4 are part of the 'model building phase'. Steps 5 and 6 are part of the 'using the model to inform and challenge thinking' phase.

In the next section, these steps will be illustrated in more detail by applying them to a real world policy problem.

4.3 Case study: Intelligent Speed Adaptation

In this section, we apply the EMCDA approach to the case of ISA implementation. The ISA case is intended strictly as an illustration and not as a thorough Policy Analysis study.

4.3.1 Deep uncertainty and implementation of Intelligent Speed Adaptation.

Each year an estimated 1.2 million people are killed in road traffic incidents around the world (World Health Organization, 2004). In 2008 there were 1.7 million reported car accidents in the EU that resulted in injuries. Of these 1,7 million injuries, 300.000 were seriously injured and more than 39,000 people died (European Transport Safety Counsil, 2009). The goal of the EU is to reduce the number of road fatalities by 50% in 2010 as compared to 2001 (European Commission, 2001). However, recent traffic safety statistics show that the EU is not going to meet its goals (European Transport Safety Counsil, 2007). Hence, additional measures are required. Moreover because speeding is a major cause of accidents (and accident severity) and traditional measures are not sufficient new measures are required. A highly promising, new policy measure would be to equip vehicles with an intelligent speed limiter, also known as Intelligent Speed Adaptation (ISA).

Although ISA has the potential to significantly reduce speeding and increase traffic safety, the implementation of ISA goes slow (at this moment no ISA that really intervenes with the driving task has been implemented). Policymaking with respect to ISA is hampered by many uncertainties, including:

- Deep external uncertainty about the effect of ISA on speed reduction and deep external uncertainty regarding the effect of speed reduction on the number of fatalities (see Aarts and Van Schagen, 2006)
- Deep internal uncertainty about the valuation of outcomes of ISA implementation. This relates to the fact that most ISA research involves studying the (current) preferences and choices of vehicle drivers regarding ISA systems. Efforts to explore the values of other stakeholders regarding the outcomes of ISA implementation are limited (Walta et al., 2006).

Few MCDA studies for ISA implementation have been performed in the past. Those that have been performed do not explicitly deal with uncertainties in a sophisticated way. The most commonly used tools used for ex-ante assessment are Cost-benefit Analysis and Multi-criteria Analysis. Macharis et al. (2004) and Macharis et al. (2009) focus on the incorporation of different stakeholder perceptions in MCDA for ISA. In their Multi-actor Multi-criteria Analysis, Macharis et al. (2004) use sensitivity analysis to deal with uncertainty concerning the (future) importance of different stakeholders.

The presence of deep uncertainty and the limited handling of these uncertainties makes the problem an interesting case for the illustration of the EMCDA approach. To illustrate the EMCDA approach, we chose to focus on ISA implementation in the Netherlands. We have done this for several reasons. First, the Netherlands is a front runner in road safety. Although the target for traffic fatalities in 2010 was reached in 2008, policymakers and the general public prefer this number to be much lower. Second, the potential of ISA has been shown in detail for the Netherlands (Oei and Polak, 2002). Third, Dutch stakeholders have shown an interest in ISA as a policy option in the past, and their current preferences have been identified (Morsink et al. 2006). In addition the Dutch Minister of Transport recently indicated that the support of ISA implementation is part of an integrated traffic safety approach that is aimed at reducing the number of traffic fatalities to 500 in 2020 (Eurlings, 2008). There is also a more practical reason the availability of data for the Netherlands. In sum, ISA implementation seems a promising policy to increase traffic safety in the Netherlands and an analysis that deals with the deep uncertainties surrounding ISA implementation in a proper manner might improve the chances of ISA implementation (and traffic safety improvement) in the Netherlands.

4.3.2 Step by step EMCDA for ISA implementation

In the following paragraphs, we apply the steps presented in Section 4.2.3 to assess ISA implementation strategies for the Netherlands. We make several simplifying assumptions and leave out some details, since our purpose is to illustrate what an EMCDA approach for ISA implementation would look like, not to perform a complete Policy Analysis.

Step 1. Conceptualize and analyze the policy problem
The first step in EMCDA is the identification of the policy problem, including: identifying goals, identifying criteria, conceptualising the policy domain, identifying the important stakeholders, and specifying policy options. A graphical representation of the relevant factors is presented in Figure 4-2. Below the figure, we give a brief explanation. (See Agusdinata (2008) and Van der Pas, et al. (2008) for a more complete explanation.)

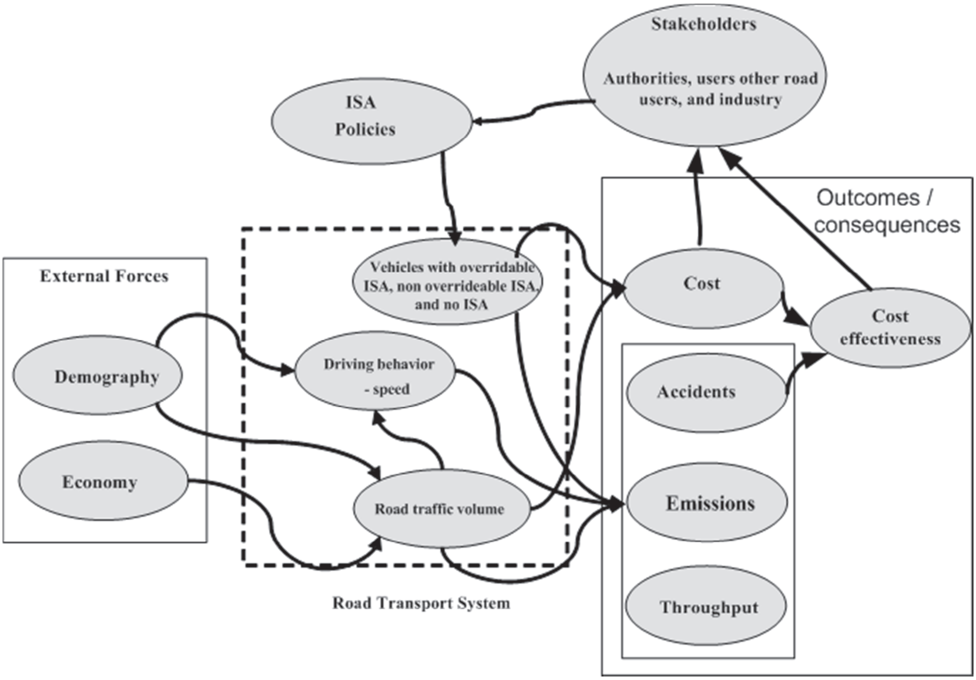


Figure 4-2 Graphical representation of the transport policy domain relevant for ISA implementation

- At the highest level, the problem can be formulated as the gap between a desired level of traffic safety (in terms of e.g. the number of accidents, fatalities, injuries, etc) and the current level of traffic safety. For instance, in the Netherlands, Dutch policymakers want to reduce the number of fatalities from 677 in 2008 to 500 between 2010 and 2020. For this chapter, we assume that ISA implementation is selected as a policy option to make an important contribution to the road safety problem. The secondary objective in this case is to develop and select the best ISA implementation strategy. Traffic safety is not the only objective for transport policymakers. There are also other transport objectives, such as the reduction of vehicle emissions and reduction of congestion.
- So, our criteria are accidents (number of accidents, severity of accidents, etc.), emissions (CO_2 emissions), throughput (capacity per road lane) and implementation cost (the cost of the ISA implementation policy).
- These outcomes can be related to three major relevant factors within the transport system: speed behaviour of the driver(s), road traffic volume, and the level of penetration of ISA within the fleet of vehicles. There are several relationships among these system factors

and the criteria, as can be seen in Figure 4-2. Road traffic safety is influenced by driving behaviour (e.g. speed choice). Speed directly influences the risk of getting involved in an accident and the outcome of an accident. Cost of ISA implementation is related to the number of vehicles that are equipped with ISA. The emissions and throughput are related to driving behaviour (e.g. a decrease in speed variance results in less pollution), the traffic volume (the number of vehicle kilometres driven per year), and the number and type of vehicles that are equipped with ISA. .

- In the past, different stakeholder analyses for ISA implementation have been performed (e.g. Marchau et al., 2002 and Morsink et al., 2007). For our analysis we include the most important: authorities, users, and the automotive industry.
- Various ISA policies can be developed by distinguishing different:
  - ISA user groups (e.g. novice drivers and/or experienced drivers)
  - Road-types ISA can be used on (e.g. urban roads, rural roads, and/or motorways)
  - Vehicle types ISA is mounted on (e.g. trucks, coaches, taxis, passenger cars)
  - types of implementation (e.g. voluntary vs. mandatory ISA retrofit)

  In this study, separate policies for novice drivers and experienced drivers have been evaluated, since young (assumed to be novice) drivers are more likely to speed than old (assumed to be experienced) drivers (e.g. Yagil, 1998). In addition, we assumed that ISA could be used on all roads and that only passenger cars are targeted for the ISA policies. We chose all roads because the technology allows it and therefore the technology should be used to its full potential, and passenger cars are selected because passenger vehicles are most likely to be involved in an accident involving speeding per km driven (SWOV, 2009). We evaluated two different types of ISA, which can be considered as extremes of all possible ISA alternatives:
  - Intelligent Speeding Assistant: an ISA that warns the driver (using a haptic throttle) in case of speeding, and that can be switched off (overridable).
  - Intelligent Speed Limiter: an ISA that prevents the driver from speeding (using a dead throttle) and that can not be switched off (non-overridable).

  Finally, three types of ISA policy implementation were considered: voluntary implementation, implementation by means of some incentive (e.g. a subsidy for consumers in case of purchasing), and mandatory implementation (e.g. obligatory by law).

A combination of a type of ISA (Intelligent Speed Assistant or Intelligent Speed limiter), a target group (young, old, or both) and an implementation measure (voluntary, subsidies, or mandatory) is what is called an implementation strategy. (In this chapter we use the word ‘strategy’ to refer to an ISA implementation strategy.)

Step 2a. Uncertainty analysis: specify the uncertainties relevant for the impact assessment analysis

An important step in the problem structuring phase is identifying and assessing the uncertainties relevant for ISA policy development and assessing whether and/or how they should be incorporated in the EMCDA process (see Figure 4-2). In Table 4-1we summarize the uncertainties for ISA implementation and indicate the level of uncertainty. Appendix 2 indicates how we dealt with each of these uncertainties in our ISA case.

Table 4-1 Overview of uncertainties for ISA policymaking

Category	Uncertainty	Level
External factors	Uncertainty about how the future transport system will look	3-4
Representation of policy domain/ transport system	Uncertainty about the relationship between speed and accidents	3
	Uncertainty about the relationship between capacity and average speed	2
	Uncertainty about driver acceptance of ISA (are drivers willing to buy ISA)	2
	Uncertainty about driver acceptance of ISA (are drivers willing to use ISA)	3
	Uncertainty about the long-term effects of ISA use on acceptance	3
Weights	Uncertainty about current preferences of stakeholders	3
	Uncertainty about future stakeholder configuration and their preferences	4 +
Total	Interaction effects between all the uncertainties	4

First there are deep uncertainties regarding the external factors (i.e factors that are not under control of the policymaker) that have an impact on the road transport system (also see Row 2 of the table in Appendix 2). To deal with these uncertainties, we use a number of scenarios. Each of these scenarios results in a different representation of the future transport system. Each policy measure is then assessed using this future representation of the transport system. A relatively large number of scenarios are available for the future Dutch road transport system (e.g. Dutch Ministry of Transport Public Works and Water Management, 1998; Janssen et al., 2006; Van Beek, et al., 2006).

Second there is deep uncertainty about the correct representation of the transport system (also see Row 1 of the table in Appendix 2). For instance, although there is general consensus that there is a positive correlation between driving speed and accident risk, there are still many debates about the correct representation of this relationship (Aarts and Van Schagen, 2006). Furthermore, there is uncertainty regarding the relationship between road capacity and average speed (Minderhoud et al., 1999). Finally, there is deep uncertainty about the drivers' acceptance of ISA policies. Not only is there uncertainty about how the willingness to buy ISA (expressed in the *penetration level*) is influenced by the implementation strategies, but also about the acceptance of ISA in terms of willingness to use it(expressed in the *level of compliance* (LC)). Different LC's have been reported by different studies, but in fact the actual level of compliance is deeply uncertain (Jamson et al., 2006). In addition, the way ISA policy acceptance might evolve over time is deeply uncertain. After-trial research indicates a decline in the level of compliance in the long run (periods longer then four years) (see e.g Vàrhelyi et al., 2001; Warner et al., 2008). It is important to notice that there are also interaction effects between all the uncertainties mentioned in Table 4-1.

Step 2b. Uncertainty analysis: specify the uncertainties regarding the criteria weights
Deep uncertainty exists regarding the weighing of the criteria (also see Row 4 of the table in Appendix 2). We apply different value sets to deal with this uncertainty. Some research regarding the valuation of outcomes has been performed (Lathrop and Chen, 1997; ADVISORS, 2002; Marchau et al., 2002; Levine and Underwood, 1996; Morsink et al. 2007). But research regarding the possible future stakeholder configuration and their future valuation of outcomes is scarce. In Step 4b we elaborate on how these value sets are defined and how the weights are included in the analysis.

Step 3a. Impact assessment: build consequence models

After the problem structuring and the identification of the uncertainties, we proceed with building the models (see also Figure 4-2). As explained in Section 4.2.2, EMCDA uses "fast and simple" models.

Figure 4-3 shows a graphical representation of the fast and simple model (FSM) that has been developed to explore the impacts of alternative ISA policies (see Van der Pas, et al., 2007; Agusdinata, 2008; Agusdinata et al., 2009 for an extensive description of the FSM). Figure 4-3, is based on the conceptualisation of the policy domain as displayed in Figure 4-2.

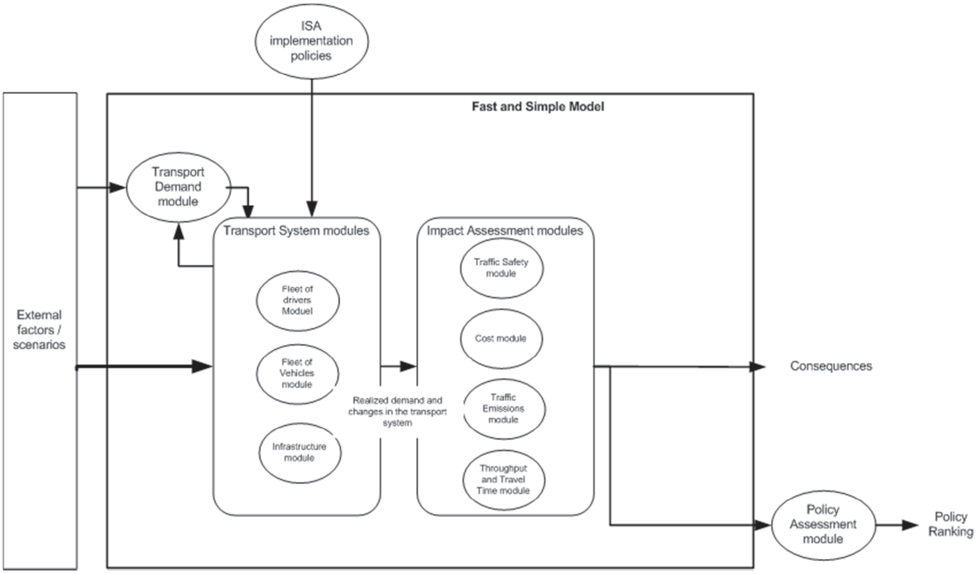
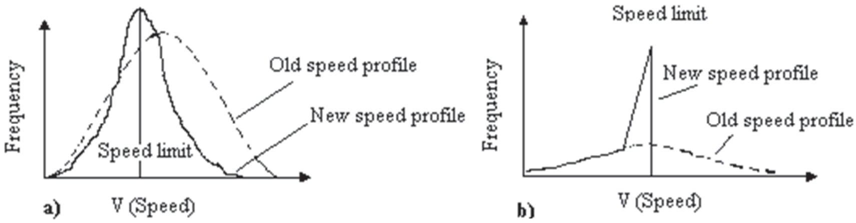


Figure 4-3 Graphical representation of the consequence model

The FSM is composed of several different modules and sub-modules. The core of the FSM is the Transport System module. Several relationships are modelled in the Transport System module:

- The way ISA policies will affect driving speed behaviour: we made a distinction between overridable and non-overridable ISA (see Figures 4-4a and 4-4b). Figure 4-4 shows the speed frequency distribution of drivers and the effect of the two different ISA types on the speed frequency distribution of drivers. An overridable ISA will shift the distribution and will reduce the variance around the speed limit, while non-overridable ISA will truncate the speed frequency distribution around the speed limit. To come up with a mechanism that represents the speed distribution shift as displayed in Figures 4-4a and 4b, we divided the speed frequency distributions into speed classes (e.g. drivers driving at the speed limit -8 km/h, drivers driving at the speed limit, drivers driving at the speed limit + 8km/h, etc.), and we defined (based upon the level of penetration of ISA and the level of compliance with the ISA system) the number of cars that shift from one speed class (e.g. drivers driving with a speed that can be defined as speed limit +8 km/h) to another speed class (e.g. speed equal to the speed limit). We constructed a distribution function for all speed classes, taking into account the whole spectrum of levels of compliance. This translation and transformation mechanism is similar to the translation and transformation mechanisms suggested by Carsten and Fowkes (1998) and Wilmink et al. (2003). Using the effects of the speed frequency shift mechanism and the effects of the external factors on the system, we used the Impact Assessment module (see Figure 4-3) to assess the impact of different actions on the criteria.



a) mechanism for assisting ISA **b) mechanism for restricting ISA**

Figure 4-4 Speed shift mechanism for different types of ISA

In addition to the relationship that describes how ISA policies affect driving speed behaviour, the following important uncertain relationships are modelled:

– The extent to which ISA policies will be accepted by drivers as a direct result of the policy that is implemented (type of ISA, type of measure) and driver characteristics (age, sex, etc.). In addition, to deal with the deep uncertainty regarding the long-term effects, we included two assumptions regarding the long-term effect of Assisting ISA in our model: a lasting effect (a fixed level of compliance for ISA Assisting drivers) and a declining effect (a reducing level of compliance for Assisting ISA drivers). (See Appendix 2 for more information.)
– The (uncertain) way ISA policy implementation will affect traffic safety has been studied by using two different speed-accident risk relationships. The same was done to identify the possible (uncertain) effects of ISA on capacity. (Also, two relationships were modelled using different assumptions regarding safe following behaviour.) (See Appendix 2 for more information.)

Based on combinations of the uncertainties mentioned above, we get alternative models (FSM's), i.e. each FSM will be based on an assumption about the long-term effect of Assisting ISA on the level of compliance, an assumption about the relationship between speed and accidents, and an assumption about the effect of average speed changes on capacity.

To represent the effects of changes due to external factors on the transport system we applied four scenarios as developed and used by the national planning agencies in the Netherlands. These scenarios are called the "*Prosperity and Habitat*" scenarios (Janssen et al., 2006; Van Beek et al., 2006) and are based upon the "Four Futures for Europe" scenarios (De Mooij et al., 2003) and are:

- *Global Economy*, in which there is a lot of cooperation between different countries on a global scale. This leads to a large increase in the demand of transportation of people and goods.
- *Transatlantic Market*, in which there is a liberalization of trade between Europe and the US, leading to an internal market without trade barriers. The growth of transport

demand mainly concerns the transportation of people and goods between the US and Europe.

- *Strong Europe*, in which there is a lot of attention for the internal European market and growth of the EU with East European countries. Furthermore, the EU cooperates with large international trading blocs, such as China and the US. This leads to a large increase in the demand for international transport, mainly resulting in long distance transportation of people and goods all over the world.
- *Regional Communities*, in which the world disintegrates into small isolated trading blocs. Countries stick to their own identity, rights, and laws. This leads to relatively small growth both in trading volumes and global spread.

The differences in mobility (demand and supply) resulting from these scenarios can be explained by four external factors: economic development, the level of development of car ownership, social-cultural trends, and developments in transport systems. For our FSM this meant that we had four different transport demand modules (one for each scenario). In addition, each scenario has an effect on the Transport System module, and in particular, an effect on the fleet of drivers, the fleet of vehicles and on the internal elements and relationships of the future transport system. Although we used only four scenarios here for illustrative purposes, EMA allows a very large number of scenarios, and we have applied many to the case of ISA in the past (see e.g. Agusdinata, 2008).

Finally, we had to set the FSM for different parameter values regarding the uncertain acceptance levels of ISA. We simulated different combinations of penetration level (PL) (which represents the number of systems implemented among a driver group) and level of compliance (LC) (which represents the degree to which drivers listen to the system). The simulated penetration levels were 0%, 10%, 55%, and 100%. These penetration levels were chosen based on reference cases, where 0 and 100% represent respectively no system on the market and mandatory (legislated implementation), and 10% and 55% represent respectively voluntary implementation without and with financial incentives (based on Argiolu et al. 2006). The simulated levels of compliance were chosen depending on the type of feedback. For restricting ISA, a 100% compliance level with the system was simulated, because this system does not allow speeding so the speed limit has to be obeyed. To deal with the deep uncertainty regarding the level of compliance for assisting (overridable) ISA, multiple levels of compliance were simulated: 0% to 100% with intervals of 10% (so 10%, 20%, 30%, 40% ….100%).

Step 3b. Impact assessment: carry out computational experiments to produce the consequences for each of the alternatives for each of the models.

Because EMCDA uses fast and simple computer models, uncertainty about the model can be handled by using multiple models. Furthermore, because of the large number of runs, EMA requires software that will automatically vary the inputs to the models (both for the external factors and the policy options), switch between models, and store the outcomes in an outcomes database. In our research, we used custom designed software called CARs (Computer Assisted Reasoning system) (Bankes, 2002) for these purposes.

So, our uncertainties are reflected in four scenarios, 24 ISA implementation strategies, four different combinations of type of ISA and penetration level, eleven levels of compliance [0% to 100%], different relationships for emissions, throughput, and safety (with two different functions for the speed-safety and speed-throughput relations), one implementation cost function, two assumptions regarding the long-term effects of assisting ISA on the level of compliance, a speed frequency transformation mechanism, and four value sets. (For reasons of structure, we explain the four value sets in Step 4b). Translating this uncertainty space into computational runs, there are 50,688 computer runs made. We assumed an implementation of ISA in 2010 and calculated the effects for the year 2020.

Step 3c. Impact assessment: Determine the ranking of alternative policies across the uncertainty space, assuming the criteria are equally important.

The result of step 3b is a database containing the results of the 50,688 computer runs. Selecting the best policy from all this information is difficult, not only because of the amount of information but also because of the ill-comparability of the different hypotheses regarding the system state and the reference scenario (do nothing). To deal with this problem, we introduce a regret based choice criterion. It has been argued that under a condition of deep uncertainty, a choice criterion based on regret is most appropriate. It is "*one of the more credible criteria for selecting decisions under uncertainty, i.e. when likelihoods of the various possible outcomes are not known with sufficient precision to use classical expected value or expected utility criteria*" (Loulou et al., 1999), since under conditions of deep uncertainty, decisionmakers need only to know the relative performance among these choices and therefore are not burdened with having to predict the precise performance values (De Neufville, 2003). A regret rule focuses on the external factors and model structures that are most relevant to the choice among alternative policies (Lempert et al., 2006). The regret function separates alternative policies that have significantly different outcomes. In addition, relative regret preserves the ranking of strategies contingent on any single probabilistic weighting over expected future states of the world (Lempert et al., 2006).

So, we use a regret based choice criterion to assess policy performance under the conditions of deep uncertainty. Regret benchmarks the consequence of a policy option against the best performing option given a specific hypothesis about the future, where relative regret scales a policy option by the best performance attainable among the candidate policy options in a given scenario. The concept of regret can be explained using a simple illustration. As it is uncertain whether it will rain or not, one will have a high regret if he decides to leave his umbrella at home and it rains. The same is true in case one brings the umbrella and carries it around, but it does not rain. The minimum regret choice in this case is to store the umbrella inside his car and use it as necessary without having the burden to carry it all the time or losing it. The regret of a policy is determined by the difference between the performance of a specific alternative and the best performing alternative given a hypothesis regarding the future state of the system.

Two types of regret are absolute and relative regret (Lempert et al., 2003). The absolute regret of policy p, $p \in \overline{P}$, in scenario s, $s \in \overline{S}$, and model structure k, $k \in \overline{K}$, using value set v is given as:

$$\text{Regret}_v(p,k,s) = \underset{p'}{\text{Max}}[\text{Performance}_v(p',k,s)] - \text{Performance}_v(p,k,s) \tag{1}$$

While the relative regret is given as:

$$\text{Relative\_Regret}_v(p,k,s) = \frac{\underset{p'}{\text{Max}}[\text{Performance}_v(p',k,s)] - \text{Performance}_v(p,k,s)}{\underset{p'}{\text{Max}}[\text{Performance}_v(p',k,s)]} \tag{2}$$

, where policy *p'* indexes through all other policy options to determine the one with the best performance in scenario *s* and model structure *k*.

We defined four relative regret categories (see Table 4-2). Here analysts make "reasonable" judgments about how much regret in various dimensions is worth bothering about. A policy, for example, can be considered to have 'no regret' when the difference of performance to the best policy is less than 5%. (i.e. the range of relative regret, r, is between 0 and 0.049). Note that the choice of the boundaries for success shown in Table 4-2 is based on the intuition of the analyst for this specific case and as such is arbitrary; our choices were made for illustrative purposes only. The detailed process of eliciting these threshold values is beyond the scope of this research. Specific methods are available for the elicitation of threshold values (e.g. von Winterfeldt and Edwards, 1986). Alternatively, one can set the threshold values based on a benchmark of best practices.

Table 4-2 Definition of categories of regret

Regret category	*Range of relative regret, r*	*Preference Ranking*	*Shading for output displays*
No regret	$0 \leq r \leq 0.049$	1	
Mild	$0.05 \leq r \leq 0.94$	2	
A lot	$0.95 \leq r \leq 9.94$	3	
Overwhelming	$r \geq 9.95$	4	

The regret categories also reflect the preference ranking of the impacts of ISA on the criteria. The 'no regret' category can be considered as the most preferred outcome, 'mild regret' as second best, and so on. When a strategy has "no regret" across all the hypotheses regarding the system (being a combination of a scenario and a state of the system), it is considered to be robust. This means that a robust ISA strategy has 'no regret' across a wide spectrum of future transport scenarios, different possible user responses to ISA, and structural uncertainties, such as the relationship between speed and accident risk.

In order to display all the outcomes of the runs performed in Step 3b, the performance of a strategy for a particular state of the system and scenario is compared with that of other strategies and a relative regret value is calculated for that strategy. The relative regret figures are then put into the four relative regret categories defined in Table 4-2. Using the shade designation for each regret category shown in Table 4- 2, the relative regret landscape across the set of scenarios and states of the system is painted for each strategy. An example of such a landscape of regret is given in Figure 4-5.

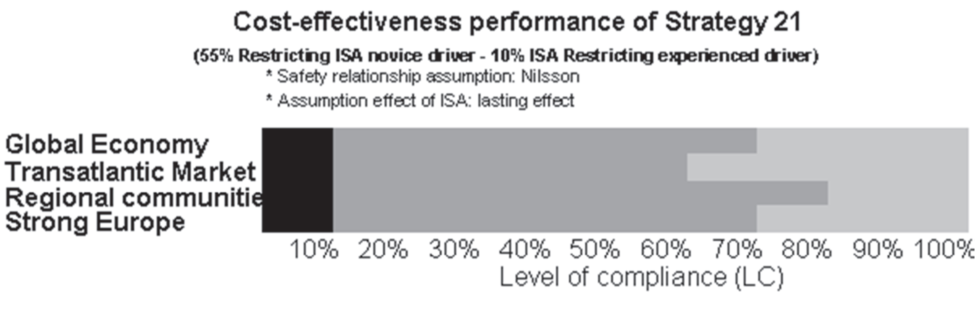


Figure 4-5 Landscape of regret for Strategy 21

One of the twenty-four assessed ISA implementation strategies is to implement restricting ISA for novice drivers (using financial incentives) and restricting ISA for the more experienced drivers based on voluntary implementation. This strategy is numbered Strategy 21. Figure 4-5 shows the landscape of regret for strategy 21, which is displayed per scenario (on the Y-axis) and per 10% increment in level of compliance with the selected ISA system (on the X-axis). Figure 4-5 shows that for the cost-effectiveness criterion under the hypothesis regarding the system state (Nilsson speed- accident relation, assuming a lasting effect of ISA), strategy 21 has overwhelming regret across all scenarios up to a 10% level of compliance. Depending on the scenario, strategy 21 has a lot of regret for levels of compliance up to 60%, 70%, and 80%, and, depending on the scenario, mild regret for the regions between 60%, 70%, 80%, up to 100%. After processing the data, we end up with 348 scorecards, indicating the landscape of regret for each system hypothesis and for each criterion (i.e. 24 strategies, 2 assumptions about the duration of the effect of ISA, 5 criteria (cost, CO_2 emission, safety, throughput and cost-effectiveness), and a total of 8 assumptions regarding appropriate relationships). Up to this point the criteria have been considered equally important. We next add the weights to the analysis.

Step 4. Include the weights in the analysis

The uncertainty about the valuation of outcomes by different stakeholders was handled by including alternative weights per stakeholder. These alternative weights were based on findings from the literature (Lathrop and Chen, 1997; ADVISORS, 2002; Marchau et al., 2002, Levine and Underwood, 1996; Morsink, 2007). Literature shows that the most important stakeholders in the ISA implementation process are the authorities, users, and industry. From this literature we found that safety is indicated to be the dominant criterion. Besides the outcomes for safety (e.g. number of fatalities, number of casualties, and number of material damage accidents), cost-effectiveness (expressed as the implementation cost reduction in fatalities ratio) is another very important criterion, since none of the stakeholders has unlimited funds available for safety improvements. Other criteria, such as environmental impacts, and impacts on throughput and travel time, are of lesser importance, and their rankings depend on the specific stakeholder. Instead of identifying a set of values for each of the three stakeholders, we identified four prominent views from the literature across the three stakeholders. The four value sets capture the variety of views and trade-offs that were found in the literature (see Figure 4-6). Using the four value sets demonstrates how uncertainty regarding the future stakeholder configuration and uncertainty regarding the importance of each of the stakeholders can be included in the EMCDA analysis.

	Highly important	Moderately important		Slightly important
V_1	Safety	Cost-effectiveness	Throughput	Emissions
V_2	Cost-effectiveness	Safety	Emissions	Throughput
V_3	Safety	Cost-effectiveness	Emissions	Throughput
V_4	Cost-effectiveness	Safety	Throughput	Emissions

Figure 4-6 The four applied value sets

Next, the results of the literature study regarding the importance of each of the criteria were used to assign weights to the criteria. The weights were assigned using the Analytical Hierarchy Process (AHP) (Saaty, 1980). Based on the literature, a pairwise comparison matrix was constructed to come up with different weights for the criteria. For illustrative purposes, we established that in value set V1, the safety criterion is:

- *weakly* more important than the cost-effectiveness criterion (score=3),
- *very strongly* more important than the emission criterion (score=7), and
- *absolutely* more important than the throughput criterion (score=9)

Table 4-3 presents the results.

Table 4-3 Criteria weights across four value sets

Value set V1	Safety	Environment	Throughput	Cost-eff	**Weight**
Safety	1	7	9	3	0,574
Environment	1/7	1	3	1/5	0,090
Throughput	1/9	1/3	1	1/7	0,044
Cost-eff	1/3	5	7	1	0,291

Value set V3	Safety	Environment	Throughput	Cost-eff	**Weight**
Safety	1	7	5	1/5	0,255
Environment	1/7	1	1/3	1/9	0,043
Throughput	1/5	3	1	1/7	0,089
Cost-eff	5	9	7	1	0,613

Value set V2	Safety	Environment	Throughput	Cost-eff	**Weight**
Safety	1	9	7	3	0,574
Environment	1/9	1	1/3	1/7	0,044
Throughput	1/7	3	1	1/5	0,090
Cost-eff	1/3	7	5	1	0,291

Value set V4	Safety	Environment	Throughput	Cost-eff	**Weight**
Safety	1	5	7	1/5	0,255
Environment	1/5	1	3	1/7	0,089
Throughput	1/7	1/3	1	1/9	0,043
Cost-eff	5	7	9	1	0,613

Step 5. Select and apply a decision criterion (or a set of criteria) for selecting the best policy

Including the weights in the analysis results in an overall performance value for each of the assessed alternatives for each of the different value sets and each of the hypotheses regarding the state of the transport system (the overall performance database, Figure 4-2). To compare the performance of the policies under each of the four value systems, a final analysis must be performed (using the relative regret principle, see Formula 2). This final analysis will indicate which policy is most robust given a value system and a hypothesis regarding the future state of the system.

To compare the performance of the policies under each of the four value systems, we introduced a robustness criterion (relative regret). As we did with the value sets, we perform a pairwise comparison, applying a 1-9 scale to establish a rating reflecting the overall performance of a strategy (this to make our qualitative score quantitative). For instance, a certain strategy under one circumstance that yields ‘no regret’ is more valuable than another strategy under the same circumstance that yields ‘overwhelming regret’ (i.e. the cell for no regret-overwhelming regret is assigned score = 9). The rating takes place for each cell of the regret scorecard, resulting in a “weight” for each of the regret categories (i.e. the performance value). The resulting performance value for each regret category is given in Table 4-4. Note that the weights are assigned to the regret categories based upon common sense, just for illustration purposes of this case.

In EMA, we are not interested in one single best policy given a most probable future, but we want to display the pattern of system behaviour over the entire uncertainty space. After performing the 50,688 computer runs, the performance of a strategy given a certain criterion, state of the transport system, and scenario is compared to the best performing strategy (assuming the same transport system state and scenario), and the relative regret is calculated for that strategy. We end up with a relative regret value for each of the strategies given a certain criterion (safety, throughput, emissions, cost), state of the transport system, and scenario. The regret category of each of the strategies is then translated into a performance value (these are given in Table 4-4), turning the qualitative regret categories into quantitative performance values. In order to determine the overall MCDA score for each of the policies, the performance value of each strategy for each performance criterion is then multiplied by the associated criterion weight belonging to one of the value sets (given in Table 4-3). This is repeated four times, one time for each of the value sets. For this chapter, Table 4-4 has been specified by the authors. In a real Policy Analysis study, decisionmakers would be elicited on how much they preferred each regret category relative to the other. Such preferences would then be converted into performance values in the same way as we established the criterion weights.

Table 4-4 Regret category translated into performance value

Regret category	No	Mild	A lot	Overwhelming	Performance Value
No	1	3	5	9	**0.561**
Mild	1/3	1	3	7	**0.272**
A lot	1/5	1/3	1	3	**0.113**
Overwhelming	1/9	1/7	1/3	1	**0.046**

We end up with the overall MCDA performance score for each of the strategies for each of the hypotheses regarding the state of the system under each of the value sets. Because we are interested in the robustness of strategies across all hypothetical states of the system and across all value sets, we perform an additional robustness analysis (i.e. apply Formula 1) to determine the strategy with the least regret. This results in a database that has to be displayed in a useful way for policymaking in Step 5 (Figure 4-7, shows a graphical representation of the data in this database).

Step 5. Analyze and display the outcomes of the experiments in a useful way for policymaking.

Step 4c results in a database containing all the performance values of the most robust alternatives. This database still has to be displayed in a useful way for decisionmakers. In EMA, we are not interested in one single best policy given the most probable future, but we want to display the pattern of system behaviour over the entire uncertainty space. One way to do this is to use the Classification and Regression Tree (CART) technique (Breiman, 1984). The CART displays the pattern of behaviour in the form of 'if-then' rules. The CART technique applies a non-parametric classification algorithm, which consists of a sequence of binary split mechanisms, to the database of model runs. The algorithm involves an iterative process answering two questions: (1) which input variable in the model should be selected to produce the maximum reduction in variability of the output variable?, and (2) which value (i.e. splitting value) of the selected variable results in the maximum reduction in variability of the output variable? CART is available in most standard statistical data analysis software packages.

Step 6. Select the best alternative.

Figure 4-7 shows the results of the CART. Usually the CART results are displayed in the form of a tree, but because of space limitations we will only discuss its top node. This top node is displayed in the form of a bar graph and shows the summary of strategy performance at the highest aggregation level.

When looking at Figure 4-7 it is important to note that, from the total 50,688 computer runs, only 1260 data points are represented in the tree (which means that out of the 50,688 runs the model made, only 1260 are displayed in the CART analysis). This is because only the best performing strategy (i.e. the first ranking of AHP outputs) is carried into the CART analysis. For our ISA analysis we choose a full factorial sampling, resulting in 50688 runs. For a relatively small model, this is still manageable. For large model, a sampling technique such Latin Hypercube Sampling (or another sampling method) may be used.

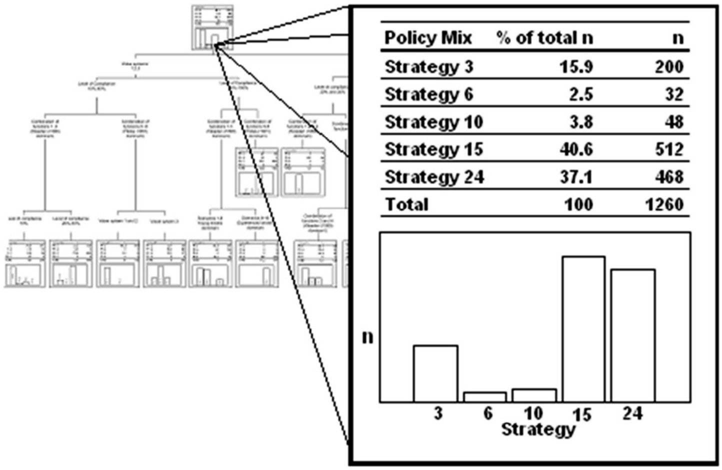


Figure 4-7 Top node of the CART diagram

Based on this illustrative case, we can draw the following conclusions. First, decisionmakers can design a strategy that will perform best in most circumstances. Such a design can be considered as a Static Robust strategy. Looking at Figure 4-7, the top node of the CART-tree shows that Strategy 15 is the most robust strategy to implement. In 40.6% of all the simulated hypotheses regarding the state of the system, this strategy came out to be the most robust. Table 4-5 shows the meaning of the most robust strategies. Looking at Strategy 15 in Table 4-5, we see that the best performing strategy is aimed at implementing restricting ISA for young drivers. The required penetration level of 100% indicates a mandatory implementation (using legislation) is most preferred. Another conclusion that can be drawn is that after 50,688 runs, we ended up with the 1260 best performing strategies. Using CART, we showed that given the large uncertainty space, only 5 out of 24 strategies were ever best performing (see Table 4-5).

Table 4-5 Overview of policies that at least once score best compared to other strategies

ISA strategy	Young drivers (18-24 years old)		Older drivers (24+ years	
	Type of ISA	Simulated PL	Type of	Simulated PL
Strategy 3	Assisting	55%	Assisting	0%
Strategy 6	Assisting	100%	Assisting	0%
Strategy 10	Restricting	10%	Assisting	0%
Strategy 15	Restricting	100%	Assisting	0%
Strategy 24	Restricting	100%	Restricting	100%

PL is penetration level
Assisting is the ISA with haptic throtle
Restricting is the ISA that limits the speed using engine

3.3 The use of EMCDA

Before drawing conclusions we will answer two more questions. As explained in Sections 4.2.2 and 4.2.3 EMCDA should be used to inform and to challenge thinking (reasoning about the behaviour of the transport system). This leads to two remaining questions: 1) how can decisionmakers and analysts use EMCDA to reason to challenge thinking and to reason about the behaviour of the transport system? and 2) how can this reasoning about the system's behaviour be incorporated in policymaking in a meaningful way?

As explained before, EMCDA can be used to reason about the system's behaviour. How can decisionmakers and analysts use EMCDA to reason about this system behaviour? A decisionmaker or analysis can select a policy option based on its performance given the whole uncertainty space or based on a part of the uncertainty space. After, for instance, selecting the best policy given the whole uncertainty space (in our case, strategy 15) the policy analyst can use the richness of the information provided by EMCDA and displayed using CART to explore where in the uncertainty space strategy 15 would be outperformed by other policies. (For this, they would need the full CART, as shown in the background of Figure 4-7.) Although not displayed clearly in Figure 4-7, the CART shows that Strategy 6 outperforms Strategy 15 when the following assumptions are made:

- the safety model of Nilsson (2004) is the appropriate speed-accident model;
- the value set of the decisionmaker is cost dominated (e.g. in times of economical crisis);
- Assisting ISA has a lasting effect (people keep listening to the ISA system);
- the level of compliance with the assisting ISA system is higher than 50%.

In this situation strategy 15 would fail because it is far too expensive compared to strategy 6 which, under the before mentioned conditions, has roughly the same consequences.

How can this reasoning about the system's behaviour be incorporated in policymaking in a meaningful way? Policy analysts can use the richness of the information provided by EMCDA and displayed using CART to develop a Dynamic Adaptive strategy. (For this, they would also need the full CART, as shown in the background of Figure 4-7.) By Dynamic Adaptive strategy, we mean a strategy that has the flexibility to be adjusted to changing circumstances. In our case, such flexibility implies the ability to scale the strategy up or down based on knowledge of the circumstances in which a strategy performs best. This type of analysis supports more recently developed policymaking approaches, such as the dynamic

APM approach suggested by Walker, et al. (2001). Using the full CART diagram and the analysis as preformed to develop the CART, decisionmakers can decide what they have to monitor (e.g. value set, type of ISA, effect etc.), and how the initial policy/implementation strategy should be changed as a response to new developments since the branches of the CART show the performance of each of the strategies given a hypothesis regarding the future system and different value sets. Examples of APM for devices like ISA and for transportation in general can be found in Marchau and Walker (2003), Marchau et al. (2010), and Walker et al. (2010).

4.4 Conclusions

The conclusions of this chapter can be separated into conclusions on ISA implementation (Section 4.4.1) and conclusions on EMCDA (Section 4.4.2).

4.4.1 Conclusions for ISA implementation

The ISA case was initially selected and applied for illustrative purposes of EMCDA. However, if our simplifying assumptions were correct we can draw the following assumptions:

- EMCDA leads to a clear, policy advice. Step 7 indicates that, if one is to implement a static robust strategy, it is wise to select a strategy that focuses on a small group of drivers with high risk (in this case young drivers) with a system that is non-overridable.
- Assessment and development of ISA implementation strategies can greatly benefit from EMCDA, because it gives insights into the effects of potential policy strategies under deep uncertainty.
- EMCDA (or more generally integration of MCDA methods with Exploratory Modelling (EM)) is a very promising ex-ante evaluation methodology for supporting innovative policymaking approaches (like dynamic APM) that could speed up ISA implementation. Instead of trying to reduce uncertainty,
- The approach is aimed at mapping the uncertainty space and looking for consequences for the policy options. This in turn allows policymakers to adequately deal with uncertainties that currently hamper implementation.

4.4.2 Conclusions regarding EMCDA

From the methodological point of view, we conclude that EMCDA contributes to the advancement of research in the area of multiple criteria ranking problems under deep uncertainty. The method as used in this chapter diverts from the common focus on criteria weight uncertainty in MCDA, and introduces an approach to deal with deep uncertainties related to both criteria performance and weight uncertainty. Also, EM can take all of the many different kinds of uncertainty into account – one does not have to bet on one specific future but, can explore the implications of a wide range of futures. Using EM has a large potential to enable the identification of a robust decision in spite of deep uncertainties. Our experience with the method is that, on the one hand, EM requires a lot of work. Building a model that is flexible enough to accommodate different model structures requires a lot of time. However, running the model 50,688 times takes only a few hours. Furthermore, the huge amount of data makes analysis hard. Although software like CARs® incorporates different tools for displaying the results, it is a tough job. EM is more of an art than a science. Each EM effort is different and there is no recipe or cookbook formula for doing it.

The insights into strategy robustness across the uncertainty space were summarized using the

CART technique. The robustness insights include information about the set of conditions and uncertainties under which an ISA strategy performs best compared with other polices. Not only is the information displayed in the CART interesting, but the analysis also produces other valuable information. First the strategies that fall out of the analysis indicate that a lot of these strategies are never the most robust (i.e. never part of the top 5% of most robust strategies). Furthermore, for this specific case of ISA implementation, the CART technique indicates that the "*Prosperity and Habitat*" scenarios (Janssen et al., 2006) make no difference in the outcomes of the CART analysis; i.e., the most robust strategy is always the most robust strategy independent of the specific scenario. This implies that these specific scenarios differ too little and that a broader range of scenarios should be developed for this policy issue.

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Appendix 2 Table with information on uncertainties, the model characteristics and the simulated runs

Source and location			Specific ISA uncertainty	How incorporated in the model	Simulated in paper
1	Uncertainty regarding the right representation of the current transport system	Uncertainty due to the fact that we do not know or cannot agree upon the right system representation	• Speed profile for different age groups of drivers (before strategy implementation	We use three speed frequency distributions for each of the two types of drivers (normally distributed, positive skewed and equally divided)	**Positive skewed for young drivers** **Normally distributed for older drivers**
			• Uncertainty regarding the right relationship between speed and crashes	We use two plausible speed – accident risk relationships, the first one is the relationship as described by Nilsson (2004), also known as the power functions (Aarts and Van Schagen, 2004) $A_2 = A_1\left(\frac{v_2}{v_1}\right)^2$ Formula 1 $I_2 = I_1\left(\frac{v_2}{v_1}\right)^3$ Formula 2 $F_2 = F_1\left(\frac{v_2}{v_1}\right)^4$ Formula 3 Where A_2 is the number of crashes after the speed change and A_1 is the number of crashes before the speed change. V_2 and V_1 respectively represent the average speed after the change and the average speed before the change. Formula 2 shows the adjusted formula for the change in sever injury crashes I, and formula 3 is the formula for the change in fatalities F. The second formula that was used is the formula as described by Finch et al. (source: Aarts and Van Schagen, 2004 (pp. 216)) ΔA = [53.40/1+exp(-0.58*Δmph))]-25.09 Formula 4 Where ΔA is the change in accidents (this is later disaggregated to injury outcome)	**Both relationships are used**

			• Uncertainty regarding the right relationship between speed and capacity changes	We use two plausible fun speed - road capacity relationships The capacity of a single lane depends, amongst others, on the assumptions regarding the safe following distance ($S_{i,min}$). We used two assumptions for $S_{i,min}$: $S_{i,min}=l_i+m_i+z_1 v_1+z_2(v_i)^2$ Formula 5 ($S_{i,min}$ is the safe following distance, l_i is the vehicle length, m_i is a margin, z_1 and z_2 are model parameters, v_i is driving speed) $S_{i,min}=l_i+m_i+(\psi \sqrt{v_{i-1}})$ Formula 6 ($S_{i,min}$ is the safe following distance, l_i is the vehicle length, m_i is a margin, ψ is a model parameter and v_i is driving speed)	**Both relationships are used**
2	Uncertainty regarding the representation of the future transport system	Uncertainty due to the effect of external factors	Uncertainty regarding the effect of different external developments (demographic, economic, political, ecologic, social, technological) on the scenarios variables in the model (e.g. traffic volume, composition of the vehicle fleet, speed-risk relationships)	We use four existing scenarios developed by renown Dutch planning agencies and actually in use for strategy assessment and development. ▪ *Global Economy*, ▪ *Transatlantic Market* ▪ *Strong Europe* ▪ *Relational Communities*	**4 scenarios**
				There is a possibility to develop new scenarios using different scenarios variables.	**Not used**

3	Uncertain effect of the strategy	• Effect of ISA (short term) • ISA penetration level that is reached (acceptance → willingness to buy) • Long term effect of Assisting ISA • Level of compliance of drivers with the system (acceptance → willingness to use) • Uncertainty side effects of ISA like changing driver following behaviour	• We assume 3 different ISA effects on road traffic safety (low/medium/high) • We use a level of compliance for each driver group (between 0-100%) • We use two assumptions regarding the long-term effects of Assisting ISA (lasting and declining effect). Decline in level of compliance over 4 years (year 1 100% of simulated level of compliance, year 2 70% of simulated level of compliance , year 3 50 simulated level of compliance and year 4 30% simulated level of compliance (years after are equal to year 4) • We use levels of penetration between 0-100% for each driver group	**(medium)** **(0%-10%-…100%)** **(Both are used)** **(0% -10% 55% and 100% are simulated)**
4 Uncertainty regarding the valuation of outcomes	Uncertainty regarding the current valuation of outcomes	• Uncertainty regarding the way different stakeholder value certain criteria • Uncertainty regarding the stakeholders themselves (which stakeholder is important)	• We use 4 value sets, assigning different weights to combinations of criteria.	**4 value sets**
	Uncertainty regarding the future valuation of outcomes	• Uncertainty regarding the way different stakeholder will value certain criteria in the future • Uncertainty regarding the stakeholders themselves (which future stakeholder is important)	• We use 4 value sets, assigning different weights to combinations of criteria.	**4 value sets**

5. Operationalizing Adaptive Policymaking

In this chapter we answer Research Question 3: How can we develop a policy that deals with the ISA-related uncertainties using the identified approach, and what would such a policy look like? In this chapter a workshop to develop and test adaptive policies with experts, stakeholders and policymakers is developed. First the design space of tools and methods that can be used to develop adaptive policies with experts is given. Next, tools and methods for the workshop are selected. Finally, the workshop results are presented.

This chapter is currently under review as: Van der Pas, J.W.G.M., Kwakkel, J.H., Walker, W.E, Marchau, V.A.W.J., Van Wee, G.P. Operationalizing Adaptive Policymaking.

5.1 Introduction

Policymakers are continually confronted with uncertainty. As Walker (2000) states: “policymaking is about the future”, and the future is inherently uncertain. For this paper we adopt the uncertainty definition of Walker et al. (2003): *any deviation from the unachievable ideal of completely deterministic knowledge of the relevant system*. Policymakers look for decision support when they are confronted with uncertainty about the future. Modern day decision support works well as long as the uncertainties surrounding the decision problem are not too deep. But what should be done in situations in which the future is so uncertain that analysts cannot agree upon the right model, or do not have a clue about what the future looks like. This paper focuses on decision support under *deep* uncertainty. Lempert et al. (2006) describe deep uncertainty as situations in which decisionmakers, analysts, and experts do not know or cannot agree on: (1) which model is the appropriate representation of the policy domain, (2) the prior probability distributions for inputs to the model and their interdependencies, and/or (3) the right representation of stakeholder preferences that can be used to rank policy alternatives.

There are various ways policymakers can deal with deep uncertainties in practice. In most cases, policymakers will apply tools and methods that are commonly used when it comes to foresight and dealing with uncertainty (see for an overview for instance: Popper et al., 2004;

Technology Future Analysis Methods Working Group, 2004; Fijnvandraat and Bouwman, 2010). Examples of these methods are: scenario analysis (Bouwman and Van der Duin, 2003), and SWOT Analysis (Ansoff, 1987). However, recently a new approach was presented, which is called Adaptive Policymaking (APM) (Walker, et al., 2001). APM integrates aspects of policy design with foresight practice, allowing for policy development under conditions of deep uncertainty. The central notion of the approach is that it accepts the inherent limits to our ability to anticipate the future and, in response, advocates implementing a flexible plan that can be adapted over time depending on how the future unfolds. The potential of APM has been demonstrated by various researchers using cases that reflect real-world policy problems (Agusdinata et al., 2007; Marchau et al., 2008, Agusdinata and Dittmar, 2009, Taneja et al., 2010a; Taneja et al., 2010b, Kwakkel et al., 2010, Marchau et al., 2010). However, APM has seen little practical application. Recently, almost 10 years after the first publication on APM, attention has been given to the state of the art on APM (Kwakkel 2010; Walker et al., 2010). From this review of the state of the art, the following issues and challenges emerged:

1. APM lacks examples of adaptive policies developed by policymakers or domain experts. (Until now, APM has almost exclusively been the subject of researchers who are familiar with the APM concept, but are not connected to real-world policymakers or domain experts (see e.g. Taneja et al., 2010a; Taneja et al., 2010b)).
2. APM lacks well worked out examples of real-world policy problems. The cases found in the literature are almost exclusively illustrative, simplified, 'toy cases'. These cases have been published to illustrate the APM process. Moreover, there are few examples of adaptive policies developed by policymakers or domain experts.
3. APM can be defined as a "high level concept, captured in a flowchart" There is only very limited insight into the tools available that can be used in each of the steps of the APM process (Walker et al., 2010; Kwakkel, 2010). A first indication of tools that can be used to design adaptive policies is given by Swanson et al. (2010). But this overview is still very broad and needs a further in-depth operationalization.

So, on the one hand, scholars claim that policymaking under conditions of deep uncertainty would benefit from developing adaptive policies (Walker et al. 2011, Agusdinata et al., 2007; Marchau et al., 2010; Van der Pas et al., 2011a); on the other hand, APM has seen little real-world application and it is unclear how such an adaptive policy can be developed. (Walker et al., 2010, and Kwakkel, 2010, concluded that insight into tools and methods that can be used for APM is lacking.) This paper aims to overcome this impasse by:

- presenting an operationalization of APM aimed at developing dynamic adaptive policies with experts;
- developing an example for a real world policy problem (the implementation of intelligent speed limiters (so-called ISA devices) for passenger vehicles in the Netherlands);
- reporting not only on the outcome of the process (a dynamic adaptive policy), but also on the process of developing and conducting a workshop, in order to provide guidance to others interested in designing and implementing adaptive policies.

One of the challenges for the field of foresight is to provide a means to develop robust strategies (Challenge #4 mentioned in Technology Future Analysis Methods Working Group, 2004). In this paper we address this challenge by operationalizing APM, an approach aimed at designing robust strategies using foresight exercises.

In Section 2, the concept of APM is briefly explained, and an inventory of tools to support the different steps in APM is made. Section 3 presents the ISA case. Section 4 describes the workshop that was designed based on a subset of the tools which are selected out of the inventory made in Section 2. In Section 3 the workshop is also tested using experts, policymakers, and stakeholders, by applying it to the ISA case. Section 5 presents the results of an evaluation questionnaire that was filled-in by the participants of the workshop. Section 6 presents the paper’s main conclusions.

5.2 Adaptive Policymaking

The aim of this section is to introduce the steps of APM.

APM is a policymaking process with five phases: one phase (Phase I) aimed at setting the stage, three phases (Phases II, III, and IV) aimed at designing the part of the adaptive policy that can be implemented a certain moment in time (call this t=0), and one phase (Phase V) aimed at designing the part of the adaptive policy that is to be implemented at an unspecified time after t=0 (call this t=0+?). Figure 5-1 presents the APM process, together with the elements that comprise an adaptive policy.

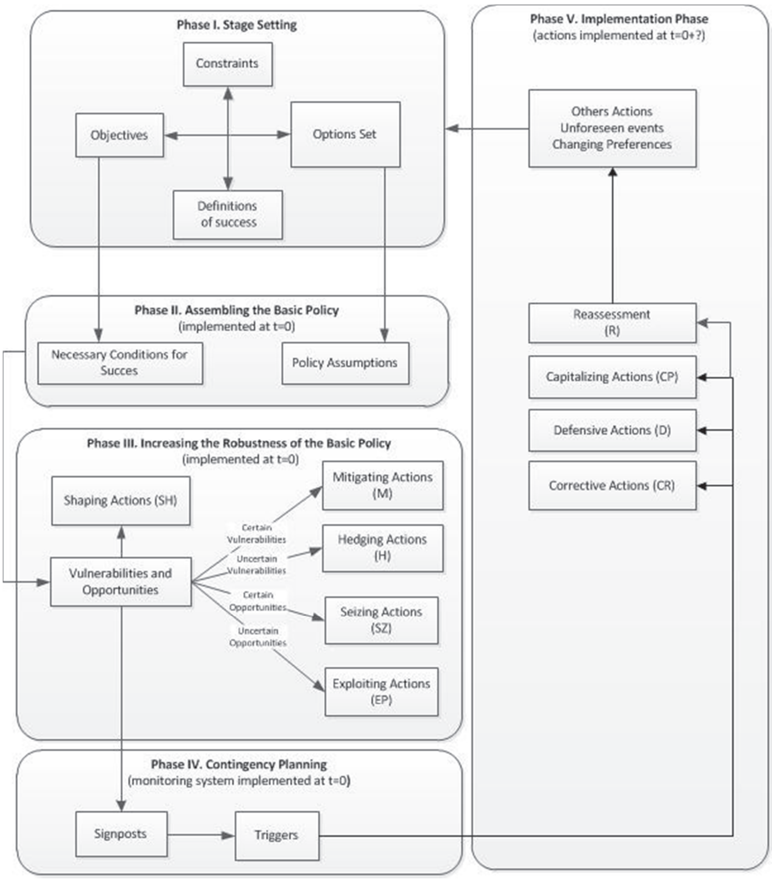

Figure 5-1 The APM process and the elements of an adaptive policy (adapted from Kwakkel et al., 2010)

We now briefly explain each phase, define each of the elements (policy actions), and elaborate on techniques that could be used to facilitate this phase in a workshop setting. For an extensive overview of each of the five phases in the APM process (see Walker et al. (2001) and Kwakkel et al. (2010)). For some example cases, see Marchau et al. (2008), and Marchau et al. (2010).

5.2.1 Setting the stage (Phase I) and Assembling the basic policy (Phase II)

In Phase I, the policy problem is analysed and the goals of the policy are formulated. The right policy problem has to be identified and formulated, goals and a definition of policy success have to be defined, and a comprehensive list of policy options has to be generated. Often, alternatives are mentioned by politicians, policymakers themselves, or other stakeholders.

In Phase II, a basic policy is defined. This is a set of policy actions together with a plan for their implementation. Based on an *ex-ante* evaluation of the policy options identified in Phase I, a promising basic policy is assembled. In this phase, the conditions for success are also formulated. There are many methods that can be used to evaluate the policy options, including cost-benefit analysis (Sassone and Schaffer, 1978), multi-criteria analysis (French et al., 2009), and balanced scorecards (Kaplan and Norton, 1993). These assessment techniques can be combined with the results from forecasts, scenarios, models, etc. Increasing the robustness of the basic policy (Phase III)

After selecting a basic policy, the vulnerabilities and opportunities of the policy are identified. Vulnerabilities of the basic policy relate to ways in which the policy could fail; opportunities are developments that can increase or accelerate the success of the policy. Based upon the vulnerabilities and the opportunities, five types of actions can be defined that should be taken at the time the basic policy is implemented (at t=0) in order to increase the chances for its success:

(1) Mitigating actions (M), actions aimed at reducing the certain vulnerabilities of a policy,

(2) Hedging actions (H), actions aimed at spreading or reducing the risk of failure from the vulnerabilities of a policy,

(3) Seizing actions (SZ), actions aimed at seizing certain available opportunities,

(4) Exploiting actions (EP), actions aimed at exploiting uncertain opportunities;

(5) Shaping actions (SH), actions aimed at reducing the chance that an external condition or event that could make the policy fail will occur, or to increase the chance that an external condition or event that could make the policy succeed will occur.

There are a variety of tools and methods that can be used to identify the vulnerabilities and opportunities of a basic policy. Without claiming to be exhaustive, these techniques can be divided into two broad categories:

1. *Techniques that use (computational) models.* Examples include sensitivity analysis (Satelli et al., 2004), scenario discovery (Bryant and Lempert, 2010), and Exploratory Modelling (Bankes, 1993; Agusdinata, 2008). These techniques can be used to detect vulnerabilities and opportunities by varying model inputs across the range of plausible parameter values (French et al., 2009), or by exploring outcomes across alternative models of the system of interest (Bankes, 1993; Agusdinata 2008).
2. *Techniques that support experts in the process of identifying assumptions, vulnerabilities, and opportunities.* Examples include Delphi, retrospective futurology (Dewar et al.,

2002), annual key bets (Dewar et al., 2002), and Strategic Assumption Surfacing and Testing (Mitroff et al., 1979; Mason and Mitroff, 1981).

Dewar et al. (1993) mention five ways of identifying actions for this phase, all of which can be used in a workshop setting: (1) using relevant theories of causation, (2) using historical and comparative experiences, (3) using creativity (4) using scenarios, and (5) using insurance or regulatory requirements. However, none these techniques offers an approach of identifying the vulnerabilities, opportunities, and related actions in a structured way. SWOT analysis (Strengths, Weaknesses, Opportunities, and Threats) (Ansoff, 1987) and TOWS analysis (Threats, Opportunities, Weaknesses, and Strengths) (Weihrich, 1982) can be used to overcome this problem. TOWS is designed to use the SWOT analysis as input. The SWOT analysis reveals the strengths, weaknesses, opportunities, and threats; TOWS is then used to identify suitable actions in light of the SWOT results.

5.2.2 Contingency planning (Phase IV)

Phase IV aims at defining a monitoring system and specifying when a change in policy should be triggered. There are four different types of actions that can be triggered:

> *(1) Defensive actions (D):* actions aimed at clarifying the basic policy, preserving its benefits, or meeting outside challenges in response to specific triggers. These actions leave the basic policy unchanged,
>
> (2) *Corrective actions (CR):* actions aimed at adjusting the basic policy,
>
> (3) *Capitalizing actions (CA)*: actions triggered by external developments that improve the performance of the basic policy,
>
> (4) *Reassessment (R):* an action that is initiated when the analysis and assumptions critical to the plan's success have clearly lost validity.

Defining signposts and trigger values can be supported through scenarios (Schwartz, 1991), backcasting techniques (Robinson, 1982), expert opinions, and Exploratory Modeling (Bankes, 1993, 2009).

5.2.3 Implementation phase (Phase V)

Once the basic policy and the adaptive elements (Phases I-IV) are agreed upon, these are implemented (call this t=0) and the APM process is suspended until a trigger event occurs. In the context of the workshop, an *ex-ante* evaluation of how the policy could play out can be based on simulation models, scenarios, forecasts, etc. Lasswell (1960) mentions the use pre-test mechanisms (deliberate changes in the context) to asses policies. One way of applying the pre-test principle is by using a wide range of wildcard events and developments (Van Notten, 2004). These can be prepared beforehand, and the performance of the designed policy can be probed by seeing how these wildcards would affect the policy.

5.3 The ISA implementation case

ISA systems take into account local speed limits and warn the driver in case of speeding; some even automatically adjust the maximum driving speed to the posted maximum speed. Since speeding is the major cause of traffic accidents (roughly 1/3 of all fatal accidents are due to inappropriate speed choice (OECD, 2006)), the potential contribution of ISA to traffic safety is high. For instance, fully-automatic speed control devices are estimated to produce up to a 40% reduction in injury accidents (Vàrhelyi et al., 2001) and up to a 59% reduction in fatal accidents (Carsten and Tate , 2000). Recently, the first ISA applications have entered the market. Speed limit information is being added to digital maps, so drivers can be warned about speeding by their navigation device using audio visual signaling (this is called warning ISA). Future ISA can, in addition, intervene with the driving task. Systems using a haptic throttle have been tested in several field trials (e.g. in Lund (Biding et al., 2002), Ghent (Vlassenroot et al., 2007), and Australia (Regan, et al., 2006)). When the driver exceeds the prevailing speed limit, the throttle pushes back (this is called assisting ISA), providing an overridable resistance. Other trials have used a system that doesn't allow the driver to exceed the speed limit (this is called restricting ISA) (e.g., in the UK (Carsten, et al., 2008) and in Finland (Päätalo et al., 2001)).

So, the ISA technology is available and there is experience with using it. Although expectations concerning the positive impacts of ISA are high, there still is a considerable gap between what is technologically possible and what has so far been implemented in practice. The implementation of ISA is hindered by deep uncertainties about the impacts of ISA, due to limited knowledge about such things as future transport demand, the way users might respond to ISA, and the relationship between speed and accidents (Agusdinata et al., 2009; Van der Pas et al., 2010). By selecting the implementation of ISA as a case, we will be developing adaptive policies for ISA implementation.

5.4 The workshop

We operationalized the steps of APM through means of a structured workshop (Figure 5-2 summarizes the setup of the workshop that was developed, an explanation of each of the steps is given in the coming sections). The idea of using workshops to involve actors in solving policy problems that are complex is not new. In 1960 Lasswell propagated the idea of decision seminars to solve problems in groups. Enk and Hart (1985), proposed the idea of using structured workshops to come-up with solutions for policy problems, and Mason and Mitroff (1981) developed the assumption-challenging approach. As was indicated by Geurts and Joldersma (2001), there is no general methodology for a participative policy exercise. Our workshop includes several principles that are mentioned in the literature on participative policy analysis. The three most important principles are: 1) that the participants take part in a policy exercise that is shaped as a structured debate in what Geurts and Joldesma (2001) call an 'Electronic Meeting System" (In this paper this is referred to as Group Decision Room (GDR), 2) the principle of" challenging the major assumptions" that underlie a policy (Mason and Mitroff (1981); Dewar et al.(1993)), in our workshop this is done using a strengths, weaknesses, opportunities and threats analysis (Ansoff, 1987), and 3) to come up with solutions for the identified vulnerabilities and opportunities the participants work together in groups, as suggested by for instance Lasswell (1960).

We used a Group Decision Room (GDR) to support the workshop process. The GDR is a group decision support tool that supports quick and efficient teamwork and generation of information. In a GDR, the participants provide input using a laptop computer that is connected to a Thinktank® server. The (anonymous) results are directly visible to the participants, so participants are confronted with their own input and that of other participants. Also, there is the opportunity to react to each other's input or to add information. Because the information is anonymous, nobody can dominate the discussion.

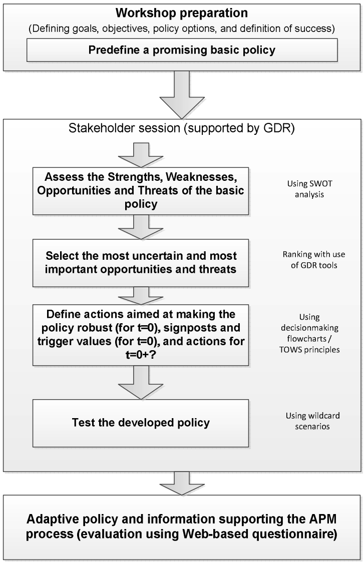

Figure 5-2 Workshop process

For the workshop, we invited (representatives of) the most important actors for ISA implementation, resulting in 17 participants. For the selection of actors we firstly defined actor categories, based on literature (Walta, 2011). Secondly in each category we made a shortlist of potential candidates either because we know them or via contacts we have in the field. The aim was to select participants that match the 'real world' arena in this area as much as possible. Figure 5-3 shows the self-reported fields of occupation of the participants. Representatives of the automotive industry and the insurance companies cancelled at the last moment. Among the participants was a representative of ISA system developers and a consultant for insurance companies. Policymakers, ISA systems developers and interest groups have a 'stake' in this arena, whereas consultancies, policy advisors and scientific researcher do not. Consultants that participated worked in the area of policymaking and transport, and insurance and transport). Based on stakeholder research for the case of ISA, it can be concluded that the most important actors for ISA implementation were represented, at least one representative of each important groups was present (Walta et al., 2006; Walta 2011).

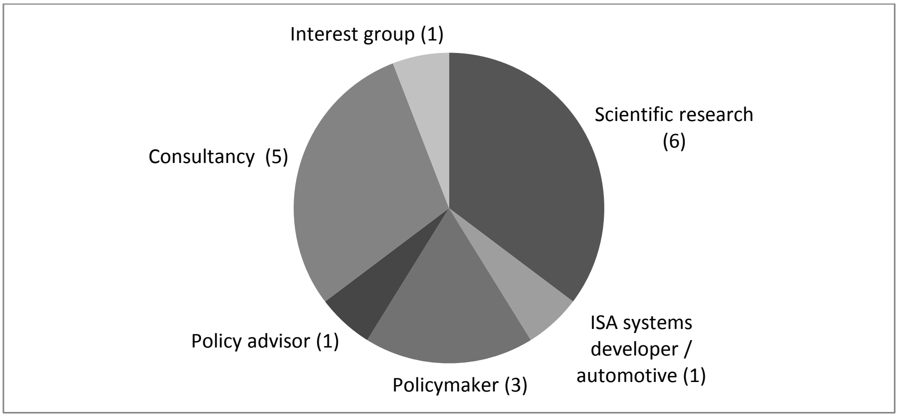

Figure 5-3 Field of occupation of the participants in the stakeholder workshop

5.4.1 Setting the stage (Phase I) and Assembling the basic policy(Phase II) (See Sec. 2.1)

To make sure the participants designed a relevant and realistic adaptive policy, it was decided to use the actual ISA implementation strategy of the Dutch Ministry of Infrastructure and Environment. This would allow policymakers in the Netherlands to use the generated information in their everyday practice, and it allows for a possible *ex-post* assessment comparison (in a few years) of the actual policy and the hypothetical adaptive policy.

The basic policy that was presented to the participants was formulated as follows: The Dutch Ministry of Infrastructure and Environment wants to implement the most appropriate ISA for the most appropriate driver. Three types of drivers are distinguished:

- The compliant driver: This type of driver has the intrinsic motivation to stick to the speed limit.
- The less compliant driver: This type of driver lacks the intrinsic motivation to stick to the speed limit.
- The notorious speed offender: Under the current regime, this type of driver would lose his or her driver's license (and would be obliged to follow a traffic behavior course).

The implementation of ISA consists of two phases. Phase I runs up to 2013. After 2013, a currently undefined Phase II will start. During the workshop, the participants were asked to reflect upon this basic policy. Table 5-1 presents an overview of the basic policy.

Table 5-1 Basic policy

Basic policy Type of driver	Type of ISA	Measure	Definition of success	Constraints
Phase I (2009-2012)				
Compliant driver	ISA (speed alert)	o Start a campaign aimed at persuading people to turn the speed alert functionality on their navigation device on. o Make agreements with companies that develop navigation devices.	Before 2013: 50% of the people that own and use a navigation device actively use the speed alert functionality.	Budget for a campaign.
Less compliant driver (But also the compliant driver)	Free to be selected	o Develop a business case with insurance companies and lease companies.	Before 2013: 50% of the car owners and 50% of lease drivers can choose an insurance or lease product that involves ISA.	
Notorious speed offender	Restricting ISA	o Perform a pilot test aimed at assessing the effects of implementing a restricting ISA for notorious speed offenders. o Make an evidence based decision regarding implementation of such a system for notorious speed offenders.	Before 2013, A decision has to be made on implementation of ISA for notorious speed offenders. Based on, amongst others, outcomes of the trial.	Budget/time
Phase II (2013)				
Phase II will be dependent of the results of phase I. For this phase, more restricting types of ISA will be considered.				

5.4.2 Increasing the robustness of the basic policy (Phase III) and Contingency planning (Phase IV) (See Sec. 2.2 and Sec. 2.3)

Phase III and Phase IV were supported through the SWOT analysis (Ansoff, 1987), and the TOWS (Weihrich, 1982) inspired flowchart, resulting in a five-step process. In Step 1, a list of over 100 different strengths, weaknesses, opportunities, and threats for the basic ISA implementation policy was created. In Step 2, the participants were grouped, assigned one SWOT category, and asked to identify the ten most important items in the assigned category. As a validation, in Step 3, the assigned categories were rotated and each group was allowed to modify the lists identified in Step 2. Steps 2 and 3 resulted in a 'top 10' for each SWOT category. Next, In Step 4, the items in the top 10's were scored by the participants using a five-point scale on their level of uncertainty and their impact on the outcomes of the basic policy. The results were displayed as scatter plots and used during the workshop for the design of actions (Step 5).

Both Phase III and Phase IV of APM involve defining actions. In the workshop, these two phases were collapsed into one step (Step 5): To support defining actions, signposts, and trigger values for the vulnerabilities and the opportunities, the TOWS (Threats, Opportunities, Weaknesses, and Strengths) matrix (Weihrich, 1982) was adapted to use in a GDR setting. TOWS is designed to use the SWOT analysis as input, and to translate the outcomes of the SWOT into actions. Figure 5-4 shows a flowchart that was developed for the vulnerabilities (for reasons of space, the flowchart for opportunities is not shown). Finally, utilizing the decisionmaking flowcharts (see Figure 5-4), the participants were tasked to define actions for handling the vulnerabilities and opportunities. In groups, the participants picked vulnerabilities and opportunities for which they defined actions (using the scatterplot), starting with the high uncertain-high impact items.

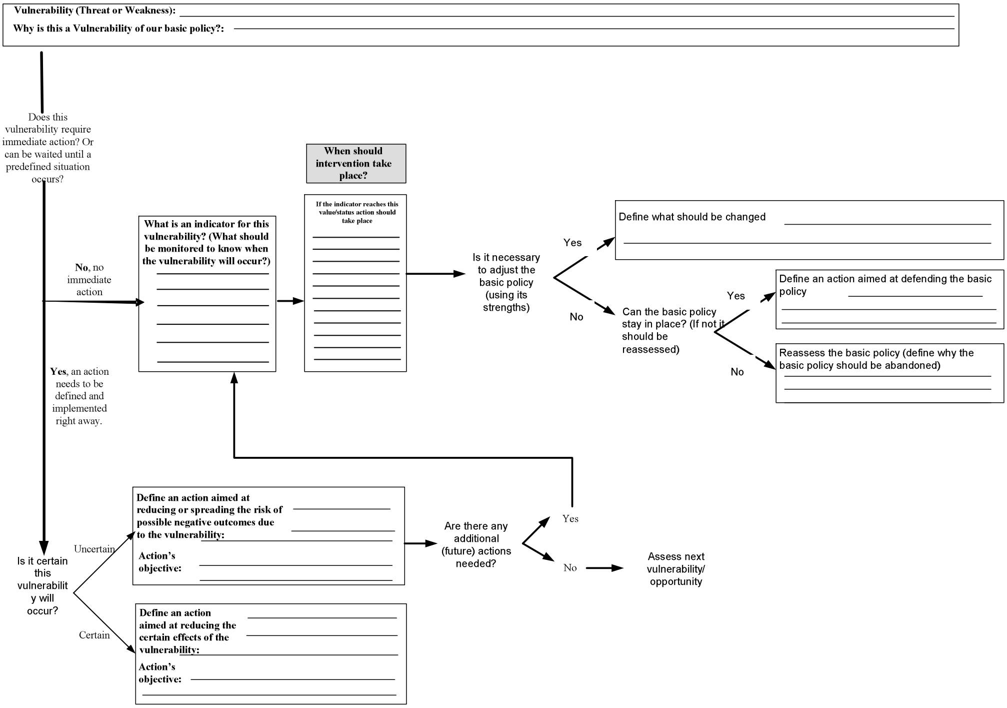

Figure 5-4 Decision-making flowchart for vulnerabilities

'The availability of an accurate speed limit database' is such a high uncertain high impact weakness. Speed limit data have to be correct for the right time (dynamic), the right location, and the right vehicle". The participants discussed whether they should deal with this vulnerability right away or whether they could wait until a predefined situation occurs. In this case, the participants decided that it is important to immediately deal with this uncertainty (so they followed the arrow down in the decisionmaking flowchart in Figure 5-4). Next, they discussed whether it is fairly certain that this vulnerability will occur or whether it is uncertain. Here, the participants discussed the level of uncertainty. Interestingly enough, for this specific vulnerability the participants decided that the effects of incorrect speed limit data are very uncertain, but decided that is fairly certain that this vulnerability will occur, so they filled in the box at the bottom of Figure 5-4.

The participants indicated several actions during the workshop. However not all of the vulnerabilities could be addressed, due to time limitations. Table 5-2 presents a subset of Phase III actions that were generated during the workshop[7].

[7] For reasons of space the complete set is not included and can be found in Appendix 3)).

Table 5-2 Increasing the robustness of the basic policy

Vulnerabilities and Opportunities	Hedging (H), Mitigating (M), Seizing (S) and Exploiting Actions (EP)
Implementing a restricting ISA for notorious speed offenders will damage the image of the less intervening ISA systems. ISA will be associated with punishment not with assistance (like it is now).	**H:** Decouple the pilot from the rest of the basic policy and avoid the term ISA (currently done by calling it speed-lock).
The availability of an accurate speed limit database. Speed limit data has to be correct for right time (dynamic), the right location and the right vehicle.	This is critical success factor, so: **M:** Define who is responsible for what before starting with implementation. **M:** Tender the development of a speed limit database (this should be arranged by public authorities). **M:** Guarantee quality through a third party that is under the supervision of the public authorities. **M:** Develop a system based on bacons that overrule the static speed limit information (Failsafe design).
Automotive lobby, to avoid large scale implementation ISA.	**H:** Include automotive in the implementation strategy.
Speed limit data becomes more and more dynamic.	**H:** Implement ISA systems that are robust against this scenario. So systems that allow for communication with the infrastructure. (systems can use all kinds of signals to transmit temporary speed limits (also dynamic) e.g. radio, Bluetooth.
Cars and ISA draw lots of attention and appeal to people's emotions. Instead of seeing this as a threat this can be used as an opportunity.	**S:** Invite stakeholders that are appeal to these feelings to participate in improving and implementing ISA (e.g. the presenters of top-gear, race drivers, etc.).
People/companies are more willing to adopt technology if they can see the technology in practice. Creating a pool of cars that are equipped can result in an uptake of the technology.	**S:** Practice what you preach. Let the Ministry themselves equip their fleet with ISA and practice an example function. Prove that it significantly reduces the number of accidents and as such results in fewer claims.

Next, using the same decisionmaking flowcharts shown in Figure 5-4, the participants defined the Phase IV actions, signposts, and triggers. A subset of these are shown in Table 5-3.

Table 5-3. Contingency planning

Vulnerabilities and Opportunities	Monitoring and triggering system	Actions: Reassessment (R), Corrective (CR), Defensive (D), and Capitalizing (CP)
Implementing a restricting ISA for notorious speed offenders will damage the image of the less intervening ISA systems. ISA will be associated with punishment not with assistance (like it is now).	• Number of negative press publications. • Level of acceptance of different ISA systems. • Number and type of ISA related questions asked in the politicians in the Lower House.	**D:** Media campaigns to manage the perception of people regarding ISA (and the speed-lock) explain the difference and the need for implementing such an ISA for this type of driver.
The availability of an accurate speed limit database. Speed limit data has to be correct for right time (dynamic), the right location and the right vehicle.	o Level of accuracy/reliability of speed limit database.	Accuracy should be monitored. Next to this: **D:** Start making it more accurate. **Co:** Stop implementation of certain types or combine with on/off switch and overruling possibilities. **Co:** Design the system in such a way that it only warns intervenes in areas with certain accuracy levels.

Technology can fail: • location determination can be inaccurate (e.g. in tunnels, in cities with high buildings). • systems can stop functioning (sensors fail, etc.).	o Cause of accidents (Relationship ISA – cause of accident). o Press releases on ISA and accidents.	**De:** Make sure the market improves the systems (Adjust implemented rules and regulations regarding system functioning). **R:** When large scale failure occurs or the effects are drastic (ISA implementation leads to fatalities).
Speed limit data becomes more and more dynamic.	o Availability of dynamic speed limits.	**De**: Make sure road authorities equip new dynamic speed limit infrastructure with infra-to-vehicle communication (So in vehicle systems can be easily adjusted). **De:** standardization of communication protocol and communication standard.
ISA implementation can result in larger cost savings than expected: by lower and more homogeneous speeds lower consumption costs (fuel savings + lower maintenance), resulting in higher levels of acceptance.	Monitor additional effects of implementation on: o Emissions; o fuel use; o throughput/ congestion.	**CA:** Up scaling of the number of participating insurance companies. **CA:** Use this information in the business case for new insurance and lease companies.

The center column of Table 5-3 can be transformed into a list of indicators that should be monitored: “the monitoring system”. The monitoring system consists of signposts that measure the progress towards the goal (i.e. success), and signposts that are directly related to the vulnerabilities and opportunities.

5.4.3 Implementation (Phase V) (See Sec. 2.4)

To test the dynamic adaptive ISA implementation policy, discontinuity scenarios or ‘wild card scenarios’ (Van Notten, 2004) were used. During the workshop, the participants were asked to think about “what if” certain wildcard scenarios were to occur. They were presented with a number of different scenarios and asked to answer the following questions:

- What would happen to the (road) transport system?
- What would happen to your policy and how would the outcomes of the basic policy be influenced if this scenario were to occur?
- Is your adaptive policy capable of dealing with this scenario?

After Phase IV, the participants were asked to reflect on the developed adaptive policy. This process was supported with wildcard scenarios. Examples of wildcard scenarios that were used are:

- After ISA is implemented, industry starts to develop equipment that misleads the ISA systems, allowing people to speed without the system noticing.
- Current ISA systems use the USA satellite system to determine their position. The Americans “play” with the accurateness of the system. In times of war the system is more accurate than in times of peace. In 2013, the U.S. is no longer at war and the accuracy is reduced. After 2013 the system becomes so inaccurate that safety issues arise.

These wildcard scenarios led to interesting (and lengthy) discussions, the full value of which could not be captured, because only the answers to the questions were documented and not the discussions that took place. A total of nine wildcard scenarios were assessed; in six cases, the groups indicated that their policy was capable of dealing with the wildcard scenarios. In three cases, additional actions were needed. In the open questions asked to the participants in the follow-up questionnaire, they explicitly indicated that they appreciated the wildcard scenario portion of the workshop, and stressed the added value of these scenarios.

5.5 Evaluation of the workshop

In addition to the above assessment of the outcomes of the workshop, we also used a (Web-based) questionnaire to elicit the participants' opinions about the workshop. We had 17 multiple choice questions (using a five-point Likert scale)[8] and some open questions. The results from two of the questions are displayed in Table 5-4, using the five-number summary (Agresti and Finlay, 1997).(Q1 represents the first quartile, and Q3 represents the third quartile. Max is the Maximum value the respondents indicated and Min is the minimum value, in addition the median is given in the first column). The five-number summary was selected because it is a clear and easy to understand way of presenting the results, and it allows the reader to gain a direct insight into the most important characteristics of the distribution of the answers.

Table 5-4. Suitability of tools and methods.

#	Workshop	Median1 [*]	Q1	Q3	Max	Min	N [**]
1	Today's workshop is suitable to develop adaptive policies.	4 [1]	3	4	4	2	18 [0]
2	The generated strengths, weaknesses, opportunities and threats, and the defined actions, signposts and trigger values can be used when developing in the on-going effort of developing ISA implementation policies for the Netherlands	4 [1]	4	5	4	3	18 [0]

1= strongly disagree, 2= disagree, 3= neither disagree, nor agree, 4= agree, 5= strongly agree
[*][indicates the interquartile range]*
[**][Indicates the number of respondents that answered "don't know']*

As can be seen from the table, the participants were very positive about the suitability and usefulness of the workshop for developing adaptive policies. Furthermore, they thought that the elements of the adaptive policy (actions, monitoring system, etc.) were useful for ISA implementation in the Netherlands. For an in-depth analysis of the results from the questionnaire, and an overview of the complete evaluation, see Van der Pas et al. (2011b).

5.6 Lessons learned about the process of developing adaptive policies

In this paper, one of the challenges left for the field of foresight was addressed (Challenge #4 mentioned in Technology Future Analysis Methods Working Group, 2004). This challenge was addressed by designing an integrated approach to develop robust policies. We included foresight exercises (performing SWOT, the use of wildcard scenarios, etc.) in the process of designing a robust policy with the use of APM. In addition, we tested this approach with experts, stakeholders, and policymakers, and evaluated it using expert opinions. When it comes to systematically integrating a foresight exercise with policy design, our research shows that the workshop we designed is promising, and does result in usable robust policies. However, better ways are needed to identify the signposts, and trigger values. This information could come from the use of other foresight methods. In addition, a promising technique to do this might be Exploratory Modeling and Analysis (EMA) (see e.g Agusdinata, 2008; Van der Pas et al., 2010). Future applications of EMA in the context of APM should prove its usefulness for identifying signposts and trigger values.

Here we address the most important lessons learned in the process of designing the workshop and running it with experts, policymakers, and stakeholder representatives. A first observation is that in APM, two moments of implementation are defined (when implementing the basic

1= strongly disagree, 2= disagree, 3= neither disagree, nor agree, 4= agree, 5= strongly agree policy (t=0) and after implementation, when a trigger value of a signpost is reached). However, in practice there are also actions that need to be taken and implemented before t=0. These are often related to the political process. During the workshop, experts had troubles deciding when to implement these.

Second, the participants indicated that a vulnerability or opportunity is not either 100% certain or uncertain, as is suggested in the APM scheme. There is a scale ranging from certain to uncertain, resulting in the fact that it can be assessed to be fairly certain or uncertain at the same time. Consider, for instance the vulnerability "technology can fail, location determination can be inaccurate". It is fairly certain that this will occur. However, one stakeholder judged this as uncertain, because the effects when it occurs are uncertain. This results in the fact that one can define mitigating actions (e.g. provide warning to drivers when system fails), but also reassessment actions (in case fatalities with the system occur). Distinguishing between the uncertainty of occurrence and the uncertainty of the impact when it occurs is an important distinction that should be made when developing adaptive policies.

Third, after the assessment of vulnerabilities and opportunities, a choice can be made whether to handle it through actions to be taken immediately or whether it requires future actions in response to the monitoring system. An assessment of the costs of both approaches is required to make a reasoned choice. No clear guidance on how to come to a reasoned choice is currently available for this. Related to this, it proved impossible to specify trigger values during the workshop. This was not only due to time reasons, but also because defining trigger values involves very specific expertise and knowledge. The participants also cited the need to address questions related to the monitoring system, such as: who should adapt the policy?, how to assess whether a policy should be adapted?, how to decide what kind of expert knowledge is needed? Here an interesting way forward could be to look at the theoretical concept of policy learning. Policy learning assumes that policy models are developed, tested, and shaped by means of a reflective policy dialog (Geurts and Joldersma, 2001).

Fourth, although the basic policy distinguishes three groups (compliant, less compliant, and notorious speeders), the analysis shows that the vulnerabilities and opportunities mostly address either the notorious speeders or the overall basic policy (without distinguishing between compliant and less compliant). This indicates that experts may find it difficult to assess a policy that consists of multiple measures (they do not address each measure consistently). In the workshop, we had the impression that the experts focused on the underlying assumptions, and tried to find vulnerabilities and opportunities for these (e.g. ISA should be a reliable technology, for GPS based ISA an accurate speed limit database is required, etc.). As a result, they came-up with more generic vulnerabilities, which can later be translated back into more specific vulnerabilities for each of the measures for the target groups for which the basic policy is composed.

Furthermore, in the analysis ISA technology is considered to be a technology that is available (because the basic policy was framed that way). In the workshop a bottom-up approach was used which resulted in strengths, threats, weaknesses, and opportunities for this basic policy. Because this paper reports on the results of the workshop there is no reflection on the some of the underlying factors that contribute to the weaknesses and threats that were mentioned (e.g. the nature of the technology, and the way ISA is developed (demand driven or not)). Future research could address these underlying factors, and by doing so, come-up with measures that address the weaknesses and opportunities related to these issues.

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6. Evaluating Adaptive Policymaking Using Expert Opinions

In this chapter we answer Research Question 4: How can we evaluate the identified approach, and what are the implications of such an evaluation for the identified approach and for the developed ISA implementation policy? Part of evaluating the approach is answering Research Question 5: How does the identified approach compare to more traditional policymaking approaches?

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6.1 Introduction

In their everyday practice of policymaking, policymakers are constantly confronted with uncertainty. As Walker et al. (2000) state: ”policymaking is about the future”, and the future is intrinsically uncertain. Where in the early days kings and emperors relied on oracles and fortune tellers to deal with uncertainty about the future, policymakers nowadays rely on science to support their decisions. Modern day decision support works well as long as the uncertainties surrounding the decision problem are not too deep, but should be done in situations in which the future is so uncertain that analysts, experts, or stakeholders cannot agree upon the right model, or have no clue about what the future will look like?

This chapter focuses on a policymaking approach designed to deal with *deep* uncertainty. Deep uncertainty refers to policy assessments in situations in which decisionmakers, analysts, and experts do not know or cannot agree upon: (1) the correct representation of the policy domain (the appropriate model), (2) the prior probability distributions for inputs to the model(s) and their interdependencies, and/or (3) the preferences and goals of the various stakeholders that can be used to rank the policy alternatives (Lempert et al., 2006). For instance, the problem of climate change might be considered a problem involving deep uncertainty. It is a problem for which long-term policies are urgently needed, while experts disagree on many things, including the correct representation of the current system (e.g. what is the relationship between increased mobility and global warming?).

In 2001, Walker et al. specified a policymaking approach that they claimed would be able to produce policies that would function well in the face of deep uncertainty. The approach, which is called Adaptive Policymaking (APM), originated as a reaction to the real-world policy and planning problems that were encountered by policy analysts at the RAND Corporation who were working on the long-term development of Amsterdam Airport Schiphol (RAND Europe, 1997). Since then, APM has been demonstrated using a variety of cases related to real-world policy problems (e.g. Marchau et al., 2008; Marchau et al., 2010; Agusdinata et al., 2007; Kwakkel et al. 2010). However, APM has seen little practical application. Recently, almost 10 years after the publication of the seminal paper on APM, attention was given to the state of the art on APM (Kwakkel, 2010; Walker et al., 2010). This review of the state of the art on APM revealed the following issues and challenges:

1. APM lacks examples of adaptive policies developed by policymakers or domain experts. (Until now, APM has been carried out almost exclusively by researchers not by the real-world policymakers or domain experts (see, for example: Marchau et al., 2008; Marchau et al., 2010; Agusdinata et al., 2007; Kwakkel et al. 2010)
2. APM lacks realistic examples of real-world policy problems. (Most cases that are published were developed to illustrate the APM process (see, for example, Marchau et al., 2010)
3. APM can be defined as a “high level concept, captured in a flowchart” (Kwakkel, 2010). There is limited insight into the tools and methods that can be used in each of the steps in the flowchart. A first indication of tools that can be used to design adaptive policies is given by Swanson et al. (2010). But this overview is still very broad and needs to be operationalized.

In addition to the above, several more specific questions remain, such as the costs and benefits of APM (Walker et al.,2010) the efficacy of adaptive policies in comparison to more traditional static policies (Walker et al., 2010; Kwakkel 2010), and the institutional implications of APM (Kwakkel, 2010). In this chapter we address all of these issues by using the opinions of the intended audience for APM. That is, we test and evaluate APM with domain experts, policymakers, and stakeholder representatives who can be considered potential users of APM. To the authors knowledge, this is the first time APM has been evaluated by the professionals for whom it was developed. This chapter has three important aims. It aims to provide insights into:

- the expected costs and benefits of using APM;
- the institutional implications of using APM;
- the efficacy of using APM in comparison to more traditional static policies.

In order to develop and test APM, a real-world decision making problem involving deep uncertainty was needed. We selected the implementation of a type of innovative traffic safety technology in the Netherlands. For decades, technical systems have been available that make sure a driver cannot exceed the legal speed limit. If these so-called Intelligent Speed Adaptation (ISA) devices would have been implemented years ago, hundreds of thousands of lives world-wide could have been saved. One barrier to the implementation of ISA is the uncertainty that still exists regarding the effects of (large scale) ISA implementation (e.g. the uncertainty about the acceptance of ISA, liability in case the system malfunctions, etc.) (Van der Pas et al., 2010). Policymakers recognize the uncertainties that are involved in ISA policymaking and often react by initiating more research (Van der Pas et al. 2006). Recently, Dutch policymakers developed an ISA implementation plan that is focused at implementing the appropriate ISA for the appropriate type of driver. This implementation plan was redesigned as an adaptive policy at a workshop by policymakers, domain experts, and stakeholder representatives, who used APM concepts. Immediately after the workshop the participants were asked to answer a Web-based questionnaire on APM. More detail on the design of the workshop and how APM was operationalized can be found in (Van der Pas et al., forthcoming). Here, we report on the results from the Web-based questionnaire.

Section 6.2 introduces APM and it is claimed that APM can handle deep uncertainty. Section 6.3 discusses the methodological and theoretical aspects of the evaluation of APM. Section 6.4 provides more detail on the workshop, including a brief overview of its content. Finally, Section 6.5 presents the results of the evaluation, and Section 6.6 presents some conclusions.

6.2 Adaptive Policymaking: the concept and its promise

APM is a policymaking approach that was developed at the end of the 1990s at the RAND Corporation in response to the need to cope with deep uncertainty in long-term policymaking for Amsterdam Airport Schiphol (RAND Europe, 1997). The approach aims at creating policies that can change over time, as the world changes and uncertainties about the future are resolved. APM specifies a series of generically formulated steps for decisionmaking under uncertainty that result in an adaptive policy. The steps in APM are based on steps of Systems Analysis (Miser and Quade, 1985), and key concepts are derived from Assumption Based Planning (ABP) (Dewar et al., 1993; Dewar et al., 2002). Given that APM is rooted in Systems Analysis, APM fits with the rational style of policy analysis (Mayer et al., 2004).

APM has undergone some minor changes and improvements over the last decade; the most recent version is specified by Kwakkel et al. (2010) . Our version of the APM framework is presented in Figure 6-1. For an extensive description of each of the steps in the APM process see Walker et al. (2001), and for some example cases see Marchau et al. (2008), and Kwakkel et al. (2010).

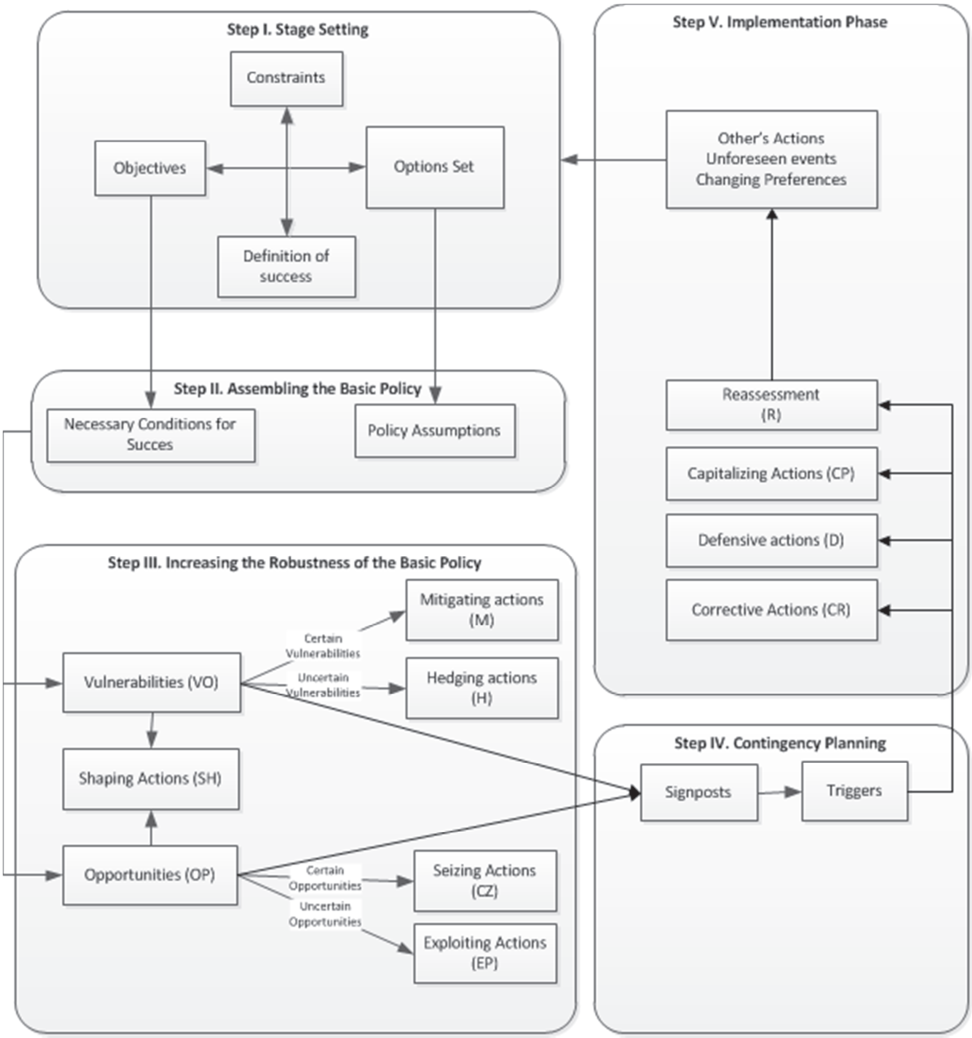

Figure 6-1 The APM framework (adapted from Kwakkel et al. 2010)

In summary, in Step I, the existing conditions of an infrastructure system are analyzed, the goals for future development are specified, a set of possible policy options is compiled, and a definition of policy success is formulated. In Step II, an initial basic policy is developed. This basic policy is made more robust through five types of actions, which are specified in Step III: mitigating actions (actions to reduce the certain adverse effects of a plan); hedging actions (actions to spread or reduce the risk of uncertain adverse effects of the policy); seizing actions (actions taken to seize certain available opportunities); shaping actions (actions taken to reduce the chance that an external condition or event that could make the policy fail will occur, or to increase the chance that an external condition or event that could make the policy succeed will occur); and exploiting actions (actions aimed at exploiting uncertain opportunities). When it comes to exploiting actions, the APM framework presented here differs slightly from previously published frameworks. Previous conceptualizations of APM do not explicitly mention actions that can be taken to exploit the uncertain opportunities that might occur. An example of an exploiting action can be building a bridge with an over-dimensioned foundation so, if the use of the bridge reached its capacity, a deck can be added above the deck that has reached its capacity. There are methods that support dealing with uncertain opportunities, such as real options (Leslie and Michaels, 1997). Even with the actions taken in Step III, there is still a need to monitor the performance of the policy and to take action if necessary. This is called contingency planning, and is specified in Step IV. Signposts specify information that should be tracked in order to determine whether the policy is achieving its conditions for success. Critical values of signpost variables (triggers) are specified, beyond which actions should be implemented to ensure that the policy keeps moving the system in the right direction and at a proper speed. There are four different types of actions that can be triggered by a signpost: defensive actions (actions to clarify the policy, preserve its benefits, or meet outside challenges in response to specific triggers, which leave the policy unchanged); corrective actions (adjustments to the policy); capitalizing actions (actions to take advantage of opportunities that can improve the performance of the policy); and a reassessment of the policy, which is initiated when the analysis and assumptions critical to the policy's success have clearly lost validity. Step V is the actual implementation of the policy. In this step, the actions to be taken immediately (from Step II and Step III) are implemented, and a monitoring system (from Step IV) is established. As time advances, signpost information related to the triggers is collected, and actions (from Step V) are started, altered, stopped, or expanded in response to this information.

After implementation of the initial actions (from Steps II and III), the implementation of other actions is suspended until a trigger event occurs.

6.3 Methodology and evaluation criteria for assessing adaptive policies

In this section an approach for evaluating APM is defined. First, a method for assessing policymaking methods will be outlined. Next, different evaluation criteria will be discussed and a selection of evaluation criteria for the assessment will be made. This results in an approach for the evaluation of APM.

6.3.1 An approach to evaluating Adaptive Policymaking

In establishing the efficacy of new infrastructure planning approaches, one faces a methodological problem, for ”nothing done in the short term can 'prove' the efficacy of a planning methodology; nor can the monitoring, over time, of a single instance of a plan generated by that methodology, unless there is a competing parallel plan” (Dewar et al., 1993). In this section, we address this problem.

In the evaluation literature, one important distinction is that between product and process (Walls et al., 2004) or between plan, process, and product (Verschuren et al., 2005). If the object of evaluation is the plan, the evaluation focuses on the assessment of the quality of the design on paper (Verschuren et al., 2005). Process evaluation focuses on the procedures for the construction of the design (Walls et al., 2004; Verschuren et al., 2005). Product evaluation involves the assessment of the value of the created artifact and its short- and long-term impacts after its creation (Verschuren et al., 2005). The distinction between plan, process, and product corresponds to the distinction between the plan as written (plan), the process of drafting the plan (process), and the effects of the implemented plan (product).

Besides the distinction of the object of evaluation, a distinction can be made with respect to the phase of the evaluation. Most clearly, this can be observed in the development of new medical treatments, which are tested on humans only after a series of other tests have proven successful. Five different types of evidence can be distinguished, ranging from theoretical evidence all the way to evidence from clinical trials. As can be seen in Table 6-1, a similar phase-wise evaluation approach can be applied to the evaluation of APM in particular, and planning approaches in general (Kwakkel et al., 2009). For APM, each, of the evidence types, (or types of evaluation), can be used to evaluate the policy, and to evaluate the policymaking process. (Product evaluation or evaluation of the executed plan is not an issue since adaptive policies have not been implemented yet).

Table 6-1 Types of evaluation for policy design (Based on Kwakkel et al., 2009))

Evidence used to develop / validate medical treatment	Evidence used to develop / validate infrastructure planning approaches	Examples with the specific aim of evaluating APM as a planning approach	Criteria used for evaluation
Theory	Theories (e.g. decision science, cognitive science, political science, organizational behavior, policy analysis)	Walker et al. (2001) Agusdinata et al. (2007) Marchau et al. (2010)	Design principles of APM
Animal Models	Computational experiments of plans across an ensemble of futures (Bankes, 2009;Bankes 1993; Van der Pas et al., 2010). Simulation gaming with students (Mayer et al., 2002)	Kwakkel et al. (2010)	Efficacy
In Vitro Experiments	Simulation gaming with actual decisionmakers (Mayer et al., 2002)	Taneja et al. (2010a and 2010b) This paper	No systematic criteria are used Evaluation criteria based on literature
Natural Experiments	Case studies of successful long-term infrastructure plans		
Clinical Trials			

Examples of adaptive policies can be found in the earlier literature (Marchau et al., 2008; Marchau et al., 2010; Agusdinata et al., 2007; Kwakkel et al. 2010; Kwakkel, 2010; Taneja et al., 2010a; Taneja et al., 2010b). However, these policies were either not evaluated at all (e.g. the adaptive policy was for illustration purposes only), or were evaluated only with respect to the main design principles of APM (e.g. the extent to which the adaptive policy allowed policymakers to deal with uncertainty). More recently, researchers have started to develop and test APM in a more comprehensive way. For example, Kwakkel et al. (2010) evaluate the efficacy of adaptive plans for long-term airport development across an ensemble of futures, Taneja et al. (2010a, and 2010b) report and reflect on a workshop-based approach to turning an existing MasterPlan for the Port of Rotterdam into an adaptive plan.

In light of the above mentioned and Table 6-1, we conclude that the logical next step in evaluating APM would be to have some real-world users of APM evaluate it in a laboratory type environment. That is, APM should be evaluated ‘in vitro’ by domain experts, policymakers, and stakeholder representatives for a real-world policymaking problem.

6.3.2 Evaluation criteria that can be used to assess Adaptive Policymaking

Having specified in detail both the object of evaluation and the levels of evidence that can be used in evaluating policymaking approaches, and having outlined the status of evaluating APM, we now turn to discussing the criteria to be used for the evaluation. We describe three different sets of criteria that will be used to assess APM.

First, APM, is in essence, a policy analysis approach (Walker et al., 2001), so criteria that are used to assess policy analysis efforts can be used to assess APM. Miser and Quade (1985) make a distinction between evaluating the input of the policymaking process, the output of the policymaking process, and the process itself. Twaalfhoven (1999) and Thissen and Twaalhoven (2001) make a more detailed differentiation; they distinguish between input, process and content, results, use, effects, and communication. The criteria that can be used for the evaluation of different elements (e.g. input, process and content, results, use, etc.) also depend upon the point of view one has on policy analysis.

The second set of criteria that can be used to evaluate APM come from the claims that are made by the developers of the method (See e.g. (McLain and Lee, 1996)). Here, the evaluation should answer the question: does APM live up to the claims of its developers? Criteria that can be used to evaluate the success or failure of APM come from an operationalization of the claims made in the APM literature. Walker et al. (2001) indicate several benefits of using APM compared to using traditional static approaches. The most important are mentioned in Table 6-2.

Table 6-2 Overview of claims made by APM developers

#	Claim
1	APM is a more realistic planning approach, which confronts the pragmatic realities that policies change as the world changes.
2	APM allows policymakers to deal with changes that cannot be foreseen, changes that simply occur due to the advance of time, and changes that occur because new information becomes available.
3	APM allows for learning.
4	APM can capture the contingency and unpredictability of future events.
5	APM explicitly recognizes the value of additional information during different steps in the policymaking process.

The third set of criteria that can be used to evaluate APM come from the design evaluation literature. When considering APM as a design methodology, there are various criteria that can be used to evaluate and validate APM (see e.g. McLain and Lee, 1996; Griffin, 1992). An important criterion is its usefulness with respect to a purpose (Seepersad et al., 2005). In this case we can distinguish between the usefulness for the test case (the policy problem used to test APM) and its usefulness in relation to the goal the method was designed for (usefulness in dealing with deep uncertainty). Seepersad et al. (2005) operationalize usefulness in terms of efficiency and effectiveness; these criteria overlap with the previously mentioned policy analysis criteria.

Based on the three sets of criteria, a list of evaluation criteria was composed. For practical reasons it would be impossible to ask the experts to assess APM using all the criteria. We prioritized the list of criteria based on the factors that are considered to be important to the success or failure of APM (Kwakkel, 2010; Walker et al., 2010). This resulted in the evaluation criteria shown in Table 6-3.

Table 6-3 Success/failure factors and criteria for assessing them

#	Success and fail factor	Criteria	Source (for criteria)
1	How do the cost and benefits of APM compare to the costs and benefits of traditional static policymaking approaches?	- Costs and benefits (case of ISA). - Costs and benefits (for problems that involve deep uncertainty).	- Walker et al. (2001)
2	What are the institutional implications of APM?	- Degree to which APM fits the political and administrative setting. - The degree to which designing and implementing adaptive policies fits the current practice of policymaking and decisionmaking in the Netherlands.	- Thissen and Twaalfhoven (2001)
3	What is the efficacy of APM?	- Promises made by APM developers . - Effectiveness. - Efficiency. - Usefulness. - Benefits compared to traditional static policymaking. - Downsides of APM compared to traditional static policymaking. - Barriers to using APM.	- Walker et al.(2001) - Thissen and Twaalfhoven (2001) Seepersad et al. (2005) - Walker et al. (2010)

6.4 A workshop to design adaptive policies for implementation of traffic safety technologies

This section presents the APM workshop that was designed to develop adaptive policies with domain experts, policymakers, and stakeholder representatives. There are a variety of methods and tools for the various APM steps that can be used in a workshop setting. These are described in a separate publication (Van der Pas et al., forthcoming).

For the workshop, a suitable case was needed. This should be a decisionmaking problem under deep uncertainty for which enough experts are available. An example of a policy problem that is surrounded with deep uncertainty is the implementation of Intelligent Speed Adaptation (ISA). ISA is an in-vehicle, technological system that prevents the driver from speeding by providing warnings to the driver, assisting the driver (e.g. with a haptic throttle, which provides resistance above the speed limit), or even restricting the driver from exceeding the speed limit (e.g. the dead throttle, which makes it impossible to drive faster than the speed limit). ISA has the potential to make a significant contribution to road traffic safety. Research suggests that it can reduce the number of fatalities by up to 59% (Carsten et al., 200). Although, research and pilot projects have shown that ISA is technically feasible and can significantly contribute to traffic safety, large-scale implementation is still far away.

An important reason for this is that many aspects relating to ISA implementation are deeply uncertain (e.g. drivers' acceptance of ISA, and how to model the traffic safety effects of ISA) (Van der Pas et al. 2010). Recently, Dutch policymakers developed an ISA implementation plan. This plan, or policy, focuses on supporting the implementation of the right type of ISA (ranging from a warning ISA, to a restricting ISA), for the right type of driver (ranging from compliant to stick to the speed limit, to notorious speeder).

In order to develop adaptive policies with domain experts, policymakers, and stakeholder representatives, we decided to use a workshop setting, supported by a Group Decision Room (GDR). The GDR used for this research had 20 laptop computers, that were connected to a Thinktank® server. The GDR can be used to structure brainstorm sessions with experts. The workshop is led by a facilitator that interacts with the experts. The facilitator asks questions or gives assignments, and the experts provide their input via the laptop computers. There are many benefits from using a GDR. It is anonymous, so all participants are equal and nobody can dominate the discussion, the results can be analyzed quickly and discussed during the session, and the results are automatically stored and can be analyzed afterwards. The workshop also included group sessions, at which experts were asked to work out specific actions for dealing with the vulnerabilities and opportunities in groups. Figure 6-2 sums up the approach that was used in the workshop to develop adaptive policies.

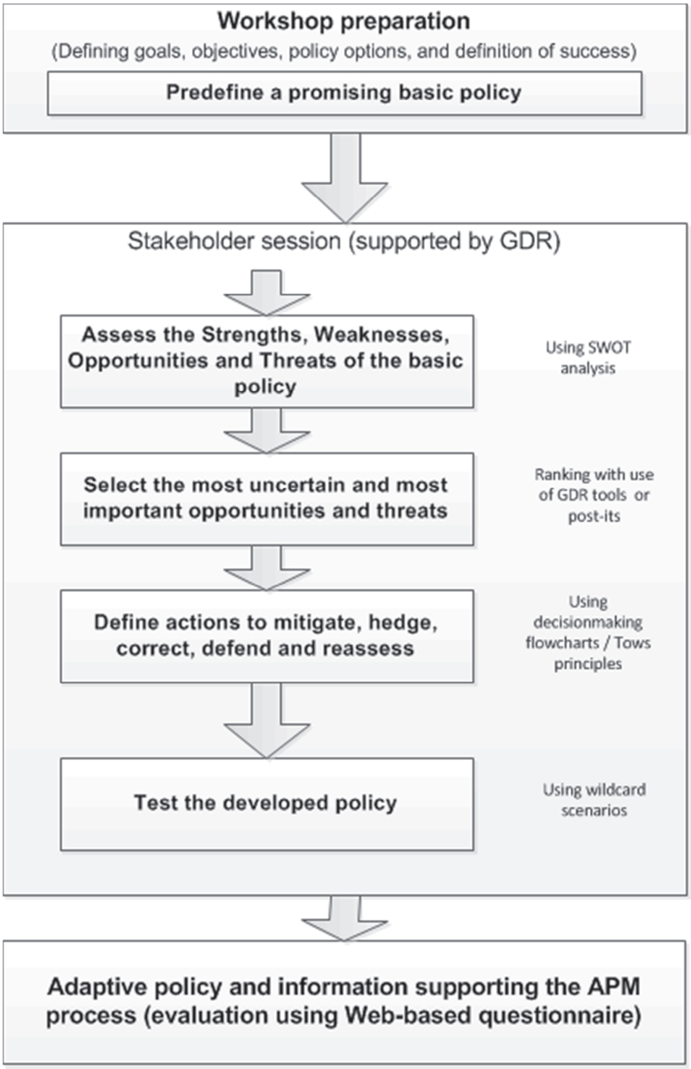

Figure 6-2 Conceptual framework of the workshop

Prior to the actual workshop, decision support material was gathered and prepared for use in the workshop. In close contact with the Dutch policymakers that are responsible for the ISA implementation policy, we specified the goals, and the definition of success, and we designed a basic policy based on the existing policy document. The basic policy is in essence the current ISA implementation policy of the Dutch Ministry of Infrastructure and Environment. The resulting basic policy consists of two phases: Phase I, running from 2009-2012, and Phase II beginning in 2013. It is based on three types of car drivers: (1) compliant drivers (intrinsically motivated to stick to the speed limit); (2) less compliant drivers (people that speed on a regular basis); and (3) notorious speed offenders (people that are known speed offenders and are on the verge of losing their driver’s license). As shown in Table 6-4, for each of these types of drivers policy measures are defined, a definition of success is defined, and constraints are identified. This basic policy was the (pre-workshop) output from Steps I and II of the APM, and was used as input to the workshop.

Table 6-4 The basic policy

Basic policy **Type of driver**	**Type of ISA**	**Measure**	**Definition of success**	**Constraints**
Phase I (2009-2012)				
Compliant driver	Warning ISA (speed alert)	o Start a campaign aimed at persuading people to turn the speed alert functionality on their navigation device on. o Make agreements with companies that develop navigation devices.	Before 2013: 50% of the people that own and use a navigation device actively use the speed alert functionality.	Budget for a campaign.
Less compliant driver (But also the compliant driver)	Free to be selected by the individual insurance companies	o Develop a business case with insurance companies and lease companies.	Before 2013: 50% of the car owners and 50% of lease drivers can choose an insurance or lease product that involves ISA.	
Notorious speed offender	Restricting ISA	o Perform a pilot test aimed at assessing the effects of implementing a restricting ISA for notorious speed offenders. o Make an evidence based decision regarding implementation of such a system for notorious speed offenders.	Before 2013, A decision has to be made on implementation of ISA for notorious speed offenders. Based on, amongst others, outcomes of the trial.	Budget/time
Phase II (2013)				
Phase II will be dependent of the results of Phase I. For this phase, more restricting types of ISA will be considered.				

During the workshop, the basic policy was discussed and vulnerabilities and opportunities were identified using a Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis (Ansoff, 1987). The SWOT analysis was a group exercise (participatory effort) that used the following steps:

1. The participants were asked to pin-point and assess the impact of contextual factors on the basic policy (opportunities and threats). They were asked to assess the effects of economic, demographic, political, ecological, technological, and sociological changes on the basic policy.
2. The participants make an assessment of “strengths and weaknesses” in terms of management and organization, operations, finance, and marketing. This meant assessing the strengths and weaknesses of the basic policy, the organization(s) that

made the basic policy (e.g. ministries), and the assumptions on which the basic policy was based.
3. The participants were grouped and asked to select the ten most important strengths, weaknesses, opportunities, and threats. Next, a peer review round took place, allowing the peers of the group to remove and add a number of strengths, weaknesses, opportunities, and threats.

After the SWOT analysis, actions, signposts, and trigger values for handling the resulting, strengths, weaknesses, opportunities, and threats were specified using a slightly modified TOWS approach (Weihrich, 1982)]. To support this, specially designed flowcharts were used. The workshop participants went through these for each of the vulnerabilities (weaknesses and threats) and opportunities, resulting in a set of actions to complement the basic policy when it is implemented and a monitoring system with associated actions to guide the policy over time (i.e. they developed an adaptive policy).

As a final step in the workshop, an ex-ante evaluation of how the overall policy might perform took place. To test the adaptive policy, the experts performed a “what if” analysis, using wildcard scenarios or discontinuity scenarios (Van Notten et al., 2005). The experts were asked to assess “what if” a specific wildcard would become reality, what would this mean for the performance of their adaptive policy. From exploring the possible effects of the wildcard scenarios to preparing to deal with these effects was done based on the five questions of Godet (2000). In light of the insights from the ex-ante evaluation of the adaptive policy, the participants were encourages to improve the initial adaptive policy. All the information given by the participants was recorded using the GDR, and by forms that the participants had to fill in during the workshop.

The APM workshop procedure was first tested in 4 workshops. In these workshops, different experts participated (mainly university students and professors). In the fifth and final workshop, we developed adaptive policies with domain experts, policymakers, and stakeholder representatives, for the case of ISA. Afterwards we asked the participants to evaluate APM using a Web-based questionnaire. This final workshop can be considered an ‘In-Vitro’ type of evaluation (see Table 6-1). This is the workshop whose evaluation is discussed in Section 6.5.

6.5 Results of the evaluation

Before discussing the results in Section 6.5.3, we summarize the background of the participants in Section 6.5.1. In Section 6.5.2, information on the questionnaire that was designed to evaluate APM will be provided.

6.5.1 The participants

Eighteen persons participated in the workshop. Figure 6-3, shows the self-reported field of occupation of the domain experts, policymakers, and stakeholder representatives that attended the workshop.

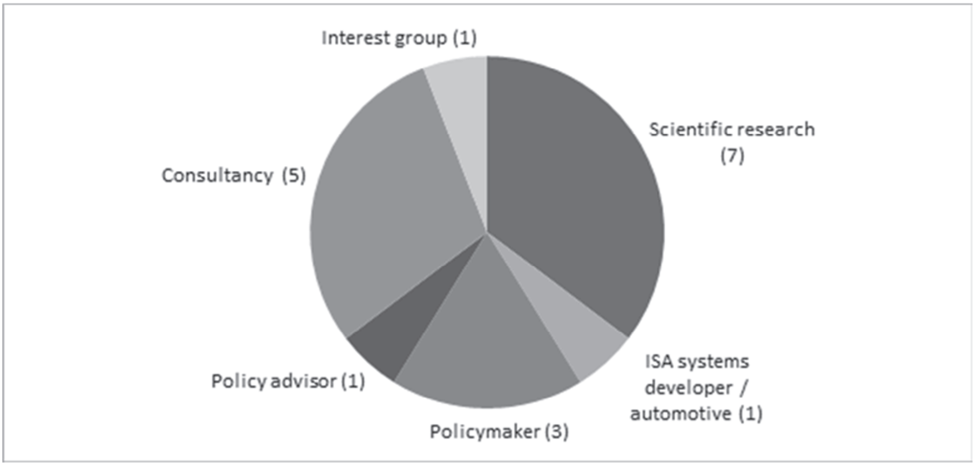

Figure 6-3 Self-reported occupation

The persons who participated in the workshop are a representative group of experts for the ISA implementation policy problem (domain experts (e.g. experts on ISA, traffic safety, driver behavior), policymakers, and stakeholder representatives). In the remainder of this chapter we will refer to them as 'participants'.

6.5.2 The evaluation questionnaire

To evaluate APM, we used a Web-based questionnaire that could be accessed using the GDR laptop computers, that were used during the workshop. The evaluation questionnaire was presented to the respondents immediately after the workshop. This had three benefits: first, it resulted in a high response, since people were already there, and it required little additional time to fill in the questionnaire. Second, the time between the APM workshop and the evaluation of APM was kept short, so the participants were able to easily remember most aspects of the APM workshop. Third, we were available for answering questions regarding the questionnaire.

The questionnaire consisted of 17 multiple choice questions, each of which used a five point Likert scale and included an 'I don't know' option. In addition to the multiple choice questions, questions were asked regarding the field of occupation of the participants and several open questions. The open questions were:

- What are the most important benefits of using APM?
- What are the most important downsides of using APM?
- What are the most important barriers for the use of APM by policymakers?
- Do you think that using APM can be useful in your everyday practice, and if so in what way?
- Is there something you would like to add (regarding the workshop, APM, etc.)?

We present the results using the five-number summary (Agresti and Finlay, 1997). The five-number summary was selected because it is a clear and easy to understand way of presenting the results, and it allows the reader to gain a direct insight into the most important characteristics of the distribution of the answers. The results are presented in Tables 6-5 to 6-11, which appear in Section 6.5.3. In Tables 6-5 to Table 6-11, Q1 represents the first quartile, and Q3 represents the third quartile. Max is the Maximum value the respondents indicated and Min is the minimum value. In addition, the Median is given in the first column. To increase the understandably of the data we added the number of respondents that answered the question [N], and the interquartile range, to the five-number summaries that are given in Tables 6-5 to 6-11.

6.5.3 Analysis of the results

Cost and benefits of APM

Table 6-5 shows the results of the multiple choice questions on the costs and benefits of APM. The questionnaire makes a distinction between the costs and benefits regarding the case, (questions 1 and 2), and the costs and benefits for policy problems that are surrounded with uncertainty in general (question 3). In addition to this, two open questions regarding the costs (operationalized as 'downsides') and benefits were asked.

Table 6-5 The costs and benefits of APM

#		Median[1] [[2]]	Q1	Q3	Max	Min	N [[3]]
1	Developing and implementing adaptive policies for ISA costs more than developing and implementing traditional static policies for ISA.	3[2]	2	4	5	1	17 [1]
2	Developing and implementing adaptive policies is more time consuming than developing and implementing traditional static policies for ISA implementation.	4[1]	4	5	5	2	18 [0]
3	The expected benefits of developing adaptive policies are bigger than the expected costs (For problems that are surrounded with deep uncertainty).	4[1]	3	4	5	2	18 [0]

[1] *1= Strongly disagree, 2= disagree, 3= Neither disagree, nor agree, 4= agree, 5= Strongly agree*

[2] *[The interquartile range]*

[3] *[The number of respondents that indicated to "don't know']*

Question 1 in Table 6-5 asks whether the participants think that "developing and implementing adaptive policies for ISA cost more than developing and implementing traditional static policies for ISA". The participants are clearly divided on this question. Most participants chose 3 on the Likert scale, which meant that they neither agree nor disagreed. Based on the answers to the open questions and discussions with the participants after the workshop, two main reasons can be identified for this result:

- Some participants saw that the basic ISA policy considered at the workshop has a very low cost. This means that, if policy goals are not reached, only limited costs will be incurred (the cost of a media campaign and labor cost reflecting a couple of man months).
- Some participants strongly disagreed with this interpretation, because they included the cost of a failing traditional static policy in the equation. They argued that APM might be more expensive in the development phase, but a failing in expensive policy will turn out to be even more costly.

As for APM in general, the participants indicated that the process of developing and implementing adaptive policies is more time consuming than developing traditional static policies. However, they also felt that the benefits of developing adaptive policies outweigh the cost (when used for policy problems that involve deep uncertainty). The answers to the open questions indicate that the participants think APM significantly increases the chance of a policy's success. In the open questions, seven of the participants explicitly indicated that they think APM is expensive and time consuming (also see Table 6-8).

What are the institutional implications of APM?

Table 6-6 shows the participants opinions on the questions regarding the institutional implications of APM. In addition to the answers summarized in Table 6-6, the open questions also revealed a number of institutional barriers for the implementation adaptive policies (see Table 6-9).

Table 6-6 Participant opinions on the institutional implications

#		Median[1] [[2]]	Q1	Q3	Max	Min	N [[3]]
1	Policymakers in general are capable of identifying the strengths, weaknesses, opportunities, and threats and to think of actions to counter the weaknesses and threats and profit from the strengths and opportunities	4[4]	2	4	5	2	18 [0]
2	Designing and implementing adaptive policies fits the current practice of policymaking in the Netherlands	3 [3]	3	4	5	2	16 [2]
3	APM fits the current political and administrative setting	2 [2]	2	4	4	1	18 [0]

[1]1= Strongly disagree, 2= disagree, 3= Neither disagree, nor agree, 4= agree, 5= Strongly agree

[2][The interquartile range]

[3][The number of respondents that indicated to "don't know']

Table 6-6 shows that the participants expect policymakers to be capable of designing adaptive policies. However, they did not agree with the proposition that designing and implementing adaptive policies fits the current way of policymaking in the Netherlands, and disagreed with the proposition that APM fits the current political and administrative setting.

A large number of participants (13 out of 18) indicated in the open questions that there are major political-institutional barriers to using APM. They said that decisionmakers are not used to thinking in terms of possible scenarios and steps that should be taken in the future, the current political process is not designed to deal with adaptive policies, and the current political discourse does not allow for APM. More specifically, the participants said that:

- Politicians often don't think about long term consequences and successes.
- It is politically unacceptable to make a decision while there is still a lot of uncertainty, which means that starting to implement a policy while some issues are still uncertain will prove politically impossible. No decisionmaker (or politician) will allow a policy to be implemented if some of its important outcomes are explicitly mentioned to be uncertain. This will be even more the case when the potential consequences are big.
- Mentioning in advance that a complete policy re-assessment is a possibility will be political and socially unacceptable.
- Adopting APM will make the political debate more complicated (more aspects to debate: actions, trigger values, signposts, etc.). Very small and detailed aspects of the policy will become part of the political debate which will result in no decision at all.

- APM will require politicians to allow policymakers more space to maneuver (e.g. policymakers need to specify actions, decide on when and how to change the basic policy, etc.); this will be difficult.
- Policymakers are not used to APM, and will be reluctant to change their everyday practices.
- An adaptive policy for a complex problem will most likely be a complex policy. It will be too complicated and too hard to understand for politicians to take a decision on.
- Politicians often are impatient; they don't want policy development to take too long.
- All parties that are involved in the policymaking process need to agree on important issues (e.g. consensus on the basic policy); this will be difficult when there is still a lot of uncertainty.
- APM assumes that policymakers take a decision based on rationality and content related issues. In reality, this is often not the case.
- Making the vulnerabilities/uncertainties explicit (and part of the political debate) will result in fear about taking a decision (nobody can or dares to take a decision).
- Above all, decisionmakers will have to explain their new way of working and their adaptive policy to their political backbench and voters, which will be hard: politicians will be very reluctant to do any of these things.

When interpreting these results it should be noticed that none of the participants was a decisionmaker.

What is the efficacy of APM?
Does APM fulfill the claims made by its inventors?

Criteria that were used to assess the efficacy of APM were criteria related to the claims made by APM developers (Table 6-7 presents the results).

Table 6-7 APM claims

#		Median[1] [[2]]	Q1	Q3	Max	Min	N [[3]]
1	The reality is that a changing world requires policies to change, APM fits this reality.	4 [1]	4	5	5	2	18 [0]
2	APM allows policymakers to deal with changes that cannot be foreseen, changes that simply occur due to the advance of time, and changes that occur because new information becomes available.	4 [1]	3	4	5	2	18 [0]
3	APM allows policymakers to learn.	4[1]	3	4	5	3	17 [1]
4	Explicitly recognizes the value of additional information during different steps in the policymaking process.	4 [1]	3	4	5	2	18 [0]
5	APM allows policymakers to better deal with, on the one hand the urgency of a policy problem and the potential of a policy measure, and on the other hand the time and money available to find additional information.	3 [1.25]	2.75	4	5	2	18 [0]

[1] *1= Strongly disagree, 2= disagree, 3= Neither disagree, nor agree, 4= agree, 5= Strongly agree*
[2] *[The interquartile range]*
[3] *[The number of respondents that indicated to "don't know']*

As indicated by the median scores shown in Table 6-7, the participants agreed with the claim that APM fits the reality that a changing world requires policies to change over time. They also agreed that APM does deal with the types of uncertainties for which the method was designed, and that it allows policymakers to learn over time as knowledge is gained. The participants also recognized the added value of APM when it comes to using the additional information that is generated during the policymaking process. Regarding the trade-off among the urgency of a policy measure, the potential of a solution, and the time and money available to find additional information the participants were less clear. Most of them indicated that they neither agreed nor disagreed. A possible reason for this might be the complexity of the question, or the fact that the added value of APM concerning this criterion was not discussed during the workshop and, as such, was hard for the participants to assess.

What is the Efficiency, Effectiveness and Usefulness of APM?

The usefulness of APM was assessed with respect to its two purposes: developing adaptive policies for the case, and more generally developing adaptive policies for problems that involve deep uncertainty. Usefulness was directly assessed using the policy analysis criteria and the design criteria discussed in Section 6.3.2.

Table 6-8 shows the results for the direct assessment of usability of APM. The usability of APM was assessed for the policy problems it was designed for, the usability of APM for the case (ISA implementation), and the usability of the final product (the developed adaptive policy). As indicated in Table 6-8, APM was considered useful on all evaluated aspects.

Table 6-8 Usability of APM.

#		Median[1] [[2]]	Q1	Q3	Min	Max	N [[3]]
1	APM is an appropriate way to develop policies for Implementation of ISA.	4 [1]	3	4.25	2	5	18 [0]
2	APM is a method that could also be useful to develop policies for other policy problems.	4 [0]	4	4	3	5	17 [1]
3	The generated strengths, weaknesses, opportunities and threats, and the defined actions, signposts and trigger values can be used in the ongoing effort of developing ISA implementation policies for the Netherlands.	4 [1]	4	5	3	4	18 [0]

[1] 1= Strongly disagree, 2= disagree, 3= Neither disagree, nor agree, 4= agree, 5= Strongly agree
[2] [The interquartile range]
[3] [The number of respondents that indicated to "don't know']

Using the design criteria (McLain and Lee, 1996; Griffin, 1992; Seepersad et al., 2005), the usefulness of APM can be operationalized as: is the method efficient and effective in reaching it goals? Effective is operationalized as: adequate to accomplish its purpose (so, reaching the objectives). In their answers to the multiple choice questions, and more explicitly in their responses to the open questions the participants indicated that APM increases the chance of reaching the goals and, as such, can be considered effective. This is also suggested by the answers to the open questions. These answers indicate that APM not only increases the chance of reaching the goals, it is also a smooth, effective, and relevant way to do it. Efficient is operationalized as: performing in the best possible manner with the least waste of time and effort. The degree to which the costs of APM outweighs its benefits is an indicator for efficiency. In general, the participants indicate that APM is more costly and time consuming than traditional static policymaking methods (e.g. see Table 6-8). For the specific case of ISA implementation, the participants disagreed on the fact whether the costs outweigh the benefits (as indicated in Section 5.3.1). In general, for problems that involve deep uncertainty, APM was considered to be efficient. Whether APM in general is more efficient than traditional static approaches wasn't assessed. This depends on too many problem-specific factors (external events that can occur, cost of the policy alternatives, cost of policy failure, etc.).

To summarize, the participants indicated that APM can be considered effective and efficient. The participants indicated that developing and implementing adaptive policies is expected to be more expensive and time consuming than developing traditional static policies. However, the chance of success increases and, thus the costs associated with policies that fail can be reduced.

Other factors affecting efficacy

The answers to the open questions suggested a number of aspects that can influence the efficacy of APM both negatively (Table 6-9) and positively (Table 6-10).

Table 6-9 Factors that can affect the efficacy of APM in a negative way

#		N
1	Political aspects.	13
2	Expensive and time consuming. - The process of APM development is (too) expensive and time consuming. - The policy itself (adaptive policy) is (likely to be) more expensive.	7
3	Consistency issues. - Bigger chance in resulting in inconsistent policies (as compared to traditional static policymaking). - Perceived by stakeholders as inconsistent.	5
4	The adaptive policy is less transparent, more vague, and harder to explain to all stakeholders.	4
5	It won't be able to capture the things that cannot be foreseen.	2

The most frequently mentioned negative factors relate to the political aspects, which is in line with the answer to the multiple-choice questions (See Table 6-6). As indicated above, APM is considered more time consuming and more costly than traditional static policymaking. Although it is considered to be a more effective and efficient policymaking approach for policy problems that involve deep uncertainty, the participants indicated that the cost and time can be an important factor that negatively influences the efficacy of APM.

There is also a serious concern for the consistency of the resulting policy. The participants indicated that APM can easily result in inconsistent policies. (For example, after specifying actions to increase the robustness of the basic policy, you might lose track of the original basic policy and why it was implemented in the first place; or all kinds of actions (defending, etc.) are triggered and implemented, but the sum of all actions should have led to reassessment; etc.). This problem might be able to be solved by using policy pathway research or assessing chains of events that can lead to certain situations (Haasnoot and Dewolfshaar, 2009). In addition, the policy can easily be considered inconsistent by stakeholders, because they do not understand why certain actions are needed (e.g. why defend a policy that seems to be failing?). Some participants mentioned that it would be wise not to make too many changes to the basic policy, and, when actions are taken, to do so transparently and supported by facts and figures.

The adaptive policy is most likely to be a complicated product. The participants indicated that this runs the risk of becoming vague and non-transparent, which would be considered politically and socially undesirable. It also affects the efficiency and effectiveness of the adaptive policy in a negative way. Finally, most participants indicated that APM is an improvement compared to tradition policymaking when it comes to dealing with uncertainty. Two participants doubted to what extent an adaptive policy would be able to deal with things that cannot be foreseen, and to what extent its ability would be better than current policymaking.

There are also factors that can affect the efficacy in a positive way. Table 6-10 indicates the responses to the open questions that give an indication of factors that influence the efficacy of APM in a positive way. As can be seen in Table 6-10, the participants explicitly mentioned that they thought APM handles uncertainty better, increases the chance of success, and it allows policymakers to learn despite uncertainty.

Table 6-10 Factors that affect the efficacy of APM in a positive way

#		N
1	It allows policymakers to deal with uncertainties in a better way. - Some incidents can be prepared for using SWOT, Actions and the wildcard scenarios. - Using the uncertainties as an advantage increases the chance of success.	5
2	The chance of success becomes bigger. - It allows policymakers to keep their policy actual/relevant. It allows policymakers to maintain policy relevance. Policymakers no longer stick to policy measures that become irrelevant due to changing conditions and progress of time. - Due to the fact that several scenarios for the future are assessed during the policymaking process, policymakers will be able to make decisions more easy and quickly when the situation occurs. - Monitoring is an important aspect and a very useful addition to the current practice. Not only does it allow policymakers to take the right actions at the right time it also allows them to learn about the effectiveness and efficiency for other future policy measures.	5
3	It allows policymakers to start implementing and learn despite of uncertainty.	2
4	Prepare for the future, thinking about the effects and continuously adapt to changing conditions matches the current paradigm of the time we live in.	1
5	It will lead more smoothly to reaching goals.	1
6	Actions are not defined in the heat in the moment.	1

As indicated by the answers to the multiple-choice questions (Table 6-11), APM is considered to be an improvement in dealing with uncertainty in the policymaking process and as such also to increase the chance of reaching policy goals. Two participants mentioned that it allows you to start implementing despite uncertainty. But, other participants disputed this based on the argument that beginning implementation would be politically impossible.

Table 6-11 Participant opinions on the institutional implications

#		Median[1] [[2]]	Q1	Q3	Max	Min	N [[3]]
1	ISA implementation using an adaptive ISA implementation policy increases the chance of reaching the ISA related policy goals.	4 [1,5]	3,5	4	5	3	17 [1]

[1] 1= Strongly disagree, 2= disagree, 3= Neither disagree, nor agree, 4= agree, 5= Strongly agree
[2] [The interquartile range]
[3] [The number of respondents that indicated to "don't know']

In the open questions, the majority of the subjects explicitly indicated that APM is something that does not differ so much from traditional static policymaking. 14 of the 18 participants indicated that they think the differences are small. This seems to contradict the notion that APM does not fit the current way of policymaking in the Netherlands (Table 6-6). An explanation for this paradox can be found in the answers to the open questions. Some participants indicated that policymakers already use a SWOT analysis, think through scenarios, and define actions. However, these actions are not formalized and explicitly presented to the policymakers and general public. Also this is not done for every policy problem. Some of the participants explicitly indicated that adding a standard SWOT and/or a scenario analysis to the process of policymaking would already be a large improvement. This is consistent with the previously mentioned results. It is the political problem posed by formalizing vulnerabilities, opportunities, signposts, trigger values, and actions that causes the paradox. But that also is the root of two of the barriers to implementing APM that the participants pointed out:

- political infeasibility: politicians are confronted with vulnerabilities, actions, trigger values, etc. which in traditional static policymaking stay "behind the scenes";
- complexity, vagueness and inconsistency, understanding a complete policy package, including vulnerabilities, actions, trigger values, etc. requires content related knowledge. Introducing it to policymakers and the general public will result in the situation that the adaptive policy is considered vague, inconsistent, and complex.

In addition, the participants consider current policies to be already adaptive; decisionmakers react to changes and adapt their policies. (In APM however, when to change, and what to change are defined in advance.)

6.5.4 Generalizability of the results

In their answers to the open questions, the participants emphasized the political barriers that APM faces. As a result, the participants consider APM not likely to be usable in the Netherlands. Given the fact that the representative democratic system of the Netherlands is similar to that in many Western countries, there is no reason to believe that this conclusion is restricted to the Netherlands.

We selected the ISA case because the literature suggests that implementation of ISA is held back by deep uncertainty, and explicitly mentions ISA as an interesting case for Adaptive Policymaking. The participants agreed. They indicated that they thought that ISA implementation was a suitable case for APM. We think that most of the conclusions regarding APM for ISA are generalizable to the use of APM for other policy problems that face deep uncertainty, since the type of uncertainties facing ISA implementation are not unique to the case of ISA (for example: uncertainty regarding (future) stakeholder valuation of a technology, uncertainty regarding the large scale implementation of a technology, etc.). This was also indicated by the majority of participants. They explicitly mentioned in the Web-based questionnaire that the workshop could be used to develop adaptive policies for other policy problems that have to deal with deep uncertainty. An exception to the generalizability of the results might be the results with respect to the costs and benefits of APM usage. In the ISA case, the basic policy had relatively low cost. Making that basic policy adaptive resulted in huge costs compared to the investment cost of the basic policy. This might be different in the case of policy problems for which all basic policy options require huge investments (e.g. infrastructure policy problems).

Two of the participants doubted whether APM results in more flexible policies than traditional static policymaking. They reasoned that, although the traditional static policy is not flexible, once it is implemented policymakers react to changing conditions, so they make the static policy adapt to changing conditions. Also, they argued that making agreements and defining actions in advance does not make the policy more flexible (it actually reduces your design space, because actions are already defined in advance). For our research, we compared APM to the traditional static approach, because the traditional static approach is the formal representation of current policymaking with respect to the implementation of ISA.

6.6 Conclusions

The introduction stated three important aims for this chapter:

- providing insights into the costs and benefits of using APM;
- providing insights into institutional implications of using APM;
- providing insights into the efficacy of APM compared to traditional static policymaking approaches.

To fulfill these aims, a research approach was designed using an ‘in-vitro experiment’. Participants were invited to develop an adaptive policy. Afterwards they were asked questions about the costs and benefits of APM, the institutional implications of APM, and the efficacy of APM.

Costs and benefits of APM: Developing and implementing adaptive policies is considered to be more expensive and time consuming than traditional static approaches. However, for the type of policy problems the method was designed for (policy problems that are surrounded with deep uncertainty), the benefits outweigh the costs. Also, APM is considered to be an approach that increases the chances of a policy’s success. Whether the cost-benefit ratio of APM is better compared to traditional static approaches is a question that couldn’t be answered. The case contained a relative cheap policy option and the price of policy failure was very low, which made APM relatively unattractive.

Institutional implications: The participants agreed that there is a need for policies that change as the world changes. APM is an approach that results in this type of policy and, as such, has added value. Important barriers for APM are mainly institutional -- related to politicians and the political process. Also, policymakers and politicians will have difficulties explaining the complex product of APM (an adaptive policy) to each other and to the other stakeholders involved. Nevertheless, APM can be considered a valuable contribution to the policymaking process. However, from a political/decision making point of view, the participants indicated that APM is not likely to be usable in the Netherlands in the near future.

Efficacy of APM compared to traditional static approaches: The participants recognized the claims made by the developers of APM, and agreed that it allows policymakers to deal with different types of uncertainty, allows for learning, and better deals with information that becomes available during the policymaking process. The design of the workshop and the selected tools and methods used in the workshop were considered appropriate for developing adaptive policies

Although not explicitly asked, the results lead us to conclude that the question "is APM better than traditional static approaches?" is not easy to answer. The answer depends on many factors (the policy problem, the available alternatives, the costs of policy options and policy failure, etc.). What can be concluded from the participants' answers is that putting uncertainty central in the policymaking process is valuable for policy problems with deep uncertainty. As such, APM can be considered a valuable contribution to the policymaking process. However, it is the decisionmaking or political process where the problems arise, and for which the participants indicate APM will not be able to be adopted anytime soon.

Also, the participants indicated, that compared to more traditional approaches APM, in practice will be particularly vulnerable for two important reasons:

1. The participants indicated that APM can easily result in inconsistent policies. (For example, after specifying actions to increase the robustness of the basic policy, you might lose track of the original basic policy and why it was implemented in the first place; or all kinds of actions (defending, etc.) are triggered and implemented, but the sum of all actions should have led to reassessment; etc.). In addition, the policy can easily be considered inconsistent by stakeholders, because they do not understand why certain actions are needed.
2. The adaptive policy is most likely to be a complicated product. The participants indicated that this runs the risk of becoming vague and non-transparent, which would be considered politically and socially undesirable. It also affects the efficiency and effectiveness of the adaptive policy in a negative way.

Solutions that are proposed to address these vulnerabilities are: (1) use policy pathway research, or assess chains of events that can lead to certain situations; and (2) not make too many changes to the original policy. Also, when actions need to be taken, make sure the reasons are clear to the general public, and are supported by facts and figures.

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Appendix 3 Actions defined in workshop

Vulnerabilities (Weakness)		Type of action	Action	Signpost	Trigger value
W1	Implementing a restricting ISA for notorious speed offenders will damage the image of the less intervening ISA systems. ISA will be associated with punishment not with assistance (like it is now).	Certain (mitigation)	• Decouple the pilot from the rest of the basic policy and avoid the term ISA (currently done by calling it speed-lock).	• Number of negative press publications.	
		Defensive actions (uncertain)	• Actively manage the image of the speed-lock. • Manage the perception of people regarding ISA (and the speed-lock) explain the difference and the need for implementing such an ISA for this type of driver.	• Level of acceptance of different ISA systems. • Number and type of ISA related questions asked in the Lower House.	5 negative publications (National media)
W2	The availability of an accurate speed limit database. Speed limit data has to be correct for right time (dynamic), the right location and the right vehicle.	Mitigation (certain)	This is critical success factor, so: • Define who is responsible for what before starting with implementation. • Tender the development of a speed limit database (this should be arranged by public authorities). • Guarantee quality through a third party that is under the supervision of the public authorities. • Develop a system based on bacons that overrule the static speed limit information (Failsafe design).	--	--
		Mitigation (certain)	There are situations where the system does not work properly due to temporary speed limits (dynamic speed limits, road works, etc.) • Develop a system based on bacons that overrule the static speed limit information (Failsafe design).	--	--
		Defensive action (Uncertain)	Accuracy should be monitored. In addition: • Start making the speed limit database more accurate • Stop implementation of certain types or combine with on/off switch and overruling possibilities. • Design the system in such a way that it only warns intervenes in	Level of accuracy/reliability of speed limit database	Warning 90% accurate Assisting 95% accurate Closed 98% accurate

			areas with certain accuracy levels.		
W3	Technology can fail: • location determination can be inaccurate (e.g. in tunnels, in cities with high buildings)) • systems can stop functioning (sensors fail, etc.) • etc.	Mitigation (certain) Defend (uncertain) Reassess (Uncertain)	• Warn drivers when the system is defect1 • Build failsafe systems (back-up systems) • Improve the systems (implement rules and regulations regarding system functioning) • When large scale failure occurs or the effects are drastic (ISA implementation leads to fatalities)	-- • Accident numbers and causes Number of complaints/test results	--
W4	Informing ISA can be seen as another source of distraction and as such another source of distraction.	--	--	--	--
W5	Rebound (adverse) effects, people get used to it and trust the system to take over part of the driving task (e.g. knowing the speed limit, watching for speed signs). When a system that drivers rely upon does not work this causes extra unsafe situations	Defensive (Uncertain)	• Develop design standards/design regulations	• Accident numbers and causes • Cause of accidents (Relationship ISA – cause of accident)	--
W6	A speed lock cannot be build-in in every car			--	--
W7	Defining types of drivers. What is a well willing driver, What is a less well willing driver, What is a notorious speeder? This is hard to communicate, people will not understand this.	Mitigation (certain)	• Do not communicate using these terms. Make clear and distinctive categories, and operationalize the terminology so it is easy to establish who is what type of driver.	--	--
W8	Cost: Expensive policy to implement it for notorious speeders also more restrictive systems for less well willing drivers are expensive. Lease and insurance companies will not be able to afford that.	Mitigation (certain)	• Develop legislation that makes sure the notorious speed offenders have to pay for the system themselves.	--	--
W9	Bad for the image of the government (paternalism)	Defend (Uncertain)	• Set up a campaign to explain the role of the government and to change the perception of the people.	The public opinion on the role of the government (for ISA implementation)	--
W10	Are all necessary/appropriate stakeholders involved in the implementation process? (Neighbour countries/ EU (no level playing field)Automotive industry) Are all necessary/appropriate future stakeholders involved in the implementation process?	Mitigate (certain) Defend (Uncertain)	• Perform a stakeholder analysis and define the role of the stakeholders. Based on this analysis invite crucial stakeholders to participate. • Actively invite new and crucial stakeholders to participate in the ISA implementation process during all phases of the implementation process.	-- Monitor the level playing field and stakeholders involved including their role	--
W11 *	Fraud (including use of emergency button)	Mitigate (Certain)	• Make agreements with authorities that perform the M.O.T. tests/ Safety inspections test to include ISA the functioning of ISA in the test. • Make agreements with enforcement agency (police) to regularly test	--	--

		Type of action	Action	Signpost	Trigger value
		Defend (Uncertain)	the systems in unannounced checks • Extensively test the systems on fraud (In case of the system for notorious speed offenders). • Allocate part of the responsibility for fraud to the user and system developers. • Implement legislation that allows punishing people that sabotage systems.	Monitor the results/reports from MOT authority and police enforcement	
Vulnerabilities (Threat)					
		Type of action	Action	Signpost	Trigger value
T1	Automotive lobby, to avoid large scale implementation ISA	Mitigate (certain)	• Include automotive in the implementation strategy	--	--
T2	Speed limit data becomes more and more dynamic	Mitigate (certain) Defensive (uncertain)	• Implement ISA systems that are robust against this scenario. So systems that allow for communication with the infrastructure. (systems can use all kinds of signals to transmit temporary speed limits (also dynamic) e.g. radio, Bluetooth. • Make sure road authorities equip new dynamic speed limit infrastructure with infra-to-vehicle communication (So in vehicle systems can be easily adjusted) • standardization of communication protocol and communication standard.	• Availability of dynamic speed limits	--
T3	Image issues, you are a 'wuss' when you use ISA (e.g. Top-Gear makes a negative item on ISA)	Defend (Uncertain)	• Campaigns to improve ISA image	Negative Press releases on ISA	--
T4	Homogeneity of ISA implementation across different EU countries	Mitigate (Certain)	• Inform the EU on Dutch policy • Make European agreements • Make bilateral agreements with neighbouring countries	--	--
T5	Notorious speed offenders are the hardest groups to convince to participate. When it comes to a pilot to assess the effects and when it comes to implementation).	Mitigate (Certain)	• Pilot: Provide incentives • Pilot: use a group of notorious speeders and a group that matches the characteristics of this group as much as possible • Actual implementation: make sure the alternative is worse (taking away drivers licence)	--	--
T6	Communication (the way different parties communicate regarding different ISA systems is very important). Policymakers cannot control all information.	Mitigate (certain)	• Make agreements with all parties involved on communication • Develop a communication protocol for parties involved in	--	--

		Defend (uncertain)	implementation • Correct in-correct communication and information	Monitor the (negative) press releases on ISA Monitor communication of other important stakeholders (insurance and lease companies, interest groups)	
T7	A blind trust in the way the systems work will lead to big effects in situations where the system does not work.	Mitigate (certain) Defend (uncertain) Reassess (uncertain)	• See actions W3. • See actions W3. • If large accidents occur due to the fact that the system is not active or fails and people did not respond properly to that → reassess.	-- -- Monitor accident statistics and police reports on accident cause.	
T8	Politics: o It is a very unpopular measure among politicians (political acceptance). o Policymakers decide without content related knowledge.	--	--	--	
T9	Public opinion turns against ISA	Defend (uncertain) Reassess (uncertain)	• Try to change the public opinion by using campaigns, explaining the benefits of ISA, etc. • If there is no way to change the public opinion, there is no ground for voluntary implementation → reassess.	Monitor the acceptance/public opinion	
Opportunities					
O1	ISA implementation can result in larger cost savings than expected: by lower and more homogeneous speeds lower consumption costs (fuel savings + lower maintenance), resulting in higher levels of acceptance.	Capitalizing (Uncertain)	Up scaling of the number of participating insurance companies • Use this information in the business case for new insurance and lease companies.	Monitor additional effects of implementation on: • Emissions; • fuel use; • throughput/ congestion.	
O1	Due to some reason the support for driving-assistance systems just keeps getting bigger.	--	--	--	--
O3	Various ISA types offer good opportunities for connection with more traditional measures.	--	--	--	--
O4	Dynamic ISA may, when a sufficient penetration rate, make a major contribution in traffic management and safety.	--	--	--	--
O5	A trial can work as an example to other drivers.	--	--	--	--
O6	The availability of existing technology. In some vehicles (such as Renault) you can have a speed controller (approximately the same as a support system). A connection with navigation system can implement supporting ISA to make it easier.	--	--	--	--
O7	Participation of key stakeholders might result in an increased up-take of these systems by other commercial parties.	Capitalizing (Uncertain)	• Adjust the basic policy. If more intervening systems start to become available and people start buying these systems. The basic policy	Monitor the market (both retrofit systems as off factory build-in).	5% off factory equipped

			should shift from stimulating and initialising to standardisation.	• Number of systems providers on the market • Type of systems on the market • Number of car manufactures offering the systems (as an option) • Number of systems sold off factory	5% of lease drivers voluntary select an ISA product
O8	Cars and ISA draw lots of attention and appeal to people's emotions. Instead of seeing this as a threat this can be used as an opportunity.	Seizing (Certain)	• Invite stakeholders that are appeal to these feelings to participate in improving and implementing ISA (e.g. the presenters of top-gear, race drivers, etc.)	--	--
O9	People/companies are more willing to adopt technology if they can see the technology in practice. Creating a pool of cars that are equipped results in an uptake of the technology.	Seizing (Certain)	• Practice what you preach. Let the Ministry themselves equip their fleet with ISA and practice an example function. Prove that it significantly reduces the number of accidents and as such results in fewer claims.	--	--
O10	An increased enforcement policy can result in ISA as a comfort system. When the chance of getting caught speeding is very high ISA helps speeding drivers to avoid getting fines.	--	--	--	--

--means not addressed during the workshop session
* there are 11 weaknesses and 9 threats (after analysis, one threat appeared to be a weakness).

7. Conclusions and Reflections

In this chapter we provide an overview of the conclusions of this dissertation. Finally, we reflect on the research done and provide a research agenda for future research.

7.1 Introduction

Speeding is a major cause in road traffic un-safety. Although various speeding measures have been implemented in the past, future safety goals remain a challenge (in 2020 a maximum of 500 fatalities in the Netherlands, and in Europe a reduction of 50% compared to 2010) are far from within reach.). A potential solution for the problem of speeding are in-vehicle devices that can reduce speeding (ISA devices). These devices have been tested around the globe, and the research always indicates that ISA has a huge potential (e.g. 59% reduction of traffic fatalities) when it comes to increasing traffic safety. So, if policymakers are aware of traffic safety as a policy problem and ISA is a proven technology, what is it that makes the implementation of ISA go so slowly? Research suggests that Decisionmakers cannot decide on the implementation of ISA due to the deep uncertainties that surround the implementation of ISA.

This dissertation is about dealing with the uncertainties surrounding the implementation of ISA. The main question that is answered is: *What is an appropriate analytic approach for handling the uncertainties involved in the implementation of ISA?* To answer this question we developed and applied an approach called Adaptive Policymaking (APM). This approach is especially designed to deal with what is called deep uncertainties in developing policies (these are also among the many types of uncertainties involved in ISA implementation). We made an inventory of all the uncertainties involved in the implementation of ISA, classified them, and indicated how policymakers might be able to deal with them.

In Section 7.2, we summarize the main conclusions of this dissertation, according to the research questions that were introduced in Chapter 1. In Section 7.3 we reflect on the social and scientific aims of the research. In Section 7.4 we synthesize these conclusions. In Section 7.5 we give some suggestions for future research.

7.2 Answers to the research questions

7.2.1 Defining and classifying uncertainty

In Chapter 1, we introduced Research Question 0: *How do we define, and classify the uncertainties involved in analyzing public policies, and what are the approaches for handling them*?

We answered this research question in Chapter 2. We defined uncertainty as ”*any deviation from the unachievable ideal of completely deterministic knowledge of the relevant system”* (Walker et al., 2003). In addition to uncertainty, we introduced a special type of uncertainty called *deep* uncertainty: "*Deep uncertainty refers to situations in which "decisionmakers, analysts, and experts do not know or cannot agree on: 1) the system models, 2) the prior probability distributions for inputs to the system model(s) and their interdependencies, and/or 3) the value system(s) used to rank alternatives*" (Lempert et al., 2006).

Also in Chapter 2, we addressed the question: *What are appropriate approaches for handling these types of uncertainty?* Although not extensively addressed in a separately published paper, we addressed this question based on a literature study and as an integrated part of different publications. First, there is the category of ignoring or passively dealing with uncertainty (e.g. postponing a decision). There are also ways of actively dealing with uncertainty. When uncertainty is actively dealt with, we distinguish three types of approaches, and conditions under which they may be useful:

- ***Predict-and-Act*:** predict the future consequences of a policy option (often based on probability distributions), and take a decision. Many transport policy decisions are based on predictions, and the method works well when uncertainty is low (the result of this approach is a static policy).
- ***What-if reasoning:*** different plausible futures are specified and policy options are assessed for these multiple futures. The policy option that performs best across these different futures is selected. This works well in situations where different future representations of the system are known, but the probability of occurrence of each of these futures is unknown (the result of this approach is a 'robust static policy').
- ***Planning for adaptation:*** policies are developed that can be adapted over time. These policies change as the external conditions change. In theory, this method can always be used, but it will be inefficient in cases where the uncertainty cannot be classified as 'deep' (the policy will be over-dimensioned). However, the policymaking approach has been designed in particular for conditions of deep uncertainty (the result of this approach is a dynamic adaptive policy).

7.2.2 ISA implementation and uncertainty

In Chapter 3 we answered Research Question 1*: What are the main uncertainties regarding the implementation of ISA, and what is an appropriate approach for handling them?*

To answer this question we first performed an extensive literature study that resulted in 24 unique uncertainties, and second a survey among the authors of this literature to evaluate these uncertainties and approaches. The results of the latter expert study were clear. Most of the 24 uncertainties were considered to be what-if uncertainties, which means that the mechanisms are known about e.g. the cost of implementation, and the effect on driver behavior, but the likelihood of such an event occurring is unknown. In addition to the level of uncertainty, we also asked the experts to what extent they thought that these uncertainties were a barrier to ISA implementation. For ISA systems that only warn the driver about speeding, there were no uncertainties that were considered real barriers to implementation. Table 7-1 shows the uncertainties that were considered barriers for the implementation of the more restricting types of ISA (Assisting ISA and Restricting ISA).

We also identified generic actions aimed at moving forward with these two types of ISA. This was also done based on the expert opinions. As shown in Table 7-1, three generic ways forward (types of actions) were defined for Assisting ISA and Restricting ISA: actions related to doing more research (column called 'more research' in Table 7-1), actions related to organizational aspects that need to be taken care of when starting implementation (column called 'more organization' in Table 7-1), and actions related to actually starting implementation (column called 'start implementing in Table 7-1). In essence most uncertainties can be dealt with by starting to implement on a small scale and expanding the installed base gradually, based on predefined values for the different criteria. However, experts also indicated that there are still uncertainties left, and that the sum of all the uncertainties, and interactions among the different uncertain effects of ISA implementation, causes deep uncertainty. Given the fact that ISA implementation is still hampered by (deep) uncertainties, and implementation is desirable, we suggest to use a 'planning for adaptation' approach, and more specifically, to use Adaptive Policymaking (APM). APM is aimed at beginning implementation despite uncertainties, which makes APM in theory a promising approach for developing ISA implementation policies. The only type of uncertainties that can not be resolved by starting to implement are those related to the policymaking and decisionmaking process.

Table 7-1Categorization of actions for the ISA related uncertainties related to major barriers to implementing Assisting and Restricting ISA

More research	**More Organization**	**Start implementing**
- Uncertainty regarding the effect of external developments on the implementation of ISA - Uncertainty regarding behavioral adaptation of drivers that use ISA (counteractive behavior) - Uncertainty regarding the effect of ISA on other (not speed choice related) drive-task related behavior of ISA users - Uncertainty regarding the effect of different ISA implementation strategies on ISA implementation (mainly the effect on acceptance) - Uncertainty regarding which stakeholders are involved in implementing ISA and the importance of each of the stakeholders for ISA implementation. - Uncertainty regarding the dynamics in stakeholder configuration	- Uncertainty regarding the technical characteristics and updating of the speed limit database - Uncertainty regarding the liability allocation in case things go wrong with the functioning of ISA - Acceptance issues (uncertainty regarding the amount of money people are willing to pay for ISA, uncertainty regarding the factors which contribute to ISA acceptance of car drivers and the degree to which each of these factors contributes to the level of acceptance, uncertainty regarding the willingness of people to use ISA) - Uncertainty regarding the cost of ISA implementation - Uncertainty regarding the technical reliability of ISA and the effects of a malfunctioning ISA	- Uncertainty regarding the effect of *long-term* ISA use. - Uncertainty regarding the large scale effects and the effects of ISA implementation in the real-world. - Uncertainty regarding the liability allocation in case things go wrong with the functioning of ISA - Synergy effects of all the uncertainties

The experts indicated that there are a number of uncertainties that were not found in the literature and that can be considered barriers for implementation; these are political-related uncertainties.

In addition to the uncertainties that can be dealt with using analytic approaches, or the types of actions mentioned in Table 7-1 the experts explicitly mentioned one category of uncertainties that are more difficult to deal with. The experts indicate that political issues are important when it comes to ISA implementation. They mention:

- uncertainty regarding the effect of lobbyists;
- uncertainty regarding the political will to take a decision on ISA;
- uncertainty regarding ways to put ISA on the political agenda;
- uncertainty regarding ISA as a policy option in relation to other policy options.

Hence, the experts hinted at a lack of political will to implement ISA. Although relevant these uncertainties were not handled in this dissertation.

In essence, it can be concluded that ISA implementation is hampered by the sum and the interactions among the different (sometimes smaller) uncertainties of ISA implementation. Based on the conclusions that ISA implementation is hampered by deep uncertainty, and starting to implement is the only way some of these uncertainties can be dealt with, the most appropriate approaches to handle deep uncertainties are ‘planning for adaptation’ approaches. We selected Adaptive Policymaking to deal with ISA implementation.

7.2.3 Decision support for ISA implementation

In Chapter 4 we addressed Research Question 2: *What decision support tools are suitable for developing a policy for implementing ISA using this approach, and what would decision support information that is generated with this tool look like?*

We looked at ways to support decisionmaking on ISA and to assess the impacts of different ISA implementation strategies ex-ante. We concluded that the two most commonly used approaches, cost-benefit analysis and multi-criteria analyses, are not equipped to deal with deep uncertainty caused by, amongst others, the synergies among the individual uncertainties, as indicated in Chapter 3. Both cost-benefit and multi-criteria analysis run into difficulties when probability functions cannot be assigned, utility functions cannot be determined, the appropriate consequence model (model used to calculate the effects of a policy option on the outcomes of interest) cannot be agreed upon, etc. As such, these two approaches are hard to use to assess the effects of ISA implementation policies ex-ante, which is hampered by deep uncertainty. We selected Multi Criteria Decision Analysis (MCDA), and we applied a new modeling technique called Exploratory Modeling (EM) as part of the MCDA process. This resulted in an EMCDA approach (Exploratory Multi-Criteria Decision Analysis). In essence the same can be done for cost-benefit analysis. However the current and future stakeholder valuation of the outcomes of ISA implementation can be considered very uncertain. The costs of an ISA system are also uncertain, but we roughly know what these will be.

EMCDA incorporates multiple scenarios, multiple models, multiple policy options, and multiple value systems to represent the uncertainty regarding the criteria performance and weight uncertainties. The multiple scenarios, multiple models, multiple policy options, and multiple value systems are varied simultaneously using ‘fast and simple models’ and EM. By doing this, EM can take all of the many different kinds of uncertainty into account – one does not have to bet on one specific future, but can explore the implications of an almost infinite range of futures. Using EM has a large potential to enable the identification of a ‘planning for adaptation’ decision in spite of deep uncertainties.

We designed and applied this EMCDA approach to the case of ISA implementation. We developed alternative models, each of which was plausible, to assess the effect of different ISA policy options ex-ante. Although the ISA case was initially selected and applied for illustrative purposes of EMCDA, we showed that:

- the EMCDA approach is aimed at mapping the uncertainty space and identifying the consequences of the policy options. This, in turn, allows policymakers to adequately deal with uncertainties that currently hamper implementation.
- EMCDA results in clear policy advice. We showed that, if one is to implement a ‘static robust’ strategy, it is wise to select a strategy that focuses on a small group of drivers with high risk (in this case, young drivers) with an ISA system that is non-overridable. Moreover, we indicated that this Static Robust policy could be used as a “promising basic policy” in the APM process;
- Assessment and development of ISA implementation strategies can greatly benefit from EMCDA, because it gives insights into the effects of potential policy strategies under deep uncertainty;
- EMCDA (or, more generally, integration of MCDA methods with EM) is a very promising ex-ante evaluation methodology for supporting innovative policymaking approaches (like dynamic APM) that could speed up ISA implementation, without focusing on trying to reduce uncertainty.

We used available Dutch scenarios to assess the outcomes of ISA implementation in different future worlds. The result was disappointing, in the sense that the results did not differ across the scenarios. Closer assessment of the scenarios revealed that these scenarios differ so little that no significant differences in the outcomes of the policies across the different scenarios would be expected. The scenarios used were primarily based on two key uncertainties (sovereignty versus collaboration, and public versus private problem solving). The way the scenarios are worked out for transport and mobility do not discriminate enough for our EMCDA example. So, we recommend the use of more discriminating scenarios for example, wildcard scenarios (oil crisis, financial crisis, etc.) should be developed and used.

7.2.4 Developing an ISA implementation policy

In Chapter 5, we addressed Research Question 3: How can we develop a policy that deals with the ISA-related uncertainties using the identified approach, and what would such a policy look like?

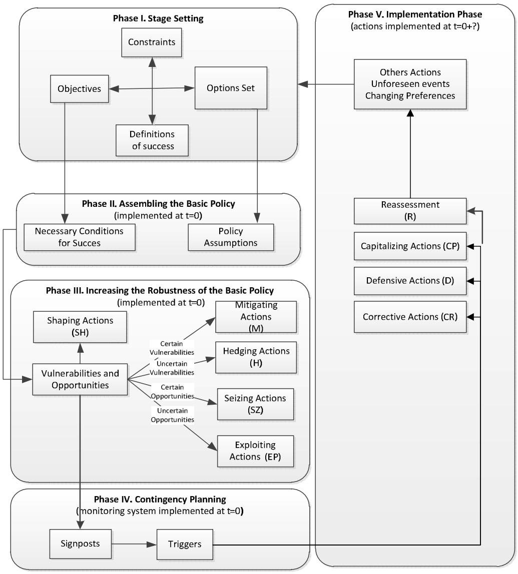
Based on the approaches to deal with uncertainty (identified in Chapter 2), and the uncertainties involved in ISA implementation (identified in Chapter 3), we concluded that ISA uncertainties are best dealt with using ‘planning for adaptation’ policies.

To develop dynamic adaptive policies we decided to use the Adaptive Policymaking (APM) approach as suggested by Walker et al. (2003). We decided to design an experiment to develop adaptive policies. Developing an adaptive policy for ISA implementation requires making the conceptual framework of APM explicit, in terms of tools and methods that can be used to design adaptive policies with experts. We started with the exploration of the design space in terms of tools and methods that are suitable. Next, different tools for the different steps in APM were selected that could be used to develop adaptive policies with transportation experts, policymakers, and stakeholders. Operationalizing the APM framework at an expert workshop, resulted in small adjustments to the APM framework, and revealed several challenges:

- There is an inconsistency or imbalance in the framework. Previous versions of the framework explicitly address ‘certain opportunities’, however uncertain opportunities were not addressed (to deal with these, ’exploiting actions’ were added);
- Within the framework, actions are differentiated by level of certainty or uncertain/ certain. In reality, everything is uncertain, because the policy that is designed is a future policy (when is something considered certain and when is something uncertain?);
- The framework implicitly assumes that the level of uncertainty determines the type of action that is designed. However, how does a policymaker decide whether he should design an action that is implemented when certain trigger values for signposts are reached, or design an action that should be implemented right away?;
- The framework does not shed light on the fact that vulnerabilities and opportunities could require all types of actions (so mitigating, hedging, but also reassessment, corrective, etc.).

Figure 7-1 shows the adjusted APM framework, on which the operationalization in terms of tools and methods is based. The operationalization that was used in the expert workshop is represented in Figure 7-2.

As indicated in Chapter 6, the overall process was supported by a Group Decision Room. Step 1 of APM (assembling of a basic policy) was based on existing policies. The basic policy was designed in interaction with Dutch ISA policymakers. Step 2 (identifying vulnerabilities and opportunities and corresponding actions), Step 3 (identifying signposts and triggers), and Step 4 (designing corresponding future actions), were carried out using specially designed decisions schemes (see Appendix 3, and Figure 5-2). Finally, the adaptive policies that were developed by the experts, were tested using wildcard scenarios, to see if they would still work.



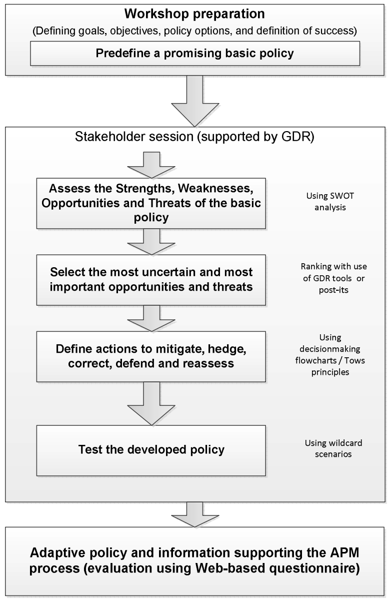


Figure 7-2 The adjusted APM Framework **Figure 7-1 Flowchart for the expert workshop**

The workshop revealed several challenges for developing adaptive policies with experts:

- In the APM Framework, uncertainty determines what types of actions should be taken. In the real world, this depends on many more criteria;
- One of the characteristics of deep uncertainty is the fact that experts cannot agree or do not know. In the workshop, this resulted in the fact that the experts had difficulties determining the level of uncertainty for vulnerabilities and opportunities;
- Specifying trigger values proved to be almost impossible (lack of time, level of detail, etc.);
- In APM, two moments of implementation are defined (when implementing the basic policy (t=0) and after implementation, when a trigger value of a signpost is reached). However, in practice there are also actions that need to be taken and implemented before t=0. These are often related to the political process. During the workshop, the experts could not really identify these.

The experts explicitly mentioned that they thought the SWOT analysis and the use of wildcard scenarios were very useful. The decisionmaking flowcharts for designing actions worked as planned. Despite the previously mentioned difficulties, the experts indicated that emphasizing uncertainties when developing policies for ISA implementation is useful, and that the workshop worked very well. It resulted in realistic adaptive policies for ISA implementation that pleased the various participating experts. The workshop participants indicated that the policy that was developed during the workshop could actually be used for implementing ISA in the Netherlands.

In Chapter 5, we also answered the second part of Research Question 3, “what would such a adaptive policy look like?”. For this dissertation, an adaptive policy that is promising selects the right type of ISA for the right type of driver. We started, in Chapter 4, with developing decision support information for adaptive ISA implementation policies by evaluating a large number of policies targeting young drivers (since literature indicates that drivers are more likely to speed). We explored different outcomes for different types of ISA, and concluded that targeting young drivers is interesting. An interesting approach here could also be to combine it with the plans to start driving at the age of 16 in the Netherlands (currently this is 18 years). So, drivers can start driving a vehicle at 16, provided that they use ISA.

In addition to giving ISA policy advice using EMCDA (a tool explicitly designed to support decisionmaking under deep uncertainty), we developed an adaptive ISA policy with experts using the APM approach. Here, we decided to start with existing ISA implementation plans, based on the same principle of starting to implement the right type of ISA for the right type of driver. Three types of drivers were identified (compliant driver, not compliant driver, and notorious speeder), and appropriate types of ISA in combination with an appropriate way of implementation were selected. The basic policy, which was defined in Chapter 6, is displayed in Table 7-2. It distinguishes three types of drivers (ranging from the compliant driver to the notorious speed offender). Using experts, this policy was made adaptive by adding signposts, triggers, and actions to deal with the opportunities and vulnerabilities that were identified during the workshop.

Table 7-2 The basic policy at the start of the expert policy workshop

Basic policy **Type of driver**	**Type of ISA**	**Measure**	**Definition of success**	**Constraints**
Phase I (2009-2012)				
Compliant driver	ISA (speed alert)	o Start a campaign aimed at persuading people to turn the speed alert functionality on their navigation device on. o Make agreements with companies that develop navigation devices.	Before 2013: 50% of the people that own and use a navigation device actively use the speed alert functionality.	Budget for a campaign.
Less compliant driver (But also the compliant driver)	Free to be selected	o Develop a business case with insurance companies and lease companies.	Before 2013: 50% of the car owners and 50% of lease drivers can choose an insurance or lease product that involves ISA.	
Notorious speed offender	Restricting ISA	o Perform a pilot test aimed at assessing the effects of implementing a restricting ISA for notorious speed offenders. o Make an evidence based decision regarding implementation of such a system for notorious speed offenders.	Before 2013, A decision has to be made on implementation of ISA for notorious speed offenders. Based on, amongst others, outcomes of the trial.	Budget/time
Phase II (2013)				
Phase II will be dependent of the results of phase I. For this phase, more restricting types of ISA will be considered.				

For each of the vulnerabilities (called weaknesses and threats in the SWOT analysis) and each of the opportunities, different actions were defined. As indicated before, these were placed into tables. Tables 7-3 and 7-4 present examples of the actions that were defined for two of the mentioned weaknesses during the workshop.

Table 7-3 Example of actions to increase the robustness of the basic policy

#[1]	Vulnerabilities and Opportunities	Hedging (H), Mitigating (M), Seizing (S) and Exploiting Actions (EP)
W1	Implementing a restricting ISA for notorious speed offenders will damage the image of the less intervening ISA systems. ISA will be associated with punishment not with assistance (like it is now).	**H:** Decouple the pilot from the rest of the basic policy and avoid the term ISA (currently done by calling it speed-lock).
W2	The availability of an accurate speed limit database. Speed limit data has to be correct for right time (dynamic), the right location and the right vehicle.	This is critical success factor, so: **M:**Define who is responsible for what before starting with implementation. **M:**Tender the development of a speed limit database (this should be arranged by public authorities). **M:**Guarentee quality through a third party that is under the supervision of the public authorities. **M:**Develop a system based on bacons that overrule the static speed limit information (Failsafe design).

[1]Corresponding code in Appendix 1

Table 7-4 Examples of contingency planning actions

#[1]	Vulnerabilities and Opportunities	Monitoring and triggering system	Actions: Reassessment (R), Corrective (Co), Defensive (D), and Capitalizing (Ca)
W1	Implementing a restricting ISA for notorious speed offenders will damage the image of the less intervening ISA systems. ISA will be associated with punishment not with assistance (like it is now).	o Number of negative press publications. o Level of acceptance of different ISA systems. o Number and type of ISA related questions asked in the politicians in the Lower House.	**D:** Media campaigns to manage the perception of people regarding ISA (and the speed-lock) explain the difference and the need for implementing such an ISA for this type of driver.
W2	The availability of an accurate speed limit database. Speed limit data has to be correct for right time (dynamic), the right location and the right vehicle.	o Level of accuracy/reliability of speed limit database.	Accuracy should be monitored. In addition: **D:** Start making it more accurate. **Co:** Stop implementation of certain types or combine with on/off switch and overruling possibilities. **Co:** Design the system in such a way that it only warns intervenes in areas with certain accuracy levels.

[1]Corresponding code in Appendix 1

When designing an adaptive policy, the experts indicated that it is important for a policymaker to keep a number of issues in mind. In Chapter 6, we presented the results of the expert workshop, and indicated that APM has two important weaknesses:

- APM can easily result in inconsistent policies (e.g. if actions are stacked, the risk is that policymakers lose track of the original basic policy and why it was implemented in the first place, or all kinds of actions (defending, etc.) are triggered and implemented, but the sum of all actions should have led to reassessment, etc.). Different solutions were proposed. To make sure policymakers deal with these issues in advance (during the design of the adaptive policy), they could use policy pathway research (see Chapter 6), or tools to assess a chains of events that can lead to certain situations. In addition the experts mentioned not to make too many changes to the basic policy. Also, when actions are taken, make sure these are transparent and supported by facts and figures.
- The adaptive policy will most likely be a complicated product. The experts indicated that this runs the risk of becoming vague and intransparent, or that the policy will be considered politically and socially undesirable, which can affect the efficiency and effectiveness of the adaptive policy in a negative way.

7.2.5 Evaluation of a Dynamic Adaptive ISA implementation policy

In Chapter 6, we addressed Research Question 4: How can we evaluate the identified approach, and what are the implications of such an evaluation for the identified approach and for the developed ISA implementation policy?

Not much literature addresses ways to test policy analysis methods and compare them to other ways of policy analysis. In a paper that was written together with Jan Kwakkel (Kwakkel and Van der Pas, 2011), we addressed this issue by making an analogy with medicine and design validation methodology. This resulted in five different types of evidence that can be used to test/validate policy design methods like APM (Theory – Animal Models – In-Vitro Experiments - Natural Experiments – and Clinical Trials). APM is still a conceptual approach. APM as designed by Walker et al. (2003) has never been applied in practice. Some of the principles have been used in practice, and often for relatively simple policy problems with limited policy options.

Based on APM’s current phase of development, we found that the logical next step that should be taken when it comes to APM research is to use “In-vitro experiments” (experts). We composed a list of predefined policy assessment criteria to assess APM, and used “In-vitro experiments” to assess APM. In order to develop adaptive policies with stakeholders, realistic decision-support information that takes into account the deep uncertainties is needed. Next, an approach to develop adaptive policies with experts needs to be designed, and the experts need to evaluate this. The approach to develop adaptive policies was presented in Chapter 5, the evaluation with experts in Chapter 6.

The main conclusions of the experts’ evaluation of APM were that APM was considered to be valuable for policy problems that are hampered by deep uncertainty. The expected benefits of using the APM approach are considered to be much bigger than the expected cost. In general some of the experts’ added in the open questions that chances of policy success become bigger. Moreover, they mentioned that it introduces a more structured and better way of dealing with uncertainty in the policymaking process. In addition, the experts mentioned that the information used and insights gained during the workshop could be used for implementing ISA in the Netherlands.

7.2.6 Comparing APM to current policymaking practice

In Chapter 6, we addressed Research Question 5: *How does the identified approach compare to more traditional policymaking approaches?*

To compare the efficacy of APM to other approaches, we designed an In-vitro experiment. Experts were invited to develop adaptive policies and afterwards elicited on the costs and benefits of APM, the institutional implications of APM, and the efficacy of APM. Below, we summarize the experts' opinions on APM compared to current policy analytic efforts.

Costs and benefits of APM: The experts thought that developing and implementing adaptive policies would be more expensive and time consuming than traditional static approaches. However, for the policy problems the method was designed for (policy problems surrounded with deep uncertainty), the experts thought that the benefits would outweigh the costs. Also, APM is considered an approach that increases the chances of success. Whether the cost-benefit ratio of APM is better compared to traditional static approaches is a question that could not be answered by our research, and as such, remains an interesting way forward for future research. The ISA implementation case contained a relative cheap basic policy (which is the actual Dutch ISA implementation policy). The initial plan was to compare the actual ISA implementation policy (or basic policy) with the designed adaptive policy. However he price of policy failure of the actual policy was very low. This meant that making the policy adaptive would cost more in the design phase than actual policy failure would cost in the worst case scenario. This made APM relatively unattractive.

Institutional implications: The expert evaluation of APM agreed that there is a need for policies that change as the world changes. APM is an approach that results in this type of policy and, as such, has added value. Important barriers for APM are mainly institutional - related to politicians and the political process. Also, policymakers and decisionmakers will have difficulties explaining the complexitiest of APM (and the resulting adaptive policy) to each other and to the other stakeholders involved. Nevertheless, APM can be considered a valuable contribution to the policymaking process. However, from a political/decisionmaking point of view, the experts indicate that APM is not likely to be able to be used in the Netherlands in the near future.

Efficacy of APM compared to traditional static approaches: The experts recognized the claims made by the inventors of APM, and agreed that it allows policymakers to deal with different types of uncertainty, allows for learning, and better deals with information that becomes available during the implementation of the policy. The design of the workshop, and the selected tools and methods used in the workshop, were considered appropriate for developing dynamic adaptive policies.

Although not explicitly asked, the results lead us to conclude that the answer to the question "is APM better than traditional static approaches?", is not easy to answer, because, the answer depends on many factors (the policy problem, the available alternatives, the costs of policy options and policy failure, etc.). What can be concluded from the experts' answers is that putting uncertainty central in the policymaking process is valuable (for policy problems with deep uncertainty). As such, APM can be considered a valuable contribution to the policymaking process. However, it is the decision making or political process where the problems arise, and for which the experts indicated that APM will not be feasible (without, further research, major changes, and education).

7.2.7 Answering the main research question.

The main question we started this dissertation with in Chapter 1 was: *What is an appropriate analytic approach for handling the uncertainties involved in the implementation of ISA?*

Based on the characteristics of the uncertainties involved in ISA implementation, and policy analysis approaches to deal with uncertainty, we decided that a 'planning for adaptation' approach would be most appropriate. We selected APM, and applied it to the case of ISA. However, APM is a conceptual approach, and developing concrete adaptive policies using APM could not be done straightforwardly in a workshop with experts. We designed, applied, and evaluated APM. The result was an ISA implementation policy that, according to the experts, allows policymakers to start implementing ISA, and to deal with the remaining ISA-related uncertainties in an appropriate way (also, better than traditional policies). The results show that APM is better than traditional approaches when it comes to dealing with the uncertainties that hamper ISA implementation. However, the challenges for both APM and ISA lie in the decision making process.

7.3 Conclusions in relation to the social and scientific aims

7.3.1 Social aims

As explained in Section 1.5.1, the social aims of this dissertation were two-fold:

- Contribute to traffic safety.
- Contribute to taking better decisions under uncertainty.

The results of this research can contribute to traffic safety in several ways. Identifying uncertainties involved in ISA implementation helps to get a clear picture of issues that still need to be addressed, and therefore helps to reduce barriers for ISA implementation. On a practical level, we organized an expert workshop in which experts worked together to develop ISA implementation policies. During the workshop we try to improve the current policies in the Netherlands for ISA implementation, by making them adaptive. The experts indicated this knowledge could contribute to ISA policymaking in the Netherlands and, as such, to ISA implementation and, therefore, to traffic safety. This workshop not only identified the vulnerabilities and opportunities of the current policies, it also familiarized the experts with Adaptive Policymaking. As indicated in Section 7.2.2. ISA implementation, and as such traffic safety, could benefit from starting to implement ISA (on a small scale). APM allows policymakers to design policies that allow decisionmakers to decide to start implementation despite all the uncertainties.

7.3.2 Scientific aims

From a scientific point of view, we gained insight into the uncertainties that obstruct policymaking for ISA implementation. Chapter 3 explicitly identifies the uncertainties that still exist for ISA implementation. It therefore contributes to scientific body of knowledge regarding the implementation barriers for ISA and the appropriate way to deal with these (and, more generally, for ISA-like ADAS).

Another scientific aim of this dissertation was to contribute to the development of new tools and methods for designing Adaptive Policies. In Chapter 4, we contributed to the field of MCDA by combining it with Exploratory Modeling, which produced EMCDA a method that helps the users of MCDA deal with deep uncertainty. We also contributed to the development of APM by helping operationalize APM in terms of tools and methods. We designed an approach to develop adaptive policies with experts. In addition, we evaluated APM and compared it to more traditional approaches.

7.4 Reflection and suggestions for future research

This section presents a reflection on the different chapters of this dissertation, and on the overall research. In addition, suggestions for future research are given.

7.4.1 Reflection on the individual chapters

Chapter 2: In this chapter, policy analysis was introduced, and we explained the view we adopted on policy analysis. Adopting the policy analysis view was an important choice, and had its effect on all the papers that were presented. By selecting the systems view on policy analysis, we adopted a view that can be considered the rational, argumentative style within the field of policy analysis (Mayer et al. 2004). This policy analysis style is what Mayer et al. (2004), in their ‘policy analysis hexagon, classify as ‘research and analyze’ or ‘design and recommend’. It is important to stress that the rational, systematic, and quantitative character of the approach has often give rise to criticism (Lynn, 1999; Walker, 2000). However, like any mature approach, policy analysis has withstood the criticism, and today is a commonly used approach both in policy science and in policymaking practice.

It is difficult to say how this dissertation would have looked in case a different perspective on policy analysis would have been selected. It would certainly have had an effect on the uncertainty typologies. But the focus on analytic approaches would also have been less strong. However, it might be promising to look at APM from a process oriented type of policy analysis (e.g. What Mayer et al. call “mediate” in the hexagon (Mayer et al. 2004)). APM can, for instance, be used to create trust among policymakers and stakeholders. Stakeholders could participate in designing mitigating actions, or agreements could be made on signposts and trigger values. For example, in situations in which new infrastructure is built, APM can be used to make agreements with residents in the areas nearby (e.g. in case noise levels (signposts) exceed a certain decibel level (trigger value), the building will be stopped or authorities will start compensating, which can increase acceptance).

Chapter 3: In this chapter we provide insights into the uncertainties that surround ISA implementation. The literature review provided a fairly good insight into these uncertainties. The use of experts was necessary to assess the level of uncertainty and the current state of the art. The experts were selected based on scientific literature (the first authors of scientific papers). A total of 75 experts filled in the questionnaire. There is a bias in this group, based on the fact that these are all scientists (or at least publish in the scientific literature). We asked the initial respondents to provide additional respondents. This resulted in a group of respondents that are 55% researchers, and 45% consultants, policymakers, people working in the automotive industry, and others. Although not explicitly mentioned in Chapter 3, an issue that affects the validity of the results is that it proved difficult for the experts to assess the level of uncertainty. This issue also emerged during the workshop. Although we paid great attention to the understandability of the levels of uncertainty, and we operationalized the levels of uncertainty as clearly as possible in the questionnaire, experts still indicated difficulty in defining the level of uncertainty.

Chapter 4: In this chapter we developed an MCDA approach that allowed us to deal with all the uncertainties involved in ISA implementation. Although the ISA case was considered a "test case", the results confirmed our intuition and compare well to other evaluation studies (Oei, 2001; Carsten et al., 2008). A problem we encountered was that we used only a small number of scenarios that, in the end, proved to be quite similar. In retrospect, we could have been aware of this problem. An earlier publication indicated this as a problem in scenario based analysis (Walker, 2000). The result could have been more interesting if a wider range of scenarios had been included. However, this would mainly have affected the ISA related results since they would have been more robust across a larger number of scenarios. For the validity of the results regarding EMCDA we believe that this will have no significant effect, since the ISA case is used as a an exemplar case. So, the findings regarding EMCDA still hold. Also, because in earlier publications we showed a similar ISA implementation case using multiple different scenarios (Van der Pas et al., 2008; Agusdinata et al., 2009).

An interesting problem to which EM can be applied in the field of MCDA is the methodological issue of determining the stakeholder valuation of outcomes or weights (different approaches are currently in use, such as rough sets, fuzzy sets, etc.). Within the field of MCDA, there is a lot of discussion regarding the best approach. For our research we did not go into the use of different methods for stakeholder evaluations since this was not the main focus of our research. EMCDA allows for all methods to be used, and in the analysis phase searches for a robust solution across the outcomes of all methods. As such, incorporating different methods in an EMCDA assessment is an interesting way forward for EMCDA research.

Chapter 5: In this chapter, we designed a workshop to develop adaptive policies. The research shows that a workshop can produce real-world ISA implementation policies that are valued positively for ISA implementation by the experts. However, we performed a limited number of workshops (only one with actual domain experts). Although not explicitly addressed in the chapters, the experience from our research shows that the more workshops that are held, the less new information is generated, doing more sessions will most likely result in additional information and, perhaps, in better adaptive policies for ISA implementation. For the purpose of this dissertation (giving an indication of what an adaptive ISA implementation policy would look like), we believe that the number of workshops is sufficient. Using the experts indicated what an adaptive policy developed by experts would look like and that, that could actually be implemented. For a real-world policymaking situation, more workshops would improve the quality of the adaptive policy, and as such are desirable. How many additional workshops are needed depends on the quality of the information gathered and the amount of new information generated in each workshop.

Chapter 6: This chapter describes how we familiarized the experts with APM. Our research showed that experts are very positive about APM as a policymaking approach. However, when it comes to implementation of adaptive policies, they see a lot of practical problems. As explained in Chapter 6, the experts worry about an adaptive policy's transparency (multiple changes over a longer period might affect the transparency) and consistency (over time the changes might affect the consistency of a policy). In their assessment, the experts provided solutions to these worries (e.g., support changes with facts and figures, communicate about actions and changes to the basic policy, and avoid changing too often). In addition to these worries, they indicated that the process and results of APM do not match the political process in the Netherlands. This is a serious barrier for the use of APM, and future research should address this issue. APM research would benefit from a political-administrative-science research approach. Such research could address the political/institutional issues that are mentioned in this dissertation. For this dissertation, a limited number of experts were introduced to APM. In what way the effect of the limited number of participants influences the results is hard to say. What can be said is that several issues were mentioned by a majority of the participants. A large majority of the experts mentioned political barriers for the application of APM. Although the arguments were well motivated by the experts, it needs to be noticed that there were no decisionmakers present at the workshop. A challenge is to make APM applicable in the policymaking process and avoid that decisionmakers have to decide on every aspect of an adaptive policy- a basic policy (a decision on when to implement what policy), a monitoring system (decisions on what to monitor), trigger values, (decisions on when to take actions), and predefined actions (decisions on what actions are taken when certain trigger values are reached). If a decisionmaker has to decide on each of these aspects, adaptive policies are not likely to implemented.

When it comes to the evaluation of APM, it needs to be mentioned that the workshop had a strong focus on the Netherlands. This raises the question: to what extent are the results are valid for other countries? When it comes to policy analysis and dealing with uncertainty, the Netherlands has a relatively open and progressive policy culture (e.g. the Dutch have a long tradition of using scenarios in policymaking, and dealing with uncertainties in big infrastructure projects is institutionalized and standardized). So the conclusions regarding the APM for the policymaking process might be less applicable to countries with a less progressive stance towards dealing with uncertainties in the policymaking process. When it comes to conclusions regarding political feasibility of APM, most have to do with effects due to policymaking in a representative democratic system. Most Western countries have similar systems. That is why there is no reason to assume that these conclusions are valid only for the Netherlands.

Finally, we also need to raise the question to which extent it is valid to compare adaptive policymaking to static policies? Policymakers often claim that they, in practice, adapt their policies due to external developments. They point out that their static policies are static in the decisionmaking, and implementation phase. However, policymakers monitor their policies. In case changes or actions are necessary, they intervene. The difference with APM is that the changes to the traditional static policies are made ad-hoc, and these changes are not predefined (prepared well in advance), whereas in the case of APM, when to change and what to change is predefined. For example, in the case of ISA, it is this predefining that enables implementation on a small scale despite the uncertainty, and to gradually expand the penetration level of the system. Something that is more difficult to realize with traditional static policies is the decision to abandon the (further) implementation. Furthermore, most policymakers agree (Chapter 6) that dealing consciously with uncertainty in the policymaking process (by putting the uncertainties central during the policymaking process) increases the policy's chances of success. Nevertheless, the question remains: to what extent does comparing APM to traditional static approaches reflect comparing APM to policymaking reality? Future APM research should address this question it should compare a dynamic adaptive policy (developed using APM) to the total lifecycle of a static policy (the static policy, the static policy as implemented, the actual changes made to the policy, and the outcomes of the policy). This research might also provide insights into the answer to a second question the experts often asked: how can an adaptive policy with all kinds of predefined signposts, triggers, trigger values, and actions be more flexible than a policymaker that reacts to the changing conditions, and that makes changes if necessary? This more philosophical question is not addressed in this dissertation, but the above mentioned suggestions for future research might provide an answer to this question.

7.4.2 A research agenda for ISA

I will not provide a research agenda for ISA, since the essential research for implementation has already been done, and the time has come to take an implementation decision. Of course, there are "knowledge" questions left that can be addressed. So, there is still research that can be done. Indications of these questions can be found in Chapter 3 of the dissertation.

A promising way forward for ISA implementation is to address the political issues. The experts hinted at a political un-will to implement ISA (mainly the more effective types of ISA). Besides this, the experts also indicated that the lobby of the automotive industry is an important factor influencing the political will to implement ISA. An in-depth analysis of the political aspects and the role of different actors in the political process can provide new insights, ISA implementation and implementation of similar innovations could benefit from this knowledge. This type of research should also address the ethics of ISA implementation (e.g. benefits of speeding are only for the speeder, while the costs are for society), and reasons why politicians are refusing to implement a technology that could save so many lives. These types of questions should be researched using different types of research methods and approaches (compared to the ones mentioned in this dissertation). Research methods like ethnographic research or in depth case study research are more suitable to address these political issues. Interesting data gathering methods to support this type of research would be participative observation, narrative interviews, and detailed document study (such data gathering should focus not only on the (policy) documents that are easy accessible, and publicly available, but also on policy documents that are controversial, (deliberately) kept out of the policymaking process, etc.). In addition the research should also focus more on a European level.

7.4.3 A research agenda for Adaptive Policymaking

APM has been around for a while and up to today has not been implemented. Not long ago, Kwakkel (2010) presented a research agenda for APM. His research agenda contained four important items. Briefly summarized, these were:

1. research into operationalizing the steps in the APM Framework using tools and methods;
2. research into the institutional implications of APM;
3. research into the efficacy of adaptive policies compared to traditional static policies (using evidence not stemming from computational models but e.g. from experts);
4. research into the costs and benefits of APM compared to traditional policymaking.

This dissertation has addressed some of the above mentioned issues. We operationalized APM in terms of tools that can be used for developing APM with experts. We also asked the experts some questions regarding the institutional implications of APM and found out that the experts think this is where the main challenges for APM lie. We developed adaptive policies with experts and discussed their inefficacy. And we elicited the experts' opinions regarding the costs and benefits of APM compared to traditional policymaking. Nevertheless, many issues remain. In particular:

1. With respect to operationalization of APM (in terms of tools and methods). we provided insights into the tools that could be used by conducting a workshop with

experts. However, a more exhaustive inventory of all the tools and methods that can be used in the different steps of APM is needed. Eventually this should result in a policymakers' toolbox for designing adaptive policies, with an identification of the tools that are appropriate for each of the APM phases.

2. With respect to the institutional barriers to APM, our research indicated that political/institutional barriers are important. Some suggestions for improvement and dealing with the institutional issues were mentioned. However, more thorough research is needed into these barriers and how they can be overcome.
3. With respect to the efficacy of dynamic adaptive policies compared to traditional static policies, Kwakkel (2010) mentioned using evidence not stemming from computational models but e.g. from experts. Our research addressed this issue using experts. The time has come to take the next step and gather more information using what Kwakkel and van der Pas (2011) call 'natural experiments' or 'clinical trials' (also see Section 2.5 of this dissertation).
4. We addressed the issue of the costs and benefits of APM by eliciting expert opinions. The experts indicated that they thought that the benefits would outweigh the costs in situations of deep uncertainty. However, they also thought that an adaptive policy would be more expensive to design and maintain (due to the monitoring system). The experiment showed that the cost of the policy alternative and the cost of policy failure influence expert opinion on the cost effectiveness of APM. Most experts mentioned that by using APM policymakers increase the chance of success for the policies. Future research should, provide evidence of the benefits of APM and an indication of the quantity of these benefits based on actual cases (e.g. cost-benefit ratios for both adaptive policies and traditional policies for several cases).
5. With respect to the details of the APM Framework, the devil is in the details. Aspects that seem logical and intuitive when reading them in APM related publications prove a challenge when actually developing an adaptive policy. The following issues would benefit from more in-depth research:
   - The monitoring system is an essential part of an adaptive policy. Guidelines and experience with other monitoring systems would be useful. What aspects are important when developing a monitoring system? How can we make sure that the monitoring system also adapts to changing conditions? How can we decide upon appropriate trigger values and come-up with appropriate actions?
   - The APM Framework suggests that (the level of) uncertainty determines what type of actions should be taken (e.g. mitigating or hedging). However, this proves troublesome for several reasons:
     - the vulnerabilities are future vulnerabilities, so, by definition, they are uncertain (what is considered certain and what uncertain?).
     - If the answer to the above mentioned question is: "that depends on the level of uncertainty", the logical next question becomes: "how do we determine the level of a specific uncertainty?" APM is used in cases of deep uncertainty, these are often cases were experts are likely to disagree on the level of uncertainty.
     - the expert workshop showered that, different factors besides uncertainty influence whether an action should be taken right away or sometime in the future (e.g. the cost of the action). Research is needed on identifying the factors that influence whether an action should be taken right away or can wait until certain conditions occur. Based on

our research, for example, urgency and cost could be mentioned as factors that could determine when an action should be taken.

7.4.4 Clearing the road for ISA implementation?

The final question answered in this dissertation is the first question the reader was confronted with when starting to read this dissertation, and which can be found, somewhat hidden, in a combination of the title and subtitle of the dissertation: *Can Adaptive Policymaking clear the road for ISA implementation?*

Interestingly enough, the answer to that question presents us with a paradox. We concluded that ISA can begin to be implemented using APM (Chapter 3 and Chapter 4). But we also concluded that APM is not likely to be used in actual policymaking, anytime soon (Chapter 6), because there are many unsolved issues. Our research indicates that putting uncertainty central in the ISA policymaking process is valuable and the preferred thing to do. However, the experts indicate that putting uncertainty central in the decisionmaking process is counter-productive and will not lead to ISA implementation. Based on these notions and the results of our Adaptive Policymaking workshop, this leads us to conclude that applying the steps of APM in the policymaking process contributes to developing better ISA implementation policies, and as such, *to clearing the road for ISA implementation.* However, the result of this process is an Adaptive ISA implementation policy that, according to the experts, is unlikely to be able to be used in the decisionmaking process. This leads us to conclude that, an adaptive ISA implementation policy *is not clearing the road for ISA implementation.*

The resolution of this paradox is not easy. One way of addressing it might be implementing the adaptive ISA policy virtually, and comparing it to what is happening in the real world (without the adaptive policy). For example, the dynamic adaptive policy developed in this thesis could be implemented virtually (with the outcomes of the policy, being assessed by models and by policymakers). Assessment should take place on a regular basis (e.g. each semester). The adaptive policy would, therefore be virtually implemented, and its performance compared (in parallel) to the actual implemented policy (by the policymakers). For the case of ISA an assessment by the policymakers would require simulation models or expert judgments (to simulate the effect of the implementation of the actions developed by during the adaptive policymaking workshop). This could be an example of a “clinical trial”. Among the benefits of such a trial, it might result in (1) real-world (ISA) implementation (because policymakers gain more knowledge during the experiment), (2) the implementation of Adaptive Policymaking (because policymakers become familiar with the approach and its characteristics), and (3) addressing many of the scientific challenges still left for APM research (if the experiment is set-up and conducted well).

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Summary
Clearing the Road for ISA Implementation?

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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. It is estimated that worldwide each day over 3,000 people die, which comes down to more than 2 every minute. In addition the WHO estimates that worldwide between 30 and 50 million people suffer non-fatal injuries due to traffic accidents. In Europe[9] alone between 1991 and 2008 734,000 citizens were killed in traffic accidents. The most recent traffic safety statistics show that in 2009, in the EU, over 35,000 people per year died, and over 1,5 million Europeans got injured from traffic accidents. This comes down to 95 fatalities a day, indicating that traffic in Europe still is a major cause of fatalities and injuries. Today traffic safety is still a major policy problem. Although the Dutch targets for 2010 were met (in 2010 there were 640 fatalities, the goal was less than 750 fatalities), the goals for 2020 remain a challenge (a maximum of 500). On a European level the goals for 2010 will not be met (in 2009 35,000 fatalities, the goal for 2010 is 27000) and the goal for 2020 (a reduction of 50% compared to 2010) are far from within reach.

In Chapter 1 we explain that speeding is a major cause in road traffic un-safety. It is estimated that one out of every three fatal accidents can be linked directly to inappropriate speed. Speeding not only influences the risk of getting involved in a traffic accident, it also affects the severity of an accident. In recent years the effects of speeding have been recognized by policymakers around the globe, and speed reducing measures (or speed management measures) have been implemented. Speed management measures are typically categorized using the three E's, Enforcement (e.g. placing speed cameras), Education (e.g. launch anti-speeding campaigns), and Engineering (e.g. building roundabouts). These speed management measures proved very effective in the past. However, new speed management measures are needed to meet the ambitious goals for 2020 set by the European Commission and the Dutch

[9] EU (15)

government. One very efficient and effective way of reducing speeding is providing speed choice support to the driver, for example by “simply” to make sure that the vehicle cannot exceed the speed limit. Devices that could reduce speeding through in-vehicle equipment, which have been available since the 1980s, are called Intelligent Speed Adaptation (ISA) devices. These devices have been tested in depth, and the tests always indicate that ISA has a huge potential (e.g. 59% reduction of traffic fatalities) when it comes to increasing traffic safety. So, if policymakers are aware of traffic safety as a policy problem, and ISA is a proven technology, what is it that makes the implementation of ISA go so slow? Research suggests that one reason policymakers cannot decide on the implementation of ISA are the uncertainties that surround the implementation of ISA. Examples of these uncertainties are; uncertainty about the technological performance of ISA under degraded conditions, the willingness of drivers to buy and use ISA, the way ISA will affect traffic flow performance, the willingness of crucial actors to support ISA (automotive industry, insurance companies).

efore presenting our research, we first briefly explain how an ISA system works. Figure 1 shows a schematic overview of ISA technology. Basically, ISA is an in-vehicle system that helps the driver to comply with the legal speed limit at a certain location. This “helping” can be done in several ways. An informative or advisory ISA system provides the driver feedback using a visual or audio signal. A supportive or assisting ISA system intervenes when the speed limit is exceeded, for example, by providing increasing counter pressure on the accelerator pedal 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. In essence, an ISA system knows the real-time position of the car (using GPS), it knows the actual speed (using the speedometer and or GPS), and it knows the legal speed limit at that specific location (using an in-vehicle database). Based on the comparison between the actual speed and the legal speed limit at that location (and sometimes also other parameters like duration of the violation), the system intervenes with the driving task.

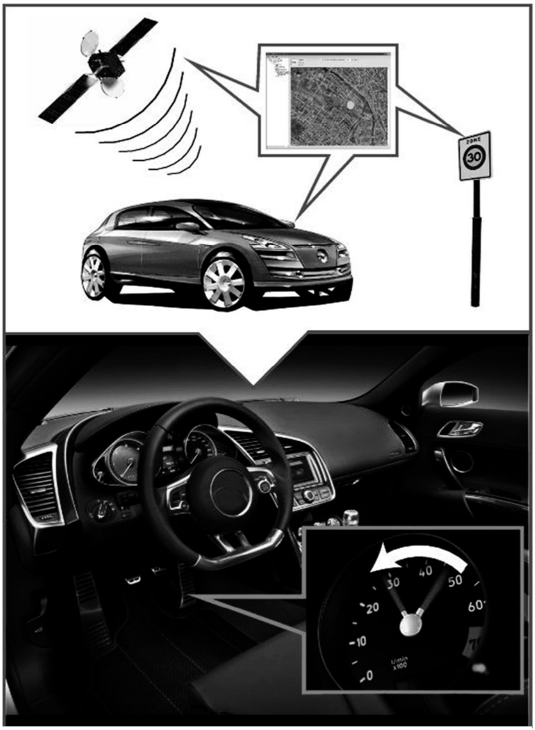


Figure 1 Picture of an ISA system

Handling the uncertainties in ISA implementation

We now turn to the central question that is addressed in this dissertation: *What is an appropriate analytic approach for handling the uncertainties involved in the implementation of ISA?*

To decide what analytic approach can be used to deal with the uncertainties involved in ISA implementation, we first answer the question, *How do we define, and classify the uncertainties involved in analyzing public policies, and what are the approaches for handling them?* In Chapter 2, we look into classifications of uncertainty and appropriate approaches for dealing with the different types of uncertainty. For this dissertation, uncertainty is defined as: *any deviation from the unachievable ideal of completely deterministic knowledge of the relevant system.* In addition we adopt an existing way of classifying uncertainty based on three dimensions. First, there is location of uncertainty. The location of uncertainty identifies where the uncertainty manifests itself within the analytical framework used in Policy Analysis (PA). Examples of these locations are the policy domain, external forces outcomes of interest, stakeholder valuation, etc.). The second dimension is the level of uncertainty. This refers to the level of uncertainty along the spectrum between complete knowledge and total ignorance. Based on an existing classification, we identify four levels of uncertainty ranging from statistical uncertainty, scenario uncertainty, recognized ignorance, to total ignorance. The third dimension, the nature dimension, indicates whether the uncertainty is due to the imperfection of our knowledge (knowledge that can be improved in the future) or is due to the inherent variability of the phenomena being described. A class of uncertainties is deep uncertainty. Deep uncertainty refers to situations in which decision makers, analysts, and experts do not know or cannot agree on: 1) the system models, 2) the prior probability distributions for inputs to the system model(s) and their interdependencies, and/or 3) the value system(s) used to rank alternatives. Using the three dimensions of uncertainty, and the above mentioned definition of deep uncertainty, we can position deep uncertainty within the uncertainty typology: it can occur at any location of the PA framework; it can have any nature; however, there are only two levels of uncertainty that relate to deep uncertainty (recognized ignorance (the situations in which decisionmakers, analysts, and experts cannot agree, or know that they don't know), and total ignorance (situations in which decisionmakers, analysts, and experts don't even know they don't know)).

Also in Chapter 2 we define three ways of actively dealing with uncertainty, based on the classification of uncertainty above, and the conditions under which they may be useful:

- ***Predict-and-Act*****:** predict the future consequences of a policy option (often based on probability distributions), and take a decision. Many transport policy decisions are based on predictions, and the method works very well when the level of uncertainty is low (the result of this approach is an optimal static policy (assuming that all of the assumptions are correct)).
- ***What-if reasoning:*** different plausible futures are specified, and policy options are assessed for these multiple futures. The policy option that performs best across these different futures is selected. This works well in situations where different future representations of the system are known, but the probability of occurrence of each of these futures is unknown (the result of this approach is a 'robust static policy').
- ***Planning for adaptation:*** the third approach is the 'planning for adaptation' approach. Here policies are developed that can be adapted over time. These policies change as the external conditions change. In theory, this method can always be used, but it will be inefficient in cases where there is little uncertainty (the policy will be over-dimensioned).

This, policymaking approach has been especially designed for conditions of deep uncertainty (the result of this approach is a dynamic adaptive policy).

We next look for an answer to the question: *What are the main uncertainties regarding the implementation of ISA, and what is an appropriate approach for handling them?*

In Chapter 2 we answer this question. Based on an extensive literature research, we identified 24 uncertainties. We then surveyed 75 experts in the field of ISA on which uncertainties are barriers for ISA implementation, and how uncertain these uncertainties are. Based on the expert opinions, we concluded that the long-term effects, and the effects of large-scale implementation of ISA are still very uncertain and are important barriers for the implementation of the most effective types of ISA. In addition to this, there is deep uncertainty regarding the interactions among the uncertainties. One way to deal with these uncertainties would be to start implementation on a small scale and to gradually expand the penetration level, in order to learn how ISA influences the transport system over time. To make this type of decision, a decision support tool is needed that is capable of assessing the effects of implementation despite the deep uncertainties that still exist.

In seeking an answer to the main question, we concluded that the type of uncertainty involved in ISA decision making can be classified as deep uncertainty. We also concluded that the uncertainties can best be dealt with by starting to implement on a small scale. More specifically, we selected a ‘planning for adaptation approach’ called Adaptive Policymaking. This approach is designed to deal with deep uncertainties, and to allow policymakers to start implementing despite uncertainty. Based on these conclusions, we focused the rest of our research on answering the following questions:

- *What decision support tools are suitable for developing a policy for implementing ISA using this approach, and what would decision support information that is generated with this tool look like?*
- *How can we develop a policy that deals with the ISA-related uncertainties using the identified approach, and what would such a policy look like?*
- *How can we evaluate the identified approach, and what are the implications of such an evaluation for the identified approach and for the developed ISA implementation policy?*
- *How does the identified approach compare to more traditional policymaking approaches?*

Decision support for ISA implementation

In Chapter 4 we address the question: *What decision support tools are suitable for developing a policy for implementing ISA using this approach, and what would decision support information that is generated with this tool look like?*

In Chapter 4 we established that, when it comes to dealing with deep uncertainty, the two most commonly used decision support approaches, cost-benefit analysis and multi-criteria analysis, run into difficulties when probability functions cannot be assigned, utility functions cannot be determined, the appropriate consequence model (model used to calculate the effects of a policy option on the outcomes of interest) cannot be agreed upon, etc. That is why, in Chapter 4, we introduce Multi Criteria Decision Analysis (MCDA) and apply a new modelling technique called Exploratory Modelling (EM) as part of the MCDA. This produced an EMCDA approach (Exploratory Multi-Criteria Decision Analysis) approach to identifying a good policy in the face of deep uncertainty. EMCDA (or, more generally, integration of MCDA methods with EM) incorporates multiple scenarios, multiple models, multiple policy options, and multiple value systems to represent the uncertainty regarding the criteria performance and weight uncertainties. The multiple scenarios, multiple models, multiple policy options, and multiple value systems are varied simultaneously using ‘fast and simple models’ and a technique called EM. In addition the results are not analysed by looking for an optimal policy, but on identifying policies with no regret. By doing this, all of the many different kinds of uncertainty can be taken into account – one does not have to bet on one specific future, but can explore the implications of an almost infinite range of futures.

Next (also in Chapter 4), we apply the EMCDA approach to the case of ISA implementation. We develop multiple models to assess the effect of different ISA implementation policy options ex-ante. For the ISA case using EMCDA we were able to show that:

- The EMCDA approach is able to map the uncertainty space and identify the consequences of the policy options. This in turn allows policymakers to adequately deal with uncertainties that currently hamper implementation;
- EMCDA results in clear policy advice. We showed that, if one is to implement a Static Robust strategy, it is wise to select a strategy that focuses on a small group of drivers with high risk (in this case, young drivers) with a system that is non-overridable. Moreover, we indicated that this Static Robust policy could be used as a “promising basic policy” in the APM process;
- Assessment and development of ISA implementation strategies can greatly benefit from EMCDA, because it gives insights into the effects of potential policy strategies under deep uncertainty;
- EMCDA is a very promising ex-ante evaluation methodology for supporting innovative policymaking approaches (like dynamic APM) that could speed up ISA implementation, without focusing on trying to reduce uncertainty.

Adaptive Policymaking

In Chapter 5 we address the question: *How can we develop a policy that deals with the ISA-related uncertainties using the identified approach, and what would such a policy look like?*

As indicated before, we selected the Adaptive Policymaking approach for ISA implementation. Before answering the research question we will first briefly introduce APM. Figure 2 shows the APM Framework as explained in Chapter 5.

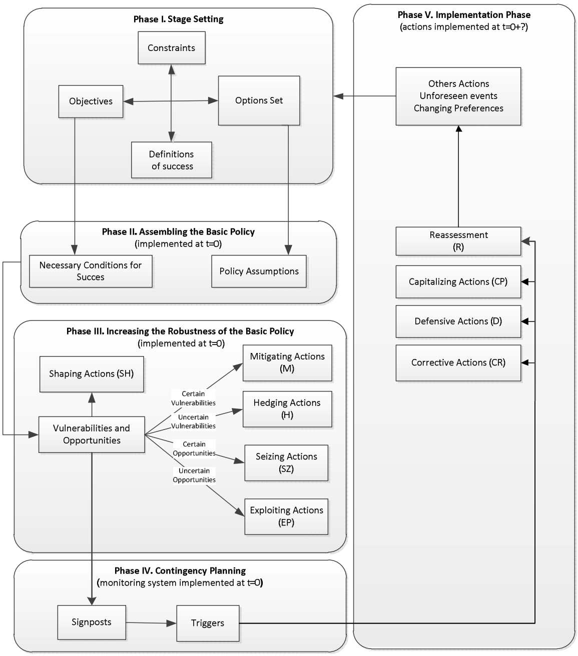


Figure 2 The Adaptive Policymaking framework

In the first phase (Phase I), as in traditional policymaking, the policy problem is analyzed and the goals of the policy are formulated. Next (in Phase II), a promising basic policy is selected. After selecting a basic policy, the vulnerabilities and opportunities of the policy are identified (Phase III). Vulnerabilities are weaknesses of, or threats for, the basic policy and indicate ways in which the basic policy can fail. Opportunities are developments that can increase or accelerate the success of the policy. Based upon the identified vulnerabilities and the opportunities, different types of actions can be defined that should be taken at the time the basic policy is implemented (say t=0), in order to increase the chances for its success:

- *Mitigating actions (M)* — actions aimed at reducing the effects of certain vulnerabilities of a policy;
- *Hedging actions* (H) — actions aimed at spreading or reducing the risk of failure from the vulnerabilities of a policy;
- *Seizing actions (SZ)* — actions aimed at seizing certain available opportunities;
- *Exploiting actions (EP)* — actions aimed at exploiting uncertain opportunities. Here the framework slightly differs from previously published versions of the framework).
- *Shaping actions (SH)* — actions aimed at reducing the chance that an external condition or event that could make the policy fail will occur, or to increase the chance that an external condition or event that could make the policy succeed will occur.

The actions defined in Phase III are actions taken in advance to reduce the vulnerabilities of the basic policy and to identify opportunities to improve its chances of success. However, uncertainties about the future require the performance of the basic policy to be monitored carefully in order to know where (and if) to implement actions. This monitoring mechanism is set up in Phase IV by defining what should be monitored (signposts) and when a change in policy is needed (trigger values). Signposts are used to determine whether the policy needs to be adapted. This adaptation occurs when a critical value of a signpost variable (trigger value) is reached (sometime at t=0+?). There are four different types of actions that can be triggered by a signpost:

- *Defensive actions (D)* - actions aimed at clarifying the basic policy, preserving its benefits, or meeting outside challenges in response to specific triggers. These actions leave the basic policy unchanged;
- *Corrective actions (CR)* - actions aimed at adjusting the basic policy;
- *Capitalizing actions (CA)* - actions triggered by external developments that improve the performance of the basic policy;
- *Reassessment (R)* - an action that is initiated when the analysis and assumptions critical to the plan's success have clearly lost validity.

Once the basic policy and the adaptive elements (Phases I-IV) are agreed upon, the basic policy, associated actions (mitigating, hedging, seizing, exploiting), and the monitoring system are implemented. In case of a trigger event an appropriate, predefined, responsive action is implemented.

Adaptive Policymaking for ISA

Although Adaptive Policymaking (APM) seems the perfect approach for ISA implementation, and a lot has been published about APM, it has mostly been used in theory. Research shows there are several challenges left for APM:

1. APM can be defined as a "high level concept, captured in a flowchart"; there is only very limited insight into the tools and methods that can be used in each of the steps in the flowchart;
2. APM lacks well worked out examples of real-world policy problems. (Most cases that have been published were developed to illustrate the APM process.);
3. APM lacks examples of adaptive policies developed by policymakers or domain experts. (Until now APM has almost exclusively been performed by scientific researchers that are familiar with the APM, concept not real-world policymakers or domain experts.)

As a result, several more specific issues remain, such as the costs and benefits of APM, the efficacy and the performance of adaptive policies in comparison to more traditional static policies, and the institutional implications of APM. If APM is to be used for ISA implementation, these issues have to be addressed. However, there is not much literature that addresses ways to test policymaking methods and compare them to other ways of policymaking. Based on an analogy with medicine and design validation methodology, we identified five different types of evidence that can be used to test/validate policy design methods like APM (Theory – Animal Models – In-Vitro Experiments- Natural Experiments – and Clinical Trials). Based on APM's current phase of development, we found that the logical next step that should be taken when it comes to APM research is to use "In-vitro experiments" (experts). We, therefore, composed a list of predefined policy assessment criteria to assess APM, and used "In-vitro experiments" to assess APM. In order to develop adaptive policies with experts, we need realistic decision-support information that takes into account the deep uncertainties. We then designed, an approach to develop adaptive policies with experts, carry out the approach. The approach to develop adaptive policies is presented in Chapter 5; the evaluation with experts in presented in Chapter 6.

Developing Adaptive Policies with experts.
In Chapter we develop adaptive policies with experts. In order to develop adaptive policies with experts, we had to operationalize APM in terms of tools and methods. We started with the exploration of the design space, in terms of tools and methods that are suitable for developing adaptive policies with experts. Next, different tools for the different steps in APM were selected that could be used to develop adaptive policies with transportation experts, policymakers, and stakeholders. Operationalizing the APM framework showed the need for small adjustments in the framework. The resulting operationalization is presented in Figure 3.

The overall process of developing adaptive policies with experts was supported by a Group Decision Room. Step 1 of APM (assembling of a basic policy – see above) was based on existing policies. Step 2 of APM (identifying vulnerabilities and opportunities and corresponding actions) was done with a SWOT analysis, using predefined Group Decision Support tools (such as input forms, ranking mechanisms, etc.) Step 3 of APM (identifying signposts and triggers) and Step 4 of APM (designing corresponding future actions) were carried out using specially designed decisions schemes. Finally, the developed adaptive policies were tested using wildcard scenarios, to see if they would still work. (The wildcard scenarios represented discontinuity and focused on assumptions that underlie the decision to implement ISA.)

The expert workshop revealed several challenges for developing adaptive policies with experts:

- In the APM Framework, uncertainty determines what types of actions should be taken. In the real world this depends on many more criteria like the cost of an action;
- ISA implementation is hampered by deep uncertainty, one of the characteristics of deep uncertainty is the fact that experts cannot agree or do not know. In the workshop, this resulted in the fact that the experts had difficulties determining the level of uncertainty for the identified vulnerabilities and opportunities;
- Specifying trigger values proved to be almost impossible (lack of time, level of detail, etc.);
- In APM, two moments of implementation are defined (when implementing the basic policy (t=0) and after implementation, when a trigger value of a signpost is reached). However, in practice there are also actions that need to be taken and implemented before t=0. These are often related to the political process, for instance informing the policymakers, market consultation to identify potential suppliers, and creating political support. During the workshop, the experts could not really identify these.

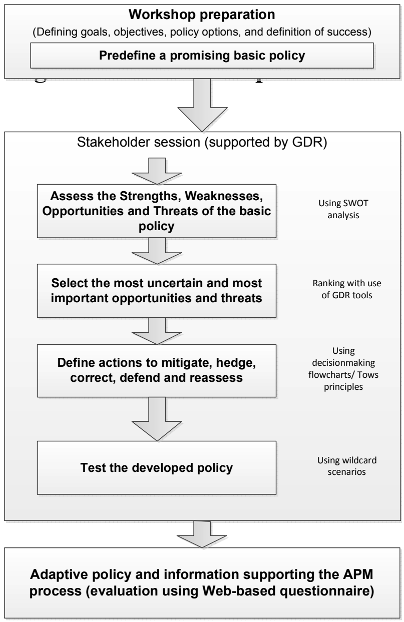


Figure 3 Operationalization of APM

To make it possible to achieve the objective of the workshop in a single day, we decided to start with existing ISA implementation plans as the basic policy, based on the principle of 'start implementing the right type of ISA for the right type of driver'. Three types of drivers were identified (compliant driver, less compliant driver, and notorious speeder), and appropriate types of ISA in combination with an appropriate way of implementation were selected. As can be seen in Table 1, for the compliant driver, the basic policy is to start a campaign aimed at turning the speed alert in navigational devices on; for the less compliant driver, a business case would be developed in cooperation with lease and insurance companies aimed at developing an insurance or lease product that involves an ISA system; notorious speeders, would be offered the option of equipping their cars with ISA instead of taking away their driver licenses.

Table 1 Overview of basic policy (Based on the existing plan which was initiated in 2009)

Basic policy				
Type of driver	**Type of ISA**	**Measure**	**Definition of success**	**Constraints**
Phase I (2009-2012)				
Compliant driver	ISA (speed alert)	o Start a campaign aimed at persuading people to turn the speed alert functionality on their navigation device on. o Make agreements with companies that develop navigation devices.	Before 2013: 50% of the people that own and use a navigation device actively use the speed alert functionality.	Budget for a campaign.
Less compliant driver (But also the compliant driver)	Free to be selected	o Develop a business case with insurance companies and lease companies.	Before 2013: 50% of the car owners and 50% of lease drivers can choose an insurance or lease product that involves ISA.	
Notorious speed offender	Restricting ISA	o Perform a pilot test aimed at assessing the effects of implementing a restricting ISA for notorious speed offenders. o Make an evidence based decision regarding implementation of such a system for notorious speed offenders.	Before 2013, A decision has to be made on implementation of ISA for notorious speed offenders. Based on, amongst others, outcomes of the trial.	Budget/time
Phase II (2013)				
Phase II will be dependent of the results of phase I. For this phase, more restricting types of ISA will be considered.				

Using experts, this basic policy was made adaptive by adding signposts, triggers, and actions to deal with the opportunities and vulnerabilities that were identified during the workshop. For each of the vulnerabilities (called weaknesses and threats in the SWOT analysis) and each of the opportunities, different actions were defined.

When designing an adaptive policy, the experts indicated that it is important for a policymaker to keep a number of issues in mind. In Chapter 6, we present the results of the expert workshop, which indicated that APM has two important weaknesses:

- APM can easily result in inconsistent policies (e.g. if actions are stacked, the risk is that policymakers lose track of the original basic policy and why it was implemented in the first place, or all kinds of actions (defending, etc.) are triggered and implemented, but the sum of all actions should have led to reassessment, etc.). Different solutions were proposed. To make sure policymakers deal with these issues in advance (during the design of the adaptive policy) they could use policy pathway research, or tools to assess a chains of events that can lead to certain situations. In addition experts mention not to make too many changes to the basic policy. Also, when actions are taken, make sure these are transparent and supported by facts and figures.

- The adaptive policy will most likely be a complicated product. Experts indicate that this runs the risk of becoming vague and intransparent, or that the policy will be considered politically and socially undesirable. Which affects the efficiency and effectiveness of the adaptive policy in a negative way.

Evaluation of Adaptive Policymaking for ISA implementation

Part of a policy development is an ex-ante policy evaluation. APM as a policy analysis approach has seldom been evaluated. That is why, in Chapter 6, we address the questions: *How can we evaluate the identified approach, and what are the implications of such an evaluation for the identified approach and for the developed ISA implementation policy?* and, *How does the identified approach compare to more traditional policymaking approaches?*

As indicated above, we used "In-vitro experiments" to assess APM (expert opinions). The main conclusion of the experts' was that APM would be valuable for policy problems that are hampered by deep uncertainty. They considered the expected benefits of using the APM approach to be much bigger than the expected costs. In general some of the experts' added in the open questions that chances of the policy's success become bigger (as compared to the chances of the policy's success in case of a static policy). Moreover, they mentioned that APM introduces a more structured and better way of dealing with uncertainty in the policymaking process. In addition the experts mentioned that the information used during the Adaptive Policymaking session for ISA could actually be used for implementing ISA in the Netherlands. In addition, the experts mention that important barriers for APM are mainly institutional -- related to politicians and the political process. Also, they felt that policymakers and politicians will have difficulties explaining the complex product of APM (an adaptive policy) to each other and to the other stakeholders involved. Nevertheless, they felt that APM can make a valuable contribution to the policymaking process. However, from a political/decisionmaking point of view the experts indicate that APM is not likely to be usable in the Netherlands in the near future (without, further research, major changes, and education). Because of problems with respect to the decision making or political process.

Conclusion

The main question we started this dissertation with was: *What is an appropriate analytic approach for handling the uncertainties involved in the implementation of ISA?*

Using literature research and expert elicitation we identified and assessed the uncertainties involved in ISA implementation. Based on the characteristics of the uncertainties involved in ISA implementation, and policy analysis approaches to deal with uncertainty, we decided that a 'planning for adaptation' approach would be most appropriate. We selected APM, and applied it to the case of ISA.

However, APM is a conceptual approach, and applying this approach to the case of ISA could not be done straightforwardly. We, therefore, designed, applied, and evaluated, a workshop to develop adaptive policies. The result was an ISA implementation policy that, according to the experts, allows policymakers to start implementing ISA, and to deal with the remaining ISA-related uncertainties in an appropriate way (also, better than traditional policies). The results of the expert elicitation showed that APM is better than traditional approaches when it comes to dealing with the uncertainties that hamper ISA implementation. However the experts also indicated that APM has some serious challenges left when it comes to political aspects.

Samenvatting
De weg vrijmaken voor ISA implementatie?

J.W.G.M. van der Pas

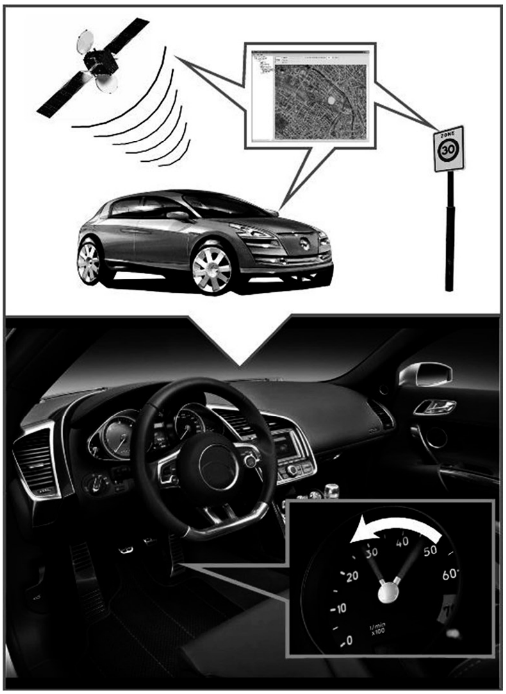
Aanleiding
Elke dag worden er inwoners van Europa en andere delen van de wereld geconfronteerd met het verlies van geliefden door verkeersongevallen. Dagelijks vallen er ongeveer 3000 verkeersdoden, wat neer komt op ongeveer twee doden per minuut. Naast het grote aantal verkeersdoden vallen er, volgens schattingen van de WHO, ook nog eens tussen de 30 en 50 miljoen gewonden per jaar door verkeersongevallen. Alleen al in Europa[10] vielen er tussen 1991 en 2008 734.000 doden. De meest recente statistieken voor Europa laten zien dat er in 2009 meer dan 35.000 doden vielen en dat er 1,5 miljoen gewonden waren. Dit komt neer op 95 doden per dag, wat aangeeft dat verkeersveiligheid nog steeds een belangrijk probleem is. In Nederland zijn de doelstellingen voor 2010 gehaald (in 2010 vielen er 640 doden, de doelstelling was 750 doden), toch blijft het doel van 2020 een uitdaging (een maximum van 500). Op Europees niveau zullen de doelstellingen van 2010 niet gehaald worden (in 2009 waren er meer dan 35.000 doden, het doel voor 2010 is 27.000. Op het moment van het verschijnen van deze dissertatie waren de definitieve cijfers voor 2010 nog niet beschikbaar), het doel voor 2020 is nog ver buiten bereik (in 2020 wil men een reductie van 50% ten opzichte van 2010).

In Hoofdstuk 1 leggen we uit dat "te snel rijden" een belangrijke oorzaak is van verkeersonveiligheid. Naar schatting één op de drie ongelukken met een dodelijke afloop kan gelinkt kan worden aan het overschrijden van de snelheidslimiet. De gereden snelheid beïnvloedt niet alleen de kans dat men een ongeval krijgt maar ook de ernst van een ongeval. Het effect van te snel rijden op verkeersveiligheid is niet onopgemerkt gebleven en wereldwijd zijn beleidsmakers begonnen met het implementeren van maatregelen die te hard rijden moeten tegen gaan. Deze maatregelen worden meestal gecategoriseerd middels de drie E's: Education (educatie en voorlichting, denk hierbij bijvoorbeeld aan overheidscampagnes tegen te snel rijden), Engineering (infrastructuur en voertuigontwikkeling, denk aan de bouw

[10] Het gaat hier om de EU (15)

van rotondes in plaats van kruisingen), Enforcement (wetgeving en handhaving, denk bijvoorbeeld aan (mobiele) radar controles). Deze maatregelen zijn effectief gebleken in het verleden maar de ambitieuze doelstellingen van Nederland en de EU voor 2020 vragen om nieuwe snelheidsbeperkende maatregelen. Een erg efficiënte en effectieve manier om te hard rijden aan te pakken is er 'simpelweg' voor te zorgen dat de auto niet harder kan rijden dan de wettelijke snelheidslimiet. Al sinds de jaren '80 wordt er onderzoek gedaan naar de effecten van Intelligente Snelheids Adaptatie systemen (ISA-systemen). Dit zijn systemen die de bestuurder ondersteunen bij het kiezen van de juiste rijsnelheid. Deze systemen zijn in het verleden tijdens vele pilots getest in binnen- en buitenland. Keer op keer tonen de testen aan dat ISA een groot potentieel heeft als het gaat om het terugdringen van de rijsnelheid en dus om de verkeersveiligheid te verbeteren (bijvoorbeeld 59% reductie van het aantal verkeersdoden). De vraag is nu: als de beleidsmakers zich bewust zijn van het verkeersveiligheidsprobleem en ISA is een bewezen technologie met zo veel potentie, waarom gaat de implementatie van ISA dan zo langzaam? Onderzoek toont aan dat beleidsmakers niet kunnen of willen beslissen over de implementatie van ISA vanwege de vele onzekerheden die de implementatie van ISA met zich meebrengt. Bijvoorbeeld de onzekerheid rond het technisch functioneren van ISA tijdens slechte weersomstandigheden, de bereidheid van bestuurders om ISA te kopen en te gebruiken, de manier waarop ISA doorstroming van het verkeer zal beïnvloeden en de bereidheid van cruciale actoren om ISA te ondersteunen (auto-industrie, verzekeringsmaatschappijen).

Voordat we ons onderzoek en de resultaten presenteren gaan we eerst kort in op de manier waarop een ISA-systeem werkt. Figuur 1 toont een schematisch overzicht van een ISA-technologie. ISA is een *in-vehicle*-systeem (een systeem dat in de auto zit) en dat de bestuurder "helpt" om zich op een bepaalde locatie aan de wettelijk bepaalde snelheidslimiet te houden. Dit "helpen" kan op verschillende manieren. Een informatieve of adviserende ISA, geeft de bestuurder audio en/of visuele feedback wanneer de snelheidslimiet wordt overschreden (ook wel *speedalert* genoemd). Een ondersteunende of assisterende ISA grijpt in op de rijtaak, door bijvoorbeeld tegendruk te geven op het gaspedaal indien de bestuurder de snelheidslimiet overschrijdt. Tenslotte is er nog een begrenzende ISA welke ervoor zorgt dat de bestuurder niet harder kan rijden dan de snelheidslimiet (de bestuurder kan in principe het systeem niet negeren). Een ISA-systeem "kent" de locatie van de auto (bijvoorbeeld door plaatsbepaling middels GPS), het systeem kent de actuele snelheid van het voertuig (door de snelheidsmeter en de GPS), en het systeem kent de wettelijke snelheidslimiet op de locatie van het voertuig (door een database met snelheidslimieten in de auto). Op basis



Figuur 1 Voorstelling van een ISA-systeem

van deze gegevens zal het systeem al dan niet ingrijpen op de rijtaak.

Omgaan met de onzekerheden die spelen bij de implementatie van ISA
We zullen ons nu richten op de centrale vraag van dit proefschrift: *Wat is een geschikte analytische methode voor het omgaan met de onzekerheden die een rol spelen bij de implementatie van ISA?*

Om te bepalen wat nu een geschikte aanpak is moeten we eerst een antwoord vinden op de vraag: *Hoe definiëren en classificeren we de onzekerheden die een rol spelen bij het analyseren van publiek beleid en wat zijn beschikbare aanpakken om met die onzekerheden om te gaan?* In hoofdstuk 2 wordt een overzicht gegeven van de verschillende typologieën van onzekerheid. Voor deze dissertatie hanteren we een bestaande definitie van onzekerheid, namelijk: *alles anders dan het onbereikbare ideaal van compleet deterministische kennis over het relevante systeem.* Daarnaast maken we gebruik van een bestaande manier om onzekerheid te classificeren, wat gebeurt aan de hand van drie dimensies. De eerste dimensie is de locatie van de onzekerheid: de locatie van de onzekerheid wordt gebruikt om te identificeren waar de onzekerheid zich manifesteert binnen het *Policy Analysis Framework* (*PA-framework*). Voorbeelden van deze locaties zijn: de conceptualisering van het beleidsdomein, externe factoren, de beleidseffecten, etc. De tweede dimensie is de mate van onzekerheid (*level*), welke varieert van complete kennis tot totale onwetendheid (met een tussenliggend aantal niveaus). De derde dimensie is de aard van de onzekerheid (*nature*), welke aangeeft wat de oorzaak is van de onzekerheid. Is het onzekerheid ontstaan door imperfectie van onze kennis of is het bijvoorbeeld onzekerheid die samengaat met de variabiliteit van het fenomeen dat wordt beschreven? Een speciaal type onzekerheid is diepe onzekerheid. Dat verwijst naar situaties waar de beleidsmakers, analisten en experts niet weten of het niet eens kunnen worden over: (1) het onderliggende model dat het relevante beleidsdomein representeert, (2) de kansverdelingen die als input gebruikt zouden kunnen worden voor modelparameters en de onderlinge samenhang tussen deze kansverdelingen, (3) de waarde die verschillende actoren hechten aan verschillende beleidsuitkomsten. Als we de drie dimensies van onzekerheid toepassen op diepe onzekerheid, kunnen we zeggen dat diepe onzekerheid: (1) op elke plek in het PA-framework kan voorkomen, (2) elke oorzaak kan hebben, (3) maar dat er slechts twee maten van onzekerheid van toepassing zijn ("recognized ignorance" en "total ignorance').

In hoofdstuk 2 identificeren we drie manieren om actief om te gaan met onzekerheid:

- **Voorspellen en handelen:** voorspel de toekomstige consequenties van een beleidsoptie (vaak gebaseerd op statistische methoden en kansverdelingen) en neem vervolgens een beslissing. Veel beslissingen in het verkeer en vervoersdomein zijn hierop gebaseerd en de aanpak werkt best aardig als de mate van onzekerheid relatief klein is. Als we ervanuit gaan dat alle gedane aannames over de toekomst kloppen is het resultaat van een dergelijke aanpak "optimaal statisch beleid".
- **"Wat-als" denken**: diverse plausibele toekomsten worden gespecificeerd (scenario's) en de verschillende beleidsopties worden geëvalueerd voor de verschillende scenario's. De beleidsoptie die het beste presteert, gegeven de verschillende mogelijke toekomsten, is de beleidsoptie die zou moeten worden geïmplementeerd. Deze aanpak werkt best goed wanneer er verschillende plausibele toekomsten geschetst kunnen worden voor het beleidsdomein (ook al is de kans dat een bepaald scenario zich zal voordoen onbekend). Het resultaat van deze aanpak is "statisch robuust beleid".

- **Plannen voor adaptatie**: de derde aanpak die we onderscheiden is planning voor adaptatie. Deze aanpak ontwikkelt beleid dat kan worden aangepast. Deze beleidsopties veranderen als de externe condities veranderen. In theorie kan deze methode altijd worden gebruikt, maar het zal inefficiënt worden in situaties waar er slechts een beperkte mate van onzekerheid is. Het beleid zal dan over-gedimensioneerd zijn. Deze aanpak is speciaal ontwikkeld voor diepe onzekerheid, het resultaat van de aanpak is "dynamisch adaptief beleid".

Daarna gaan we opzoek naar een antwoord op de vraag: Wat zijn de belangrijkste onzekerheden bij de implementatie van ISA en wat is een geschikte aanpak om met deze onzekerheden om te gaan?

In hoofdstuk 2 gaan we in op de bovenstaande onderzoeksvraag. Op basis van een uitgebreide literatuur studie identificeren we 24 onzekerheden voor ISA-implementatie. Vervolgens hebben we een enquête uitgezet onder 75 ISA-experts waarbij we hebben onderzocht welke van deze 24 onzekerheden een barrière zijn voor de implementatie van ISA en hoe onzeker deze onzekerheden nu eigenlijk zijn. De experts concluderen dat de effecten van grootschalige implementatie onzeker zijn en dat de langer termijn effecten van ISA implementatie onzeker zijn. Voor de meest effectieve ISA-vormen zijn dit belangrijke barrières voor implementatie. Naast deze onzekerheden werd door de experts ook aangegeven dat het niet alleen de individuele onzekerheden zijn die belangrijke barrières vormen, maar dat er diepe onzekerheid is over de interacties tussen de onzekerheden. Een manier om hiermee om te gaan is te starten met implementatie op kleine schaal en vervolgens langzaam de implementatie graad op te voeren. Belangrijk is dat zo ook geleerd kan worden hoe ISA het transportsysteem beïnvloedt. Om een dergelijke beslissing te nemen zal een beleidsondersteunend model nodig zijn dat geschikt is om de effecten van implementatie te evalueren ondanks de diepe onzekerheden die nog bestaan. De aanpak die het beste past bij het type onzekerheid dat een barrière vormt voor ISA-implementatie en bij het advies om te beginnen met implementatie op kleine schaal, is de eerder genoemde "Plannen voor adaptatie" aanpak.

Tot nu toe concludeerden we al dat het type onzekerheid dat aanwezig is bij het implementeren van ISA geclassificeerd kan worden als "diepe onzekerheid". Daarnaast concludeerden we dat deze onzekerheid het beste aangepakt kan worden door te starten met implementatie op een kleine schaal. Meer specifiek selecteren we een aanpak die *Adaptive Policymaking* (APM) heet (Adapatief of flexibel beleid maken). Deze aanpak is ontwikkeld om om te gaan met diepe onzekerheid en om beleidsmakers toe te staan te beginnen met implementatie ondanks de onzekerheid die er nog is. Gebaseerd op deze conclusies focussen we de rest van het onderzoek op de volgende vragen:

- *Welke beleidsondersteunende methoden en technieken zijn geschikt voor het ontwerpen van een ISA-implementatiestrategie, en hoe ziet beleidsondersteunende informatie die is ontwikkeld met zo'n methode er dan uit?*
- *Hoe kunnen we, gebruikmakend van de geïdentificeerde aanpak, beleid ontwikkelen dat op een juiste manier omgaat met de onzekerheden en hoe ziet dat beleid er dan uit?*
- *Hoe kunnen we de geïdentificeerde aanpak evalueren en wat zijn de implicaties van zo'n evaluatie voor de geïdentificeerde aanpak en voor het ontwikkelde ISA-implementatie beleid?*
- *Hoe verhoudt de geïdentificeerde aanpak zich tot meer traditionele aanpakken?*

Beleidsondersteunende informatie voor ISA-implementatie

In hoofdstuk 4 gaan we in op de vraag: *Welke beleidsondersteunende methoden en technieken zijn geschikt voor het ontwerpen van een ISA-implementatiestrategie, en hoe ziet beleidsondersteunende informatie die is ontwikkeld met zo'n methode er dan uit?*

In hoofdstuk 4 stellen we vast dat de twee meest gebruikte beleidsondersteunende aanpakken, "kosten baten analyse" en "multi-criteria analyse", in de problemen kunnen komen zo gauw er bij het modelleren van de effecten van verschillende maatregelen bijvoorbeeld geen kansverdeling kan worden bepaald, geen nutsfunctie kan worden vastgesteld, het ex-ante assessment model omstreden is, etc. Om deze reden introduceren we in hoofdstuk 4 een multi-criteria analyse waarbij we een nieuwe modelleertechniek toepassen (*Exploratory modelling* (EM)). Dit resulteert in een EMCDA aanpak (*Exploratory Multicriteria Decision Approach*). Deze aanpak is gericht op het identificeren van een goede beleidsmaatregel in tijden van diepe onzekerheid. EMCDA (of in het algemeen integratie van MCDA-methoden met EM) omvat meerdere scenario's, meerdere modellen, meerdere beleidsopties, meerdere waardesystemen (bijvoorbeeld van verschillende actoren of een representatie van mogelijk veranderende waardesystemen in de tijd). Al deze scenario's, modellen, beleidsopties en waardesystemen worden simultaan gevarieerd door het gebruik van relatief snelle en eenvoudige modellen. Vervolgens wordt niet gezocht naar de optimale beleidsoptie maar die beleidsopties waar men het minste spijt van zou hebben. Door het zo aan te pakken kunnen ontelbaar veel mogelijke toekomsten worden meegenomen in de analyse en zijn beleidsmakers niet langer genoodzaakt te wedden op een specifieke toekomst. Dit laat toe dat men opzoek gaat naar de implicaties van het beleid in een haast oneindige reeks van mogelijke toekomsten.

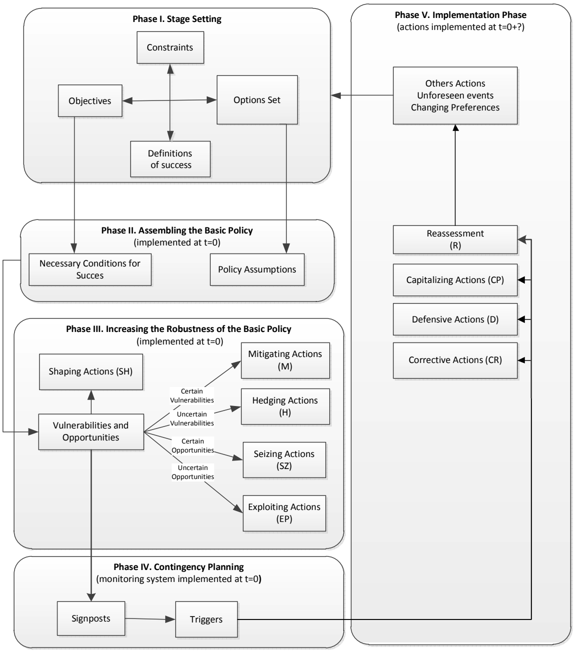
Vervolgens passen we (ook in hoofdstuk 4) de EMCDA aanpak toe op de ISA-implementatiecasus in Nederland. We ontwikkelden verschillende modellen om het effect van ISA-implementatiestrategieën in te kunnen schatten. Voor de ISA-casus konden we laten zien dat:

- De EMCDA-aanpak in staat is om de onzekerheid in kaart te brengen samen met de consequenties van de beleidsopties. Dit zorgt ervoor dat beleidsmakers adequaat omgaan met de onzekerheden die op dit moment de implementatie van ISA bemoeilijken;
- EMCDA resulteert in een helder beleidsadvies. We laten zien dat, als men een statisch robuuste strategie wil implementeren, het verstandig is om te beginnen met een relatief klein aantal bestuurders (in dit geval is gekozen voor jonge auto bestuurders) met een systeem dat niet te negeren of uit te schakelen is;
- Ex-ante evaluatie en ontwikkeling van ISA-implementatiestrategieën kunnen veel voordeel hebben van EMCDA omdat het inzicht geeft in de effecten van potentiële strategieën, ook als er sprake is van diepe onzekerheid;
- EMCDA is een veel belovende ex-ante evaluatie methodologie die bij kan dragen aan innovatieve manieren van beleidsontwikkeling (zoals *adaptive policymaking*) die de implementatie van ISA zouden kunnen versnellen, zonder daarbij te focussen op het verminderen van onzekerheid.

Adaptive Policymaking (Adaptief beleid ontwikkelen)

In hoofdstuk 5 gaan we in op de vraag: *Hoe kunnen we, gebruikmakend van de geïdentificeerde aanpak, beleid ontwikkelen dat op een juiste manier omgaat met de onzekerheden en hoe ziet dat beleid er dan uit?*

Zoals eerder aangegeven hebben we de ‘Adaptive Policymaking’-methode geselecteerd voor ISA-implementatie. Voordat we ingaan op de onderzoeksvragen zullen we eerst kort uitleggen wat deze ‘Adaptive Policymaking’-methode nu inhoudt. Figuur 2 toont het *framework* zoals het wordt uitgelegd in hoofdstuk 5.



Figuur 2 Het Adaptive Policymaking (PA) Framework

In de eerste fase (Phase 1) wordt net zoals bij het maken van traditioneel beleid, het beleidsprobleem geanalyseerd en de doelen geformuleerd. Vervolgens wordt in de tweede fase (Phase II) een veelbelovende beleidsoptie geselecteerd. Dit noemen we het basisbeleid. Na het selecteren van het basisbeleid worden, in fase 3 (Phase III), de kwetsbaarheden (zwaktes en bedreigingen) en de kansen (kansen en sterktes) voor het basisbeleid geïdentificeerd. De kwetsbaarheden van het beleid zijn manieren waarop het basisbeleid kan falen. Kansen zijn ontwikkelingen die het succes van het beleid kan versnellen of vergroten. Op basis van de geïdentificeerde kwetsbaarheden en kansen voor het basisbeleid, kunnen verschillende typen acties worden gedefinieerd. Deze acties moeten genomen worden op het moment dat het basisbeleid wordt geïmplementeerd (zeg op t=0) om de uiteindelijke kans op succes te vergroten en de kans op falen te verkleinen. Hieronder worden de acties toegelicht:

- *Mitigating actions (M)* ─ acties gericht op het reduceren van de effecten van de kwetsbaarheden van het basisbeleid (het gaat hier om kwetsbaarheden die zich zeer waarschijnlijk voor zullen doen);
- *Hedging actions* (H) ─ acties gericht op het spreiden of op het verminderen van het risico van falen ten gevolge van de kwetsbaarheden van het basisbeleid (het gaat hier om kwetsbaarheden die onzeker zijn);

- *Seizing actions (SZ)* — acties gericht op het verzilveren van kansen (het gaat hier om kansen die zich zeer waarschijnlijk voor gaan doen);
- *Exploiting actions (EP)* — acties gericht op het uitbuiten van onzekere kansen (hier wijkt het framework iets af van eerder gepubliceerde frameworks);
- *Shaping actions (SH)* — acties gericht op het reduceren van de kans dat iets van buitenaf ervoor zorgt dat het beleid faalt, of om de kans te vergroten dat er zich een situatie voordoet die ervoor zorgt dat het beleid zal slagen.

De acties gedefinieerd in fase III zijn acties die vooraf genomen kunnen worden om de kwetsbaarheid van het basisbeleid te verminderen en de kans op succes te vergoten. Echter, de onzekerheden over de toekomst vereisen dat de uitkomsten van het beleid nauwkeurig gemonitord worden om erachter te komen of (en zo ja, waar en wanneer) bepaalde acties geïmplementeerd moeten worden. Het monitoringsmechanisme wordt gedefinieerd in fase IV (Phase IV), door te definiëren wat er gemonitord moet worden (dit noemen we "signposts") en wanneer er ingegrepen moet worden (dit nomen we "triggers"). Het basisbeleid wordt aangepast als een kritieke waarde van een signpost overschreden wordt. Op dat moment kunnen er vier type acties worden geïmplementeerd:

- *Defensive actions (D)* – acties gericht op het verdedigen van het basisbeleid. Bij het implementeren van deze acties blijft het basisbeleid intact;
- *Corrective actions (CR)* - acties gericht op het aanpassen van het basisbeleid;
- *Capitalizing actions (CA)* - acties die worden getriggerd door externe gebeurtenissen die de kans op succes van het basisbeleid vergroten;
- *Reassessment (R)* – actie die wordt getriggerd als de analyse en aannames, die ten grondslag liggen aan het beleid, hun validiteit verliezen.

Als het basisbeleid en de adaptieve elementen (fasen I tot IV) zijn bepaald, kan het basisbeleid, de bijbehorende acties (mitigating, hedging, seizing, exploiting) en het monitoringssysteem worden geïmplementeerd. Op het moment dat er een *trigger event* plaats vindt zal een gepaste vooraf gedefinieerde actie worden geïmplementeerd.

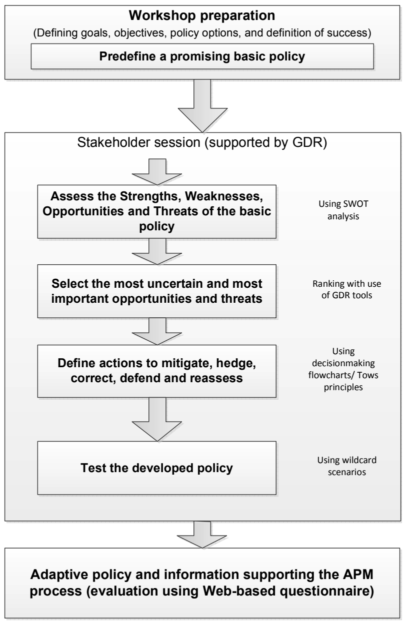
Ondanks het feit dat APM een geschikte aanpak lijkt voor de implementatie van ISA en het feit dat er veel gepubliceerd is over APM, is APM slechts een theoretisch concept dat nog nooit gebruik is in de praktijk. Onderzoek laat zien dat er nog verschillende uitdagingen zijn voor APM:

1. APM kan worden geduid als een concept, beschreven in de vorm van een "stroom diagram": er is slechts in beperkte mate inzicht in de methoden en technieken die kunnen worden gebruikt in elk van de stappen/fases van APM;
2. Het ontbreekt aan goed uitgewerkte voorbeelden van echte beleidsproblemen waarvoor APM is toegepast. Bijna alle casuss die zijn gepubliceerd zijn illustratieve problemen;
3. Het ontbreekt aan voorbeelden van adaptief beleid dat is ontwikkeld door de partijen en personen die in de beleidspraktijk ook betrokken zouden zijn bij het ontwikkelen van (adaptief) beleid. Tot op vandaag is APM bijna exclusief het domein van wetenschappelijk onderzoekers geweest. (Die overigens ook nog eens bekend waren met het concept APM, dit zijn dus geen beleidsmakers of domein experts.)

Dit heeft geresulteerd in het feit dat er nog veel specifieke vragen onbeantwoord zijn zoals: wat zijn nu exact de kosten en de baten van APM?, wat zijn de doelmatigheid en de resultaten van adaptieve beleidsplannen als je ze vergelijkt met meer traditionele (statische) beleidsplannen?, en wat zijn de institutionele implicaties van APM? Voordat APM gebruikt kan worden voor de implementatie van ISA zullen deze uitdagingen geadresseerd moeten worden. Literatuur over methoden om beleidsontwerp methodes te testen en vergelijken met andere beleidsontwerp methoden is schaars. Op basis van een analogie met geneesmiddelenonderzoek en ontwerponderzoek hebben we vijf verschillende aanpakken gedefinieerd die gebruikt kunnen worden om beleidsontwerp methoden (als APM) te testen en valideren (Theory – Animal Models – In-Vitro Experiments- Natural Experiments – and Clinical Trials). Als we kijken naar het onderzoek dat gedaan is op het gebied van APM en de huidige staat van ontwikkeling van APM stellen we vast dat de logische volgende stap is om “in-vitro experiments” te gebruiken om APM te testen (met andere woorden: we gaan experts gebruiken om APM te evalueren).

Allereerst is er een lijst opgesteld met criteria die gebruikt worden om beleidsondersteunende processen te evalueren, daarnaast hebben we “in vitro experimenten” gebruikt om APM te evalueren. De aanpak die we hebben geformuleerd wordt gegeven in hoofdstuk 5, een expert evaluatie van APM wordt gegeven in hoofdstuk 6.

Adaptive Policies ontwerpen met experts.
In hoofdstuk 5 ontwerpen we adaptief beleid met experts (we noemen dit “in vitro experimenten”). Om dit te realiseren zal er eerst een operationalisatie gemaakt moeten worden van APM. Er moeten methoden en technieken gezocht worden die kunnen worden gebruikt bij het ontwerpen van adaptief beleid met experts. Allereerst is gezocht naar een zo breed mogelijk scala aan methoden en technieken dat kon worden gebruikt binnen elk van de verschillende fasen van APM (randvoorwaarde was dat het methoden en technieken gebruikt konden worden in een expertsessie). Daarna zijn voor elk van de fasen van APM-methoden technieken geselecteerd die tezamen een consistent geheel vormden (de uiteindelijke APM-workshop). Het uiteindelijke resultaat, de APM-workshop of de operationalisatie van het APM-concept, is weergegeven in Figuur 3. Deze APM-workshop hebben we uiteindelijk een aantal malen getest en vervolgens samen met beleidsmakers, experts en stakeholders, middels de workshop, adaptief beleid voor ISA implementatie ontworpen.



Figuur 3 operationalisatie van APM

De APM-workshop werd ondersteund door een zogenaamde Group Decision Room (GDR) of ook wel “Versnellingskamer genoemd”. De eerste fase van APM (assembling of a basic policy) is gebaseerd op bestaand beleid. De tweede stap, het vast stellen van de sterktes, zwakten, kansen en bedreigingen (assess the Strengths, Weaknesses Opportunities and Threats), is gedaan middels een SWOT-analyse. Stap 3 (identifying signposts and triggers) en stap 4 (designing corresponding future actions) zijn gedaan met behulp van special ontwikkelde *flowcharts*. Tenslotte is het adaptieve beleid getest met behulp van *wildcard*scenario’s om te zien of het beleid nog zou werken als zich extreme scenario’s voor zouden doen (de wildcard-scenario’s weerspiegelden extreme trendbreuken waarbij de focus lag op de aannames die ten grondslag liggen aan de beslissing om ISA te implementeren).

De APM workshop bracht verschillende uitdagingen aan het licht voor het ontwerpen van adaptief beleid met experts:

- In het APM-framework bepaalt de onzekerheid wat voor type actie er ondernomen moet worden (bijvoorbeeld: voor onzekere kwetsbaarheden worden andere acties ontworpen dan al voor zekere kwetsbaarheden). In de praktijk zal dit van meerdere criteria afhangen, bijvoorbeeld van de prijs van een actie;
- ISA-implementatie wordt gehinderd door diepe onzekerheid. Een van de karakteristieke eigenschappen van diepe onzekerheid is het aspect dat de betrokkenen relevante kennis niet kennen of hebben, of dat ze het er niet over eens kunnen worden. In de workshop leidt dit tot het feit dat de deelnemers moeite hebben met het bepalen van de mate van onzekerheid van de kwetsbaarheden en kansen;
- Het vaststellen van trigger waarden bleek om verscheidene redenen niet mogelijk (te veel detail, gebrek aan tijd, etc.);
- In APM zijn er twee momenten van implementatie (t=0) als het basisbeleid en bijbehorende acties geïmplementeerd worden en (t=0+?) als er een triggerwaarde bereikt wordt op enig moment in de toekomst. Er zijn echter ook acties denkbaar die genomen moeten worden voor t=0. Deze hebben vaak te maken met het politieke proces, bijvoorbeeld het inlichten van de verschillende politici, het creëren van draagvlak (lobbyen), het uitvoeren van een markt consultatie. Gedurende de workshop hadden de deelnemers vaak moeite met het positioneren van deze acties, omdat t=0 te laat is.

Er is gekozen voor het gebruik van een bestaand beleidsplan als basisbeleid voor ISA-implementatie. Dit is (onder andere) gedaan om het mogelijk te maken de workshop in een dag af te ronden. Het uitgangspunt van het basisbeleid is de implementatie van de juiste ISA voor de juiste bestuurder. Hiertoe zijn drie typen auto bestuurders gedefinieerd (welwillende bestuurders, minder welwillende bestuurders en notoire hardrijders), is het meest geschikte ISA type bepaald en is er gezocht naar een geschikte manier van implementatie (subsidies, via verzekeraars, etc.). Tabel 1 geeft het basisbeleid weer. Zoals kan worden gezien in tabel 1 is het basisbeleid gericht gedifferentieerd naar het type bestuurder: voor de welwillende bestuurder overweegt men het starten van een campagne om de “speed-alert”-functionaliteit in de navigatie aan te zetten. Voor de minder welwillende bestuurder is er voorzien in een speciale verzekeringspolis. Hiertoe zal samen met de verzekeringsbranche een *business case* ontwikkeld worden. Voor de notoire snelheidsovertreders zal de mogelijkheid gecreëerd worden om te kiezen voor een ISA-system in plaats van het afnemen van het rijbewijs. Hiertoe wordt eerst een proef naar de haalbaarheid uitgevoerd.

Tabel 1 Overzicht van het basisbeleid (gebaseerd op een bestaand plan dat was geïnitieerd in 2009)

Basisbeleid Type bestuurder	Type ISA	Maatregel	Definitie van Success	Beperkingen
fase I (2009-2012)				
Welwillende bestuurder	Ondersteunde ISA (speed alert)	o Het starten van een campagne gericht op het overhalen van bestuurders om de speed alert functionaliteit op hun navigatie system aan te zetten. o Afspraken maken met navigatie ontwikkelaars om het system default op speed alert te zetten.	Voor 2013 moet 50 van de bestuurders die een navigatie system hebben actief de speed alert functionaliteit gebruiken.	Budget voor een campagne.
Minder welwillende bestuurder (maar ook de welwillende bestuurder)	Vrij om te worden bepaald	o Ontwikkelen van een business casus.	Voor 2013 moet 50% van de auto bezitters en 50% van de lease rijders kunnen kiezen uit een verzekeringsproduct met ISA erin.	
Notoire snelheidsovertreder	Beperkende ISA	o Het uitvoeren van een proef om de effecten van een dergelijk system te testen voor notoire snelheidsovertreders. o Het nemen ban een beslissing op basis van de resultaten van de proef over implementatie.	Voor 2013, moet ere en beslissing genomen zijn over de implementatie van ISA voor notoire verkeersovertreders.	Budget/tijd
fase II (2013 tot …)				
Fase II zal afhankelijk zijn van de resultaten van fase I dat geldt ook voor het type ISA dat in de toekomst overwogen zal worden.				

Tijdens een ‘expert’-workshop is het basisbeleid (Tabel 1) adaptief gemaakt door allerlei acties, signposts en triggers (en trigger values) te definiëren.

De experts geven aan dat bij het ontwerpen van adaptief beleid een aantal factoren belangrijk zijn. In hoofdstuk 6 presenteren we de resultaten van de workshop. Daaruit komt naar voren dat APM twee belangrijke zwaktes heeft:

- APM kan makkelijk resulteren in inconsistente beleidsmaatregelen. Bijvoorbeeld bij het stapelen van acties zou het kunnen dat een beleidsmaker uit het oog verliest wat het oorspronkelijke beleid was en waarom dit beleid in de eerste plaats werd geïmplementeerd. Of indien er over langere tijd allerlei acties geïmplementeerd worden die het beleid aanpassen, zou de situatie kunnen ontstaan dat men eigenlijk beter het beleid had kunnen herevalueren. Verschillende oplossingen voor deze problemen worden in hoofdstuk 6 gegeven (bijvoorbeeld het gebruik van *policy pathway research*). Ook zeggen de experts dat het regelmatig aanpassen van het beleid negatief kan worden uitgelegd. Dit kan het vertrouwen in het beleid en de beleidsmakers kunnen ondermijnen; veel wijzigingen wordt dus als onwenselijk beschouwd. In de gevallen waar wijzigingen aan het beleid nodig zijn, is het raadzaam dit goed te documenteren en te onderbouwen met de juiste cijfers en getallen.
- Het is zeer waarschijnlijk dat een adaptief beleid een gecompliceerd product is. De experts geven aan dat je met een adaptief beleid het risico loopt om vaag en

intransparant te zijn. Dit is politiek en maatschappelijk onwenselijk en beïnvloedt de effectiviteit van het beleid.

Evaluatie van Adaptive Policymaking voor ISA-implementatie

APM als een beleidsanalyse-aanpak is zelden geëvalueerd. Dat is waarom we in hoofdstuk 6 ingaan op de vraag: *Hoe kunnen we de geïdentificeerde aanpak evalueren en wat zijn de implicaties van zo'n evaluatie voor de geïdentificeerde aanpak en voor het ontwikkelde ISA-implementatie beleid? En, hoe verhoudt de geïdentificeerde aanpak zich tot meer traditionele aanpakken?*

Zoals hierboven aangegeven hebben we "In-vitro experiments" gebruikt om APM te evalueren (expert meningen). De belangrijkste conclusie van de experts is dat APM waardevol is voor problemen met diepe onzekerheid. De voordelen van het gebruik van Adaptive Policymaking zijn dat de verwachte voordelen van het gebruik van APM veel groter zijn dan de verwachte kosten. Ook gaven een aantal experts in de open vragen aan dat zij verwachten dat de kans dat het beleid ook daadwerkelijk zijn doelen haalt veel groter wordt dan met traditioneel statisch beleid. Daarnaast noemden ze dat APM een gestructureerdere en betere manier is om om te gaan met de onzekerheden in het beleidsontwerp-proces. Ook gaven de experts aan dat ze dachten dat de informatie die gegenereerd is tijdens de workshop daadwerkelijk gebruikt kan worden voor ISA-implementatie in Nederland. Toch zijn er een aantal belangrijke institutionele barrières voor APM – gerelateerd aan politici en het politieke proces. Adaptief beleid is een complex product en beleidsmakers en politici zullen moeilijkheden hebben met het uitleggen van het ontworpen beleid, zowel aan elkaar als aan alle stakeholders. Desalniettemin, vonden ze dat APM een waardevolle bijdrage kan leveren aan het beleidsontwerp proces ondanks het feit dat vanuit een politiek/besluitvormings oogpunt APM niet bruikbaar is op de korte termijn (zonder verder onderzoek of grote veranderingen), vanwege de problemen die het op zal leveren in de besluitvorming of het politieke proces.

Conclusie

De centrale vraag waar we dit proefschrift mee begonnen was: *Wat is een geschikte analytische methode voor het omgaan met de onzekerheden die een rol spelen bij de implementatie van ISA?*

Met behulp van literatuurstudie en expert ondervraging hebben we de belangrijkste onzekerheden geïdentificeerd en geanalyseerd die een rol spelen bij de implementatie van ISA. Op basis van de belangrijkste karakteristieken van de onzekerheden die een rol spelen bij ISA implementatie en beleidsanalyse hebben we een "planning for adaptation" aanpak gekozen voor de ISA implementatie casus.

Echter, APM is een conceptuele aanpak en voor de toepassing op ISA is geen standaard aanpak voorhanden. Er is daarom een APM-workshop ontwikkeld, toegepast en geëvalueerd om uiteindelijk adaptief beleid te ontwerpen. Het resultaat was ISA-implementatie beleid dat volgens de experts de beleidsmakers toestaat om ISA te implementeren, en om op een geschikte manier om te gaan met de onzekerheden die een rol spelen bij ISA-implementatie. (beter dan het traditionele statische beleid). Het resultaat van de expert analyse laat zien dat APM beter werkt dan de traditionele aanpak als het gaat om het omgaan met onzekerheden die ISA-implementatie in de weg staan. Desalniettemin, geven de experts ook aan dat als het gaat om het besluitvormingsproces er nog serieuze uitdagingen liggen voor APM.

About the Author

Jan-Willem van der Pas was born in Breda, the Netherlands, on 22 June 1977.
He graduated from the Onze-Lieve-Vrouwe Lyceum in Breda and received his Bachelor's degree in Electrical Engineering at the Hogeschool Brabant in the same town. In 2004 Jan-Willem received his Master's degree in Technology and Innovation Policy at the University of Technology Eindhoven (TU/e).

Jan-Willem respectively worked for Siemens Nederland N.V. and the University of Maastricht before commencing his PhD research in 2005. The PhD research took place at the Faculty of Technology, Policy and Management of the Delft University of Technology.

Currently Jan-Willem works at the same faculty as part-time researcher for the section Transport & Logistics. He researches success and failure factors of transport innovations. He further works at DTV Consultants in Breda for two days per week.

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