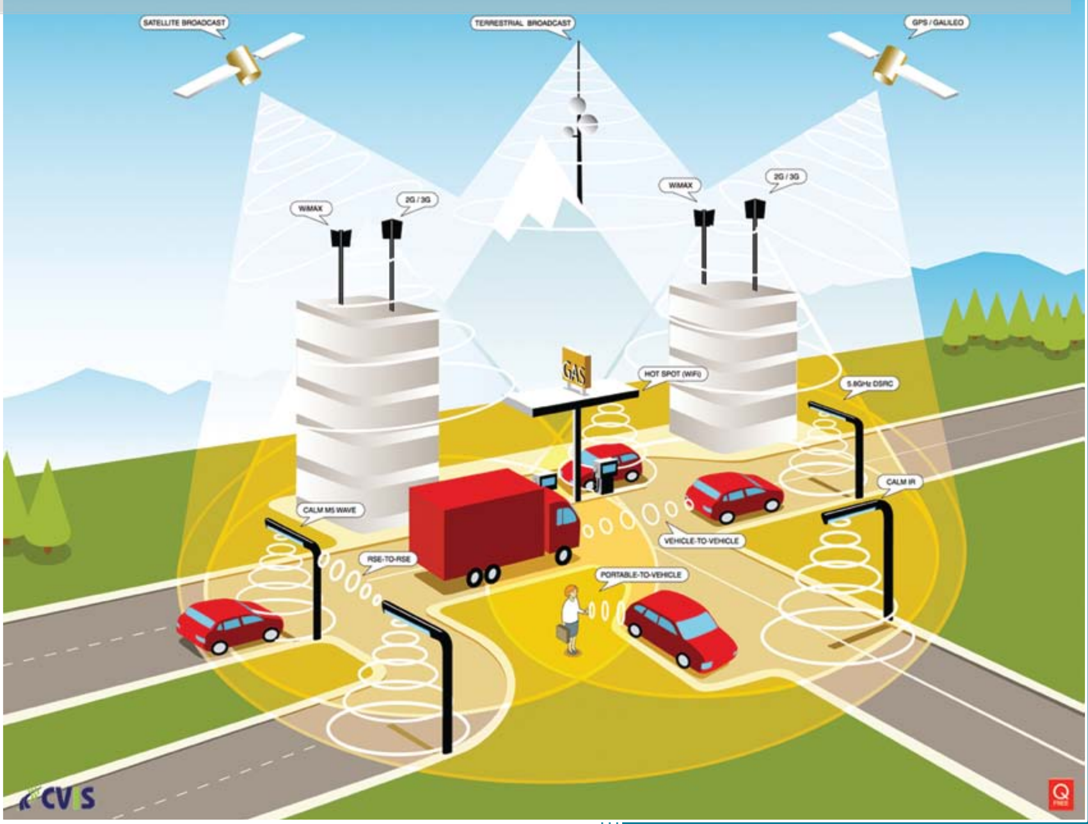
Traffic Safety Speed Advisor



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Intelligent Transport Systems 2

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EXECUTIVE SUMMARY

Since the integration of different functions often leads to synergy advantages of many natures, this should be a goal for many technologies. When important information can be integrated in a system that has effects on as many aspects of transport and traffic as possible, it can be foreseen that safety, environment and economy may benefit in a combined fashion. The development of the Traffic Safety Speed Advisor (TSSA) is such a technology, which major focus is to improve traffic safety. The TSSA is a (portable) in-car system which will provide the user of the system with a speed advice that should be safe to maintain given various safety factors. This safe speed is calculated using information from different modules. Using the definition of *task load*, we can define what modules the safe speed will be based upon.

The modules are based upon the sustainable safety principles by the SWOV. The TSSA must take into account statistical risks, homogeneity, predictability, forgivingness and user related factors. The first module is the driver module which contains situational factors (alcohol & drugs, following distance, aggression, concentration and fatigue) and the driver profile (age, experience, education, track record and culture). The second module is the car module which contains car profile (age, maintenance, weight, tires, breaks and safety options), the Euro NCAP rating and the car status (load and trailer). The third and latest module is the external influences module which contains weather (rain, snow, wind, hail and temperature), road properties (width, layout, surface and curvature) and traffic (traffic density, road accidents, ghost-drivers, incidents and hot-spots).

The safe speed will be calculated upon a rating system. Putting the rating system into the speed perspective, it should be clear that it is not feasible, nor recommendable, to be too precise in the calculation of the speed advice. That is why the difference in speed should be at least 5 km/hour. Accordingly, also because experimental tests always have a certain amount of error or uncertainty (meaning if the scale is too large, differences could be noted that may not be significant), we do not need a wide scale to rate the security, so we propose a scale ranging from 1,0 to 5,9 to still allow for enough discriminative power. Every sub module will have its own rating. To actually determine system safety, ratings need to be combined into a rating per module, which in turn leads to an overall rating that depicts the safety status of the module combination. For every module, critical situations need to be defined, as well as a threshold value for functioning. For the driver module, this may be the alcohol limit, tiredness and license revocation. The threshold ratings are normative values, which means that if a value is below the threshold rating, it becomes the final rating for that module. We propose a weighted average of the module ratings into a combined safety rating: the lowest rating should have the highest weight in determining the final score. Based on this rating, a safe speed will be calculated. If one takes the average highway in The Netherlands for example, there already is a speed range of 80 km/h (trucks) to 120 km/h (cars). One could relate the combined safety rating to this speed range: a rating of 1,0 would mean an advised maximum speed of 80 km/h, while a rating of 5,9 would mean an advised maximum speed of 120 km/h. The calculated safe speed can be displayed as an advice speed, but it can also be hard-limiting.

For the development and implementation process of the TSSA different stakeholders can be described. The stakeholders all have their own interest in the TSSA. The most important stakeholders are the TSSA manufacturer, government and European Union. For the TSSA manufacturer the most important thing to know is if there is enough user acceptance. When the users do not accept the TSSA system, no systems will be sold and developing the system will not benefit. For the government and the European Union it can be interesting to subsidize the development and implementation of the TSSA, so traffic safety will increase. For them it is important to know if implementing the TSSA will increase the traffic safety. Because of this an user acceptance assessment and an impact assessment will be carried out.

In the user acceptance assessment a survey is carried out. This is done by putting a questionnaire online. In total a number of 218 respondents filled in the questionnaire of which 179 responses were useful. The results from this questionnaire are that 35% is willing to buy the system with an average willingness to pay off €150. When the system is offered for free 75% of the respondents indicated that they are willing to drive with the system. When users of the system get a monthly rebate, 78% of the respondents indicated that they want to have the TSSA. The respondents indicated the modules weather, road conditions and car the most useful. There was also an question on follow up the TSSA speed advice. In most cases respondents would follow up the TSSA speed advice, especially

when the speed advice is above the speed limit. When people get incentives they are willing to follow up the safe speed advice more often. Especially when they get money for every kilometre driven with the safe speed. The latest questions were about hard limiting the speed of the car. In total 57% of the respondents indicated that they find the hard limiting unacceptable. It is remarkable that almost 50% of the respondents think hard limiting is unacceptable when the driver is under influence of alcohol or drugs.

In the impact assessment, the increase in traffic safety is assessed. When the TSSA is sold at a price of €150 euro, 13% of all cars is equipped with the TSSA. In that case 8% of all drivers will follow up the speed advice. Looking at only highways, the number of injuries will reduce from 3.122 to 3.032 and the number of fatalities will reduce from 119 to 114. These numbers are very promising, because these reductions are only on highways. Looking at the statistical value of a life (around €2,2 million), only on highways a reduce of €11 million is achieved. When the percentage of equipped cars will be higher (through for instance subsidizing the purchase of the TSSA or other incentives), much more promising results will be achieved.

The latest part that is carried out in this document is the risk analysis. The most threatening risks for the development and implementation of the TSSA are:

- The price of the TSSA is too high.
- People do not see the advantages of the system, so they are not willing to buy the TSSA.
- The costs for the development and implementation are exceeding the budget.
- Not enough funds to invest in the TSSA.
- Telecommunication systems for communication between TSSA and information provider become obsolete.
- Advice speed above speed limit is not legislated by law.
- After the TSSA becomes available for selling, some faults in the system are detected.
- The user does not like the system.

For these risks mitigation actions are described:

- Lower the selling price of the TSSA.
- Subsidize the purchase of the TSSA.
- Manufacture the TSSA in another way, so the costs for making the TSSA are lower.
- Make a campaign to promote the TSSA.
- Let people test the system so they see the advantages of the system.
- Let the Government subsidize the TSSA project.
- Sell the TSSA for higher prices.
- Make a good analysis of the costs and benefits of the TSSA project with as less uncertainties as possible.
- Define the risks for every stakeholder as good as possible, so the stakeholder knows exactly what his/her responsibilities are and how they must cope with the project when it does not work.
- Get information about projects from future communication methods and make it possible that the TSSA device later can be adapted to this newer communication method.
- Try to make it happen that driving above the speed limit is legislated by law.
- Use test results from tests with the TSSA to convince the law makers, that driving with the TSSA is safer. This implicit that driving above the speed limit does not lower the safety level of the road users.
- Test the TSSA system thoroughly, so the chance that there are faults in the TSSA system is very low.
- Make sure that the HMI of the TSSA is attractive to the user.
- Test the TSSA system thoroughly, and ask the testers if they like the system.
- Let people test the system so they see the advantages of the system.
- Carry out an user acceptance assessment.

Contents

INTRODUCTION

Before you lies a report with traffic safety as the main topic, implemented through an intelligent transport system called *Traffic Safety Speed Advisor*. The goal of this system is, as the name implies, to provide drivers with a speed advise that is related to their individual characteristics, hereby creating a safer transport system. In our current system of maximum speeds, it is easily assumed that one can drive the given maximum speed, for it also serves like a speed advice in some way. However, this speed may sometimes not be applicable due to external factors, like fogginess or heavy rain, or because the driver has a history of malicious driving. Drivers might still drive too fast in certain conditions, or too slow, in both situations causing extra safety risk. The TSSA system will assist the driver in choosing a safe speed, while still maximizing the speed that can be driven in a safe matter.

The development of this system is part of a master course at the University of Twente, called Intelligent Transport Systems 2. The original assignment is to design and assess an ITS system using the methods that were presented in the master course Intelligent Transport Systems 1. It includes some explicit goals like the use of models (Excel, SPSS, etc.), the use of CONVERGE (a method presented in ITS1) and the use of literature. The assignment will be scored on the following topics:

- Originality
- Correct use of methodologies
- Use of literature
- Understanding
- Quality of report
- Combined group and individual score

This report therefore contains a concept development of the system which the authors chose and was invented by themselves. Stakeholders for the system are defined and assessed, while also a risk analysis concerning the system has been executed. To assess the user acceptance, an online questionnaire has been developed and administered to a staggering amount of 218 respondents, to find out different aspects of possible users: would they want the system, in what form and how much should it cost? Would they actually follow the speed advise or just let it be? Finally, a basic impact assessment has been done, in order to be able to say something about the systems impact on both safety and traffic flow.

We hope reading this document will be an interesting and enlightening experience. We would like to sincerely thank dr. Jing Bie for his ongoing effort of helping us wherever it was possible and putting us on the right course many times: 謝謝!

Ellen Z. Vos and Bouke P.J. Vrind

Enschede,
January 29th, 2009

1 BUILDING THE TSSA SYSTEM

1.1 Concept development

Since the integration of different functions often leads to synergy advantages of many natures, this should be a goal for many technologies. Especially in the complicated world of transport, where humans are in the mix, integrating all different sets of information, goals and effects can be seen as a worthwhile and even necessary objective. When important information can be integrated in a system that has effects on as many aspects of transport and traffic as possible, it can be foreseen that safety, environment and economy may benefit in a combined fashion. Optimization is the key.

The development of the system we are proposing is such a technology. In our minds, it will be positioned on the safety side of the integrated picture, providing for safer roads and more individual application of the system. We started out defining the position of the safety system as a part of this integrated effort, leading to the definition of a single safety indicator: speed. Once we got to this point, the naming of the system was changed from *Traffic Safety Component* (describing the place of the system in the integrated context) to *Traffic Safety Speed Advisor* (describing the function of the system). This exercise is included in Appendix A, for those that are interested.

1.2 About TSSA and this chapter

The Traffic Safety Speed Advisor will provide the user of the system with a speed advice that should be safe to maintain given various safety factors. That so called 'safe speed' does not, however, consist only of information sources, it is also governed by principles of traffic safety. Before actually discussing the components that provide information for the TSSA, we need to define traffic safety attributes in order to be able to evaluate our design. For this, we will primarily use a framework developed by the Dutch organisation for traffic safety research (SWOV), called 'Sustainable Safe'. Since that framework is actually aimed at infrastructure design, it is necessary to translate it to an 'in-car' situation. The translation of the Sustainable Safe parameters can be found in Appendix A. Using the definition of *task load*, we can define what modules the safe speed will be based upon.

After that, the complete structure of the TSSA system will be discussed, among which the – in our eyes – most practical way to translate information sources to the safe speed, given the safety principles and other considerations that might be of importance. This will also include touching the different aspects of the implementation of the device, like technical possibilities and necessities.

At this point, the implementation of the safe speed limit is still a question mark, as it could be somewhere ranging between informative and hard-limiting. It depends largely on user acceptance in what form the safe speed would be applied. Plus of course there are ways in which acceptance can be influenced, for instance through insurance rebates or the passing of laws. As with this subject we are touching peoples freedom however, this will prove to be a difficult question to answer.

In short, the following research questions need to be answered to define the TSSA system:

1. What are the safety related principles that govern the Safe Speed implementation?
2. What are the information sources for the safe speed?
3. How can the information sources be related to speed in a practical way?
4. What implementation is best? Should the TSSA be just an advice or should it be the limit?
5. How is user acceptance of the system affected and what incentives could be used?

1.3 Building the Safe Speed: safety principles

Considering the end-point of the TSSA is an individualised, dynamic speed that is made up of factors influencing traffic safety, it is time to dig deeper into the subject of safety to see what actually defines it. We know that speed is now our preferred indicator. But how do we get there?

A first step in articulating safety principles to define the input information framework is a publication on 'sustainable safe' by the SWOV, which gives five aspects of road safety (SWOV, 2006).The SWOV primarily focuses on research as a foundation for (inter)national planning effort aiming at traffic safety. This means that although the principles are based on thorough analysis and are of great use, they might not directly be applicable to the in-vehicle solution we are developing. The implications of these principles for the device are explained in Appendix A.

Sustainable safety principle	Description
Functionality of roads	Mono functionality of roads as either through-roads, distributor roads or access roads
Homogeneity of masses and/or speed and direction	Equality in speed, direction and masses at medium and high speeds
Predictability of road course and road user behaviour by a recognizable road design	Road environment and user behaviour that support road user expectations via consistency and continuity in road design
Forgivingness of the environment and of road users	Injury limitation through a forgiving road environment and anticipation of road user behaviour
State awareness by the road user	Ability to assess one's own task capability

Table 1: Sustainable safe properties (SWOV, 2006)

As may be noticed, the principles focus only on infrastructure design and user behaviour, not on the performance of the vehicle. Still, the character of the principles may be applied to the car itself, how it helps the user and infrastructure when design fails expectations. It cannot be expected of the infrastructure to always and under any condition, be up to the latest standards. This is why it is important that the TSSA system will support the five principles, since an in-car dynamic and integrated system will provide for the necessary flexibility. The principles give us goals (or limits) to accomplish with the TSSA, leading to a safer traffic participation.

1.3.1 A note about intrinsic values

Another thing that was learned through the translating effort, is that two dimensions to the principles can be defined: first there is the direct influence by the system, and secondly there is a learning behaviour. The forgivingness factor for instance could consist of tools or systems to provide for it (like Lane Departure Warning devices) and/or on top of that a learning device that tries to teach the driver what forgivingness is about and what uses it has. Sometimes drivers do things not out of bad intentions but through ignorance or poor judgement. It can be argued that those instances of unsafe behaviour may be even more important than directly minimizing the actual behaviour itself.

1.4 Building the Safe Speed: information sources

Now that we know that the TSSA must take into account statistical risks, homogeneity, predictability, forgivingness and user related factors, we will want to take a closer look at the information sources that will feed the TSSA. In order to compose a list of those information sources and later on define their practical implementation, the decomposition will start with the state awareness. As state awareness is all about the driver, it is the centre of all information sources: the driver has control over the vehicle and at the same time influenced by external factors.

1.4.1 Components of state awareness and the resulting TSSA Modules

As stated in the preceding paragraph, state awareness focuses on all aspects influencing a person's capability of driving a vehicle safely. This can range from temporary behavioural influences like alcohol to actual details about the driver who is currently driving the car. Or in other words: the task capability of the driver is subject to both situational factors and competence. The decomposition can therefore be drawn as in Figure 1 to the right. References are provided in subsequent paragraphs.

It will be clear that task competence is the key to the definition of the safe speed, and is comprised of (1) the driver and his properties, (2) the car and its properties and (3) external influences. Those three aspects are the main modules, which in turn are made up of sub modules. The different modules are the information feeders of the TSSA system.

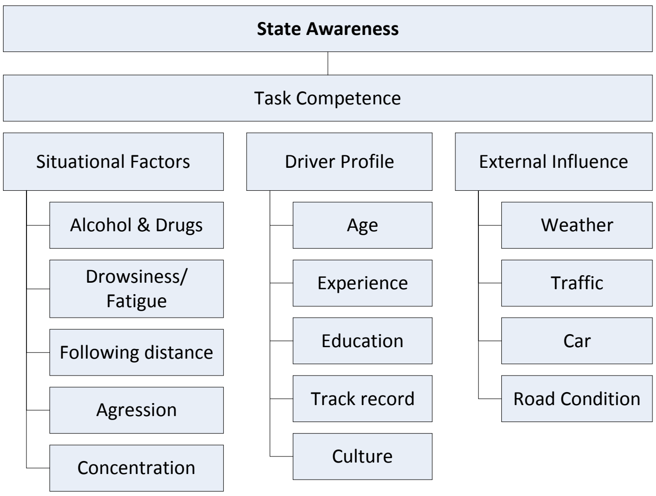

Figure 1: Decomposition of the State Awareness principle

1.4.2 The Driver Module

For the driver module, decomposition has already taken place in Figure 2. Factsheets published by the SWOV illustrate a connection between safety and all of the situational factors that are named under the sub module ***situational factors***: alcohol and drugs (SWOV, 2006, november), drowsiness/fatigue (SWOV, 2008, december) (ERSO, 2008), aggression (SWOV, 2008, august), concentration (SWOV, 2008, september) and following distance (SWOV, 2007, september).

Also for the sub module ***driver profile***, information is available: different age groups have a different safety risk profile (SWOV, 2008) (SWOV, 2009), as well as experience (SWOV, 2006). Although we have not been able to find resources on a connection between education level and traffic safety risk, we consider it as a factor that can be of importance because traffic education programs are an important part of measures taken to improve road safety, as the SWOV website states. Surprisingly, there are indications that cultural background may influence safety related behaviour, as a cross-cultural study between Norway and Ghana points out (Lund & Rundmo, 2008). Culture is also used in a broader sense than just different countries (Moeckli & Lee, 2007). As a consequence, culture is included as a possible safety risk factor. Last but not least, past accidents may give information about the drivers susceptibility to traffic accidents and therefore the risk factor. This is supported by the common practice by insurance companies of cutting insurance breaks after claims.

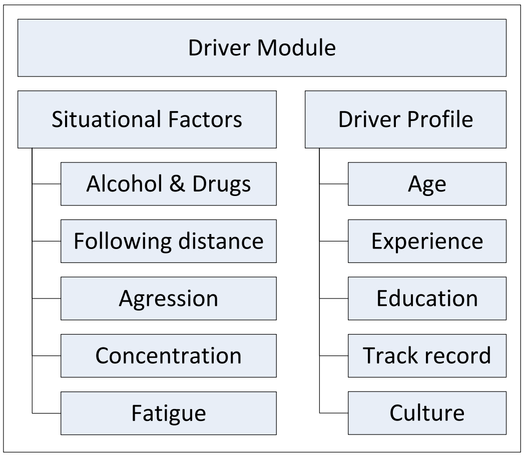

Figure 2: Contents of the Driver Module

1.4.3 The Car Module

Although they overlap in theory, equipment of the car (meaning the technological safety of the car) and the Euro NCAP scores of the car are a good team. In a way that different cars have different options enabled which all have an effect on traffic safety and not every car safety aspect can be articulated just by looking at the equipment. Since the Euro NCAP is based on experiments, this is an excellent addition to the cars safety. Or even the other way around: Euro NCAP scores can be the starting point, after which equipment variance decides the level of individual safety. A car scoring high on Euro NCAP will be less safe if poor performing tires are put under the car, or if poor maintenance impairs the breaking function. Another point of interest are the variable influences on the car. Many people sometimes have ski-boxes on the roof of their car to carry skis and extra luggage. Also the Dutch are known for their caravans, which also is a large factor to take into consideration: caravans and other trailers change the cars characteristics (axe load, traction, etc.).

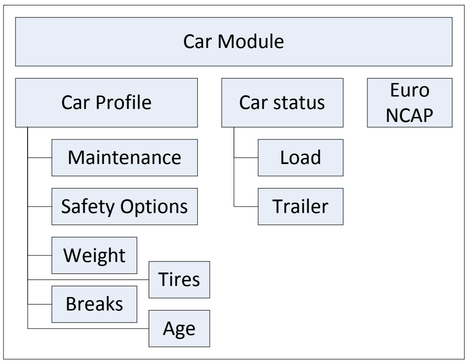

Figure 3: Contents of the Car Module

- Car Profile
  - Age — *Older means less reliable and thus safe*
  - Maintenance — *Bad maintenance means the possibility of badly functioning parts*
  - Weight — *The more mass, the longer stopping distance*
  - Tires — *Tires are important for stopping and handling*
  - Breaks — *The better the breaks, the smaller the stopping distance*
  - Safety Options — *More safety features (ESP, ASR, TCS) means more traffic safety*
- Euro NCAP rating
- Car status
  - Load — *A heavily loaded car behaves differently and has a longer brake path*
  - Trailer — *The car will behave differently if pulling a trailer of any sort*

1.4.4 The External Influences Module (a): weather

Almost every winter there are warnings on the news about slippery roads, foggy conditions or heavy winds. All of these circumstances require an adaption of the drivers behaviour, or in other words: a lower speed. With heavy wind reaching speeds of 100km/h, for instance, the forces that try to push the car out of its direction leaves no time to counter-steer when driving at high speed. Slippery roads due to snow and ice for instance will lead to less traction, so lower forces are required to start spinning out of control. Also, in a rainy country like The Netherlands, aquaplaning is real threat and is also dependent on speed. Temperature is both a factor and itself and a moderator. At temperatures lower than about 7 degrees, winter tires should take the place of summer tires: summer tires are very dangerous in those circumstances. As a moderating factor, it plays a role by freezing snow, rain or hail to the ground, making the already slippery properties of those factors even more dangerous. The weather module can therefore be decomposed into:

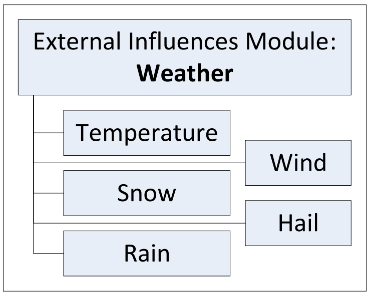

Figure 4: Contents of Weather

- Rain — *Heavy rain limits sight and heightens threat of aquaplaning*
- Snow — *Snow limits sight and may cause slippery roads*
- Wind — *Especially gusts of wind are dangerous as they influence steering*
- Hail — *Hail will limit sight and lead to immediate slipperiness of the road*
- Temperature — *At 7^o and below winter tires are needed, plus ground may be frozen*

1.4.5 The External Influences Module (b): road properties

Road properties influence safe speed because they influence the risk factor. A very small road will leave less room for steering errors than a very wide road. Narrower roads need slower speeds, wider roads can allow for higher speed: the Dutch 120km/h highways have a lane width of 3,35m (Rijkswaterstaat, 2007), whereas the German highways with no speed limit have a lane width of 3,75m (FGSV, 1996). Also, many provincial roads have certain lay-out features, that will limit the safe speed. Consequences of steering errors on roads that have many trees alongside will be much higher than if a car would crash in the field. Another very important factor is the road surface: different kinds of surface react differently to external influences like temperature, but they also provide for different roughness and therefore properties like breaking distance. The clearest example of places where speed limits are of value is the curvature. For that reason, curves are not included in 'layout' but named separately.

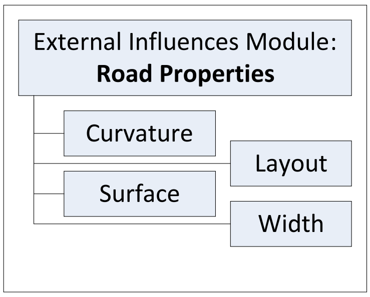

Figure 5: Contents of the Road

- Road width — *Larger width leaves more room for errors*
- Road layout — *Presence of objects affecting speed, like trees and guard-rail*
- Road surface — *The surface influences properties like braking distance*
- Road curvature — *Sharp curves need much slower speeds*

1.4.6 The External Influences Module (c): traffic

The third and final externality module is the traffic module. On many places in The Netherlands, speed limits are already enforced when the amount of traffic is nearing road capacity. Although this is primarily capacity (congestion) related, it also serves a safety goal, for many cars doing different things (remember the fact that the driver is in the loop) will overload the driver. At a slower speed there will be more time to process what is happening. Also it is beneficial to know beforehand when congestion is up ahead: in that case, nearing that at top speed is an unsafe situation. The safe speed would therefore also include information about traffic density. Besides that, accidents or ghost-drivers are also of safety concern and should be included. A fourth factor are incidents, like oil on the road, which causes slipperiness, or cattle, which become dangerous objects. Another factor which is not directly traffic related but is categorised as such, is the presence of 'hot spots'. This category includes schools, children playgrounds, high risk road sections and, very important, migrating wild-life. In places where it takes place, like for instance the Dutch National Park "Veluwe", the risk of wild-life is considerate at times, especially in the dark. Of course, there may be many sorts of hot spot, we cannot include them all.

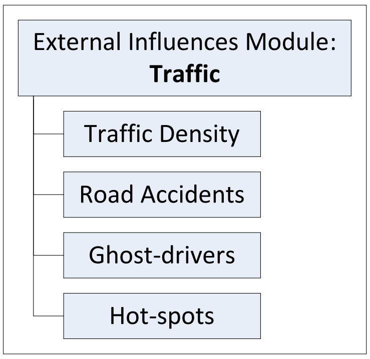

Figure 6: Contents of Traffic

- Traffic density — *High density has a larger chaos factor (unpredictability)*
- Road accidents — *Road accidents can indicate danger and will lead to congestion*
- Ghost-drivers — *Ghost-drivers are a great danger, especially on highways*
- Incidents — *Oil on the road leads to sudden loss of traction, for instance*
- Hot spots
  - Schools — *Children can suddenly appear on a road for numerous reasons*
  - Playground — *Children may suddenly enter the road to fetch a ball, for instance*
  - Risk sections — *Some road sections have a relatively high accident risk*
  - Wild-life — *Migrating wild-life can be dangerous objects*

1.5 Translating information sources to the Safe Speed

In this paragraph we will talk about actually getting to the safe speed in a practical and transparent way. The technical considerations surrounding the system, such as connection types and service needs, will then be elaborated on in the next paragraph. As the final part of the paragraphs about the structure of the TSSA system, the implementation possibilities of the system are mentioned. Finally, the position of the system within the earlier denoted traffic safety principles will be discussed. There are of course many arguments in favour and against, which we will try to address in that discussion.

The problem we face at this point is that we, as civil engineers, are not educated to make direct technical connections between e.g. tire compound and safe speed. For that, mechanical engineers would be needed. Therefore, we consider it both necessary and beneficial to design an easily maintainable transparent system that is based on relative properties of the various sub modules.

1.5.1 Defining a rating system

Looking at many tests conducted by for instance the German automobile association regarding winter and summer tires (ADAC, 2009), or tests by the Euro NCAP organisation on car safety (Euro NCAP, 2009), one can conclude that there is much information available in a relative form (stars or ratings). Many consumer organizations, whether exclusively car and traffic orientated or not, conduct tests to tell the consumer what is good and what is not good. This information could be used to say that 'product X is half the quality of product Y', for instance. But not only those external tests are a possible source of performance information. All car manufacturers today have to provide information on fuel consumption and carbon (di)oxide emission rates, this could be extended to data on safety performance that could be used to assess (relative) performance between cars.

Although it seems completely off topic, one might have noticed that the newest Windows computer operating systems by Microsoft, Vista and 7, sport a computer properties rating system, which assesses the performance on a number of topics, giving a rating to each of those. The rating ranges from 1,0 to 5,9 in Windows Vista or 1,0 to 7,9 in Windows 7 (Microsoft, 2009). This rating system, called Windows Experience Index, can be analogically applied to the TSSA system. It not only sports a relative performance index, one of its distinct features is also a minimum index requirement for certain features (for instance the need of a DirectX 9.0c capable graphics card to get a rating of 3,0, the minimum rating needed to run the Aero interface). This could be compared in a TSSA situation to for instance winter tires when temperature drops below 7 degrees: this is a critical consideration, as it has tremendous effect on traffic safety. So if we would use this rating system, we would get relative performance indexing, but also the depiction of key variables and their required values.

Putting the rating system into the speed perspective, it should be clear that it is not feasible, nor recommendable, to be too precise in the calculation of the speed advice. A faster car will want to overtake a slower car, which should not be done with only 1-2 km/h speed difference, as this takes too long, leading to irritation and flow disruption. That is why the difference in speed should be at least 5 km/h, so a swift overtaking manoeuvre is possible. Accordingly, also because experimental tests always have a certain amount of error or uncertainty (meaning if the scale is too large, differences could be noted that may not be significant), we do not need a wide scale to rate the security, so we propose a scale ranging from 1,0 to 5,9 to still allow for enough discriminative power.

At this point every sub module will have its own rating. To actually determine system safety, ratings need to be combined into a rating per module, which in turn leads to an overall rating that depicts the safety status of the module combination. For every module, critical situations need to be defined, as well as a threshold value for functioning. For the driver module, this may be the alcohol limit, tiredness and license revocation. For the car module, this may be the tire choice (winter/summer tires), presence of airbags and braking power (ABS) of the vehicle. Extreme external factors may include <50m sight, extreme slipperiness and wind speeds above 103 km/h (KNMI, 2008).

The threshold ratings are normative values, which means that if a value is below the threshold rating, it becomes the final rating for that module. One might argue however, that during strong winds driving a heavy, sideways aerodynamic car is more safe than if one would drive a light, cubic car. Or that an old driver in a new BMW is more safe than in a 20 year old Skoda. Therefore we propose a weighted average of the module ratings into a combined safety rating: the lowest rating should have the highest weight in determining the final score. We propose the following calculation method:

- If none of the module ratings is below a threshold rating/value, the module ratings should all be taken into account, in 2:1:1 relation: [2 x lowest + middle + highest] / [4]
- If one or two of the module ratings is below a threshold rating/value, only the two lowest factors should be taken into account, in a 2:1 relation: [2 x lowest + middle] / [3]
- If all module ratings are below a threshold rating/value, the lowest rating is used

Of course, over time the performance of safety systems will change. Every year, car and accessories manufacturers produce new and improved versions of their products. What used to be one of the safest cars in the world could be only moderately safe five or ten years later. To account for this change, rating systems and performance should be revised every few years. We recommend a five year interval, since it is sufficiently long to allow for stability and short enough to be responsive.

1.5.2 From rating system to safe speed

Now that we have established that the safety input variables all get a rating that depicts their relative security performance, it is time to look at the translation to the safe speed advise. The easiest and most natural way would again be, working with speed ranges. If one takes the average highway in The Netherlands for example, there already is a speed range of 80 km/h (trucks) to 120 km/h (cars). One could relate the combined safety rating to this speed range: a rating of 1,0 would mean an advised maximum speed of 80 km/h, while a rating of 5,9 would mean an advised maximum speed of 120 km/h. Since the current uniform maximum speed applies to all cars on the road, while assuming that speed should be (and is) safe for a certain majority percentile of all vehicles on the road, one might even assume that the highest TSSA rating may translate to an even higher speed: one might think of a maximum speed of 130 km/h, as is implemented in France, Luxembourg and on some parts of the German highway, or even up to 150 km/h, allowed in Italy on some highways (Verkeerskunde, 2006), though faster than 120 km/h on a highway is currently not allowed by law in The Netherlands.

To put it short, for every distinctive road section a speed range is defined, within which the ratings determine the actual speed. For a relatively tight curve in a highway, the range may be reduced to 60-90, for instance, after which the exit of the curve changes the range back to 80-120, and so on.

1.6 Technological aspects of the TSSA system

Before going to the subject of the technological systems and services that are possible or even needed for the TSSA system, we will want to spend a thought on the subject of 'fraud'. As this system makes it possible to use factors that determine a safe speed, they have to be reliable in order to be actually safe. Someone who has the intention of driving a car, even though he might be drunk or have a revoked drivers license, will of course never voluntarily fill in that he/she is in no shape to drive. In that case the system is useless (no advise is taken anyway). Especially in the case of the advisory speed being a speed limit for the car, this is an important design aspect. We will not want to design a system where a Suzuki Alto driver can fill in that he is driving a big Mercedes, because that would allow him to drive faster than the actual safe speed. So we need to define a way in which at least the most important and direct input variables can be read reliably.

In the following sections, we would address the separate modules and their technological needs, but the general scope of this project does not include such an exercise. For illustrative purposes, we will define the driver module in more detail, by addressing technology available.

1.6.1 Technologies for the driver module

In order for the TSSA system to know exactly who is driving the vehicle and in what state, technology is needed to input this data into the TSSA device on top. This has to be done in a reliable way, so that fraud can be made impossible or at least hard to do.

Combining this, we find one technology to be very interesting, and in our eyes actually the only option: the electronic driver licence.

In Sweden, an Electronic Driving License has already been developed and tested. It can be a smart card containing personal information about the driver, including which vehicle types or even individual vehicles he or she is authorized to drive. The smart card serves as an ignition key, and the vehicle will only start if everything is okay (Goldberg, 1995).

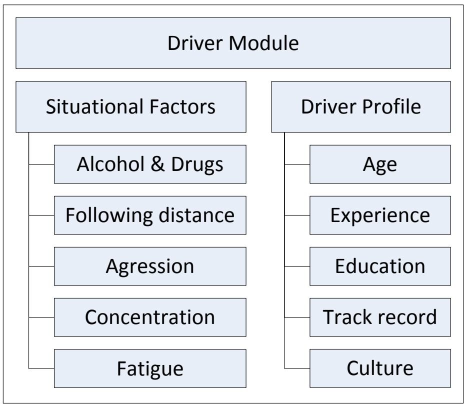

Figure 7: Contents of the Driver Module

The choice can be between a RFID based design, like the OV chip card currently in process of implementation in The Netherlands, or in credit card format with a chip on it, just like current credit cards or other bank cards have. The latter probably is the most practical implementation, since it should not happen that the passenger, who also has an electronic drivers licence, by accident gets his one used, instead of the driver himself. If at any time it turns out that someone uses the license of someone else to drive in a car he or she is not allowed to drive in, criminal law should be in place.

The Situational Factors are a bit more complex. However, for all factors except for *Aggression*, we were able to find references of systems that already exist, in order to detect those states. There is, to begin, of course the famous alcohol interlock system (European Road Safety Observatory, 2008), which requires the driver to blow into a mouthpiece connected to an alcohol meter.

For *Drowsiness/Fatigue*, there even exists a separate European project, called AWAKE, of which the website[1] states that it is a “System for Effective Assessment of Driver Vigilance and Warning According to Traffic Risk Estimation”. These systems make use of sensors that measure all kinds of fatigue related aspects, like amount of eye movements or steering corrections per unit of time. The same way of measuring can also be used to determine *Concentration*, which is connected to Fatigue.

Following distance is probably the easiest, because this effectively constitutes the Adaptive Cruise Control, which is already widely available: if following distance becomes to small, lowering speed is necessary in order to maintain a safe following distance. The ACC is already an option on cars in and above the executive segment, like the Audi A6 and the Volkswagen Passat CC. A clear downside of this system is that it is only available on expensive cars and very expensive (€1495 on the Passat CC).

Although we were unsuccessful in finding concrete systems that measure aggression, literature can be used as a source to define aspects of aggressive driving, which can in turn be used to define the degree of aggressiveness. One could think of factors like rate of acceleration and braking, distance to cars in front, speed in relation to curvature, G-forces, et cetera.

The same exercise can be repeated for the other modules, but doing so would exceed the scope of this paper. Therefore, we will now move on to the implementation forms of the TSSA system.

1.7 Implementation of the TSSA system

The implementation of the TSSA system, as the name already states, is advising the driver. It is primarily meant to inform the driver, assist him, in the driving task. Once the task load becomes lower, the person will better be able to react to situations. User acceptance will probably also be high in case of an unobtrusive, advisory system which still leaves them the freedom associated with driving a car. The question is whether the effectiveness of the system is still high in this case. To raise effectiveness, it would be recommendable to still advice, but make the system more obtrusive through voice feedback, for instance.

A different option, though of which we think average users will not accept it, is the hard limiting of the car to the TSSA advised speed. This has to be done of course with the greatest of hesitation, by still allowing people to overtake slightly faster, or accelerate in precarious situations. We think that in order for this system to be acceptable to drivers (and their representative bodies like the ANWB), this

[1] http://www.awake-eu.org/

hard-limiting will not be the preferred standard operation of the system. However, in case of multiple traffic law offenders, using it will pose some benefit, since they are no longer able to 'drive like maniacs', as a result lowering the risk for all cars on the road. One might think in this relation of individuals who were arrested for drunk driving multiple times, or people who on a regular basis speed with enthusiasm. Still, hard-limiting should be a possibility of the system, since it might also be useful for instance in the case of parents who want to limit the system if they let their 'irresponsible' 18 year old son drive their newly bought car.

An important factor to consider in both functionality and acceptance of the system is the speeding above the current maximum limit. As the maximum limit currently applies for all vehicles by law, it would mean changing traffic law to allow for the TSSA equipped drivers to drive faster than that. We think that being able to drive faster than others will greatly influence the user acceptance of the system, since this is an incentive for people to want the system. Still, this shall have to be within limits in order to prevent misuse of the possibility: an option would be to include a minimum accordance rate to the TSSA advice, for instance 80% of all kilometres driven. The other rationale behind including this possibility in the TSSA system is that the current maximum speed is designed to be safe for a certain (majority) percentile of all cars (drivers) using that road. There will, therefore, be cars that could drive faster at the same level of safety, while other cars should drive slower at that same safety level. It will be clear that this is one of the main thoughts behind the TSSA system.

Another factor to be mentioned is user incentives. Since the system promotes safer driving by adjusting the speed to a certain safety level, less (near) accidents will occur and the risks for insurance companies are reduced. As both the government (as protector of the 'general good') and the insurance companies will profit from this, it might be translated to incentives for people to not only want the system, but also use it (more often). This could come down to various options:

- Subsidise the purchase of the system or cap the prices the manufacturers may ask
- Giving rebate on tax or insurance policy when a person follows the advice more often
- Paying the user an amount per unit driven if that person follows the advice X% of the time

2 STAKEHOLDERS

There will be no TSSA without different stakeholders. You can think of different stakeholders like users, manufacturers or the government, but there are more stakeholders. In this chapter the different stakeholders will be described. First their actions and interests are described. After this has been done, the two most important stakeholders will be selected and an assessment plan will be carried out for these two stakeholders.

2.1 Stakeholders' interests and actions

In this paragraph, different stakeholders with their different interests and actions are described. Stakeholders are all kind of people and organisations that have an interest in the TSSA. Every stakeholder has an interest in the new system. To for fill these interests, one or more actions can be undertaken by the stakeholders themselves.

Stakeholder	Interests	Actions
Car/bus/truck driver (user)	The greatest interest of the user lies in the increase of safety during driving. Other points of interest are the increase of comfort during driving, because of the information the TSSA supplies to the users. Users are warned for dangerous situations, so they early can react in order to prevent accidents. The information that is used is real time, so users always have information about the current traffic situation.	The users will buy the system and adapt their driving behaviour to the recommendations of the system. They also react early in case of a dangerous situation, compared to drivers without the system.
Vulnerable road users (for example cyclists and pedestrians)	TSSA users are being warned for dangerous places, for example school areas, crosswalks, places with priority for cyclists or pedestrians and so on. When TSSA users adapt their speed and awareness on these places, the safety for vulnerable road users will be improved.	The vulnerable road users can lobby for governmental support of the TSSA. When the government is aware of the increase in safety for vulnerable road users due to this system, they may subsidise the TSSA.
TSSA application manufacturer	The main goal of the TSSA manufacturer is to increase profit. They also want to have a greater market share of their products. To increase the income, the manufacturer will sell reliable systems, so the users will be satisfied using the TSSA system. When users are satisfied, more people are willing to pay for the system and more people will buy the system.	The manufacturer has to put money in the Research & Development department, in order to create a good working TSSA. They also have to invest money in marketing, so potential users and the car industry get to know the system. Another important action is to cooperate with other important parties such as the traffic information provider and the communication provider.
Car industry	The car industry is interested in the TSSA, because this system increases the safety of car users. People are willing to pay for a car with an integrated system which provides safety. When a car company implements the TSSA in their cars, more people are buying their cars, so the company's profit increases.	The car industry has to make contact with the developer of the TSSA, in order to integrate the system in their cars. After this has been done, they have to integrate the system into their cars.
Traffic information provider	The traffic information provider	Sell actual traffic information to

	has information about the current traffic situation and with selling these information to the TSSA user, they can increase profit.	TSSA users. This can be done via the TSC manufacturer. (The TSSA manufacturer sells the system, which is accompanied with an agreement between the traffic information provider and the system user)
Communication provider	The communication provider wants to increase profit, so their interests lies in letting the TSSA make use of their communication platform.	Set up an agreement with the TSSA manufacturer about the use of their communication platform.
Government	The government has interests that are positive for all inhabitants of a country. Because traffic safety always can be improved the government has an interest in the TSSA. The costs of traffic fatalities and injuries are very high. The government will reduce these costs and also reduce the emotional damage due to traffic accidents.	The government can subsidise the development of the TSSA. They can also give a subsidy to people that are buying the TSSA. The TSSA also must be legislated. This can be done by the government.
European Union	The European Union has interests in an open platform, which is equal in all countries that are part of the European Union.	The European Union can be the project champion by implementing an open platform and standardise this in all European countries.
Road operator	The road operator wants to provide safe roads and a good throughput on these roads. With implementing TSSA, the road safety for all road users will increase and because there are less traffic accidents, there will be less congestion.	The road operator can cooperate in the development of the system, by giving important information about their roads concerning safety to the TSSA developer.
Traffic safety institutes (for example SWOV)	Traffic safety institutes conduct research about traffic safety. They do have a knowledge about traffic safety and how to improve traffic safety. Because for example the SWOV is funded by the government, they are willing to improve traffic safety by sharing their knowledge.	Sharing their knowledge about traffic safety and dangerous roads with the developer of the TSSA.

Table 2: Stakeholders' interests and actions

2.2 Assessment plan

The following step is to determine which two stakeholders are the most important in the TSSA project. For these two stakeholders the assessment objectives can be written down. With the use of the CONVERGE method (Zhang, Kompfner, White, & Sexton, 1998, September), different assessments can be carried out. This will be done for the most important objective of each important stakeholder.

2.2.1 Assessment objectives TSSA application manufacturer

The first one of the two most important stakeholders is the TSSA application manufacturer. Without a manufacturer the system will never be made. As mentioned in paragraph 5.1 the TSSA application manufacturer has different interests. The main interest of the TSSA application manufacturer is increasing profit. This can only be accomplished, when there’s a good working system. Another important point to increase profit is user acceptance. When users aren't willing to pay for the system, the TSSA application manufacturer isn't able to make profit out of the TSSA system. The latest point the TSSA application manufacturer is interested in, is if the system really is increasing the level of safety. A list can be made which carries out the assessment objectives of the TSSA application manufacturer and the accompanying assessment categories:

Assessment objective	Assessment objective category
Increase profit	Financial assessment
System reliability	Technical assessment
User acceptance	User acceptance assessment
Increase traffic safety	Impact assessment

Table 3: Assessment objectives and categories TSC application manufacturer

The most important assessment objective is the user acceptance. When there's a lack of user acceptance, introducing the TSSA will be a disaster for the TSSA application manufacturer. There aren't customers so there will be no profit. It's important to know what the users expect from the system and which parts they like. After investigating this, the outcomes can be used for the design of the TSSA. In chapter 3 the user acceptance assessment will be carried out.

2.2.2 Assessment objectives government/European Union

The second most important stakeholder is the government/European Union. The government/European Union can play a great role in developing and implementing the TSSA system. Their interests lay in increasing traffic safety in order to decrease the number of traffic accidents and the number of dead and injured people. This because they want to decrease the costs due to traffic accidents and the emotional costs. You can say that these interests are socio-economic. As done by the assessment objectives of the TSSA application manufacturer, in this paragraph a table can be made for the assessment objectives of the government:

Assessment objective	Assessment objective category
Increase traffic safety	Impact assessment
Improve economy for all inhabitants	Socio-economic assessment

Table 4: Assessment objectives and categories government/European Union

Because increasing traffic safety is the main goal of this project, an impact assessment should be carried out. In this assessment shall be looked at how the traffic safety will increase after the TSSA is implemented. Another point that shall be looked at is the impact of the TSSA on traffic flows. The impact assessment will be carried out in chapter 4.

3 USER ACCEPTANCE ASSESSMENT

For the TSSA application manufacturer it is important to know if there will be enough user acceptance. When this is not the case, developing and implementing the system will lead to high costs and no revenues for the manufacturer. Because of this, an user acceptance assessment will be conducted. In this user acceptance assessment a survey will be conducted. The focus of the survey lies on the interest of people for the TSSA, to limit their freedom by taking over a certain amount of control over their car and their willingness to pay for the TSSA. Also the interest to get a discount on the insurance of their car, or a revenue when driving with the TSSA will be investigated.

First the assessment methodology will be described, due to the CONVERGE method (Zhang, Kompfner, White, & Sexton, 1998, September). After this has been done, the questionnaire will be designed. This questionnaire will be put on the internet for more than one week. When the results are collected, these can be observed with the use of SPSS. Also the willingness to pay can be estimated. In this chapter the description and performance of these steps can be found.

3.1 Assessment methodology

3.1.1 Expected impacts

Before carrying out the user acceptance assessment, it is important to tell something about the expectations of this assessment. In the results from a questionnaire conducted by van Driel and van Arem (2005), some interesting conclusions can be found due to the TSSA. The research they conducted is related to the acceptance of drivers on driver assistance. The results from the survey they conducted showed that among the most popular driver support functions, the task regulating speed also was mentioned. This means that the respondents are willing to have assistance from the car during driving concerning the task regulating speed. They like to get information about downstream traffic conditions and warnings for traffic in blind spots. They also like information on the speed limit and a warning when they are exceeding the speed limit. The level of support was also investigated. The respondents like systems in their cars to give information or warnings, but they indicated hardly any need for driver support functions that consisted of control. Due to the TSSA there can be said that drivers would like to have a TSSA that gives the driver an indication about the preferable speed. They don't like a TSSA that is controlling their speed. In this assessment should be investigated if drivers are willing to have a component in the TSSA that is registering the driven speed, so the company that gives a revenue (for instance the insurance company or the government) can check if the drivers kept up to the personal speed limit.

About the willingness to pay for the TSSA also some expectations can be drawn. People are probably willing to pay for the TSSA, especially when they get a revenue on their car insurance or a revenue from the government. The insurance company or government can also subsidize the purchase of the TSSA. When this is done, more people are willing to buy the TSSA. When people get a revenue for keep driving to their personal speed limit, they are probably willing to buy a TSSA which is also registering the speed they actually drove.

The last expected impact that can be discussed is if people are willing to keep up with the speed advice given by the TSSA. When they can imagine the speed limit, they probably accept it. When they don't understand why they have to slow down or speed up, it can be that they won't accept the speed limit, so the TSSA will have no effect on driving behavior. That's why it is important the TSSA displays a believable speed limit.

3.1.2 Indicators

In this assessment the two most important subjects to seek out, are if drivers are willing to pay for the TSSA and if they will keep up to the personal speed limit. The disadvantages of such a system can be that the driver must drive slower than the applied speed limit, in order to have a safer trip. The advantages of such a system can be that when people are keeping up to the speed limit, they get a revenue for it. The main indicators are the willingness to pay for the system and the acceptance for driving with the speed represented by the TSSA. Another indicator is if a revenue should be given, so the driver will accept the speed limit represented by the TSSA.

3.1.3 Reference case

In this user acceptance assessment, the reference case is the case when driving without the TSSA. People filling in the questionnaire should imagine that they are driving with the TSSA. Because of this, the respondents should be aware of all the functions of the TSSA, so they really understand it. What also must be clearly explained is why the TSSA is being developed. People must know that their level of safety during driving will increase when driving with the represented speed of the TSSA. When they understand the working of the TSSA, the answers they give are more representative which is important for reliable outcomes of the survey.

3.1.4 Data collection

The questionnaire that will be used to conduct the user acceptance assessment will be put online (www.thesistools.com). The link will be send via e-mail and social networking sites to possible respondents. To encourage the receivers of the e-mail to fill in the questionnaire, a short clarification about the TSSA and the purpose of the survey will be given. Besides the questions about the TSSA also some general questions should be asked, such as gender, age, having a car and driving license and how often the respondent is driving. It is important to do so, because then is known which kind of people filled in the questionnaire, so a comparison can be made between the people who filled in the questionnaire and the drivers in reality.

3.1.5 Conditions of measurement

Because in this assessment a survey will be conducted there are no measurement conditions. Filling in the questionnaire will be done in the same way by all the respondents. The questions are the same and they all have one week time to choose a moment to fill in the questionnaire. The questionnaire will be on the internet from the 13th of January 2009 until the 22th of January 2009.

3.1.6 Statistical considerations

The total number of respondents should be large enough, to take some conclusions which make sense. It is desirable to have a total number of 100 respondents, because the size of this sample will be large enough to draw some conclusions. The user acceptance for the TSSA will be measured on the van der Laan scale (van der Laan, Heino, & de Waard, 1997), which is a scale with nine items to rate the TSSA. There will also be other questions on the user acceptance of the TSSA. To measure the willingness-to-pay, respondents should fill in a price that they are willing to pay for the TSSA.

3.1.7 Measurement plan

As stated in paragraph 3.1.5, respondents can fill in the questionnaire during the period from the 13th of January 2009 until the 22th of January 2009. After the closing date, the filled in questionnaires will be collected. The questionnaires that are not seriously filled in by the respondents are removed. This is the case when answers on questions are very different compared to the average answer given on those questions. This is also the case when the total amount of time used to fill in the questionnaire is very small compared to the other respondents. After this has been done, the obtained data can be analyzed and conclusions about the user-acceptance and the willingness-to-pay can be drawn.

3.2 Results

In this paragraph, we will shortly address the most remarkable results from our questionnaire. First some general remarks about the questionnaire and the way it was administered are given.

3.2.1 Abnormalities of the questionnaire

Unfortunately, the tool used to administer the questionnaires (www.thesistools.com) has a very large shortcoming, which severely cripples the results:

Once a respondent uses the ‘back’ button to review answers on a previous page, the results on the questions are lost. The result of this is that some respondents have missing information, others are recorded multiple times with answers only on every other page.

In the first case, they are easy to spot. Only the demographic questions are answered, with the rest being empty. However, there are some respondents that only answered the demographic questions, and from the rest of the questions only one or two. In the second case, there are “multiple” respondents with incomplete answers, who sometimes actually are one and the same person. This is very hard to spot, as many respondents give equal answer to the questions, plus the answers to the questions might change due to the ‘looking back’ or simply due to time influencing their thoughts.

We used the following procedure to ‘clean up’ our data sheet:

1. Delete all empty respondent lines
2. If partly empty lines are present, respondent results are compared to the one above, when demographic details are the same, it can be assumed that this is one and the same person. If also the answers to the questions appear to be about the same, the results are combined in one respondent line.
3. Delete respondents that have only answered demographic questions and/or only a few further questions.

Some notes about our data:

- Some people who said they would want the system failed to fill in a number for an acceptable price. We conclude that they do not wish to pay and therefore put a 0 as willingness to pay. There were also people that did not want the system, but also filled in a price they would find acceptable. We did not change anything there and used the value. People who filled in a number but did not choose an option are assumed to choose “yes”.
- There was one respondent who answered 50-75 as an acceptable price for the system. We took the average of that in our analysis: 50+75 divided by two makes 62,5.
- There were three kinds of ‘other’ education named by the respondents: MMS, MULO and NGPR-A. The first two were schooling systems that existed before the introduction of the so called “Mammoth law”, which introduced the MAVO/HAVO/VWO system. According to inquiries from individuals that have had that education, MMS can be compared to HAVO, and MULO can be compared to MAVO, in terms of educational ‘level’. As for the ‘NGPR-A’, which seems to be an education about PR and communication, we are not able to find information. We assume that this education is at MBO level.

3.2.2 Results in short

The sample size of the questionnaire is 218 respondents, of which we could use 179. This is quite an impressive number, so conclusions that are drawn from this research are reasonably robust.

The demographics of the respondents are also quite well distributed, with about 50/50 male and female, equal distribution of 18-23/24-39 and 40-59. There are less 60+ respondents. Even though the distribution does not follow Dutch national demographics, we argue that this is actually good, since the robustness of the conclusions that could be drawn from these groups is equal.

Many of the demographic properties were checked for correlation with results, or in other words, if different groups had different results, although we did not include that in written form in the report. Only for the current speeding behaviour, we found clear effects: people that are currently speeding more have a lesser probability of (1) wanting the device and (2) following its advice when the advice is lower than the maximum speed. There was a clear and significant tendency towards following the advice once it was giving a speed higher than the maximum speed (which is, as was stated before in this report, both a design and a user incentive).

The results of the attitude research are relatively positive, as all are on the positive side of the mean. Some are more clear, some less, but the overall tendency is positive. Still, it must be noted that there might be some positive offset since the respondents are all direct or indirect friends, relatives and acquaintances. This has not been inserted in the calculation, but with almost two-hundred respondents, this error will probably be only marginal.

About 35% of the respondents is willing to buy the system from the outset. The mean willingness to pay is € 150. When subsidy is granted or monthly rebates on insurance or taxes is given (meaning in the first sense the system might also be free), the former number changes to respectively 76% and 79% (the average monthly rebate is 27,5%). The increase from 35% to 79% is very large, which is explained by the overall rating of the system: people rate the system positive, but are obviously only interested if it provides them extra incentives above the promised increase of safety. In our eyes, this might have something to do with the aversion many people have towards the current way police enforces speed limits and therefore the limiting of speed in general.

Of the information sources that were presented to the respondents, the Euro NCAP is rated the least useful (about 25% rates it as such), followed by driver profile and status. As the Euro NCAP is directly related to the car status in our eyes, we can only assume that people do not choose what they do not know, and there is some publicity required by the Euro NCAP to make them known better to people. Also, the low rating of the driver profile does not come as a surprise, since many will regard themselves as better drivers (it is always 'the other' that drives badly), even if they are not. The blank options that were given provided some interesting input, like for instance the loading of the car, but it also made clear that we made an error in the description used in the questionnaire, since many answered 'traffic status' as a possible option while this has always been thought to be one of the information sources. However, on a positive note, respondents have been paying attention to the subjects and filled out the questionnaire with enthusiasm.

In relation to the previously noted TSSA abiding behaviour, respondents generally answered that they would keep to the TSSA more often if that would provide them more (financial) benefit. This is in line with the conclusion that safety alone is not enough to get many people to want and use the device: extra incentives of financial sort are needed for that. Something remarkable was found when people were asked if they found getting an amount of money per driven kilometre if they would keep to the speed a certain percentage of time. Respondents actually thought of this as a better way than flexible rebates on monthly cost, probably while it is more transparent and thus provides clearer benefit to them.

The last two questions were related to the hard limiting of the car. The majority of respondents (57%) thought this unacceptable, although some (26%) would be influenced by financial incentives. We think it is a remarkably positive result, where 17% would even accept this without further compensation. This exceeds our expectations and may provide possibilities in terms of public acceptance of enforcing certain parts of the system for malicious individuals.

However, a shocking result was found when people were asked about the limiting of the car in case of alcohol, drugs, drowsiness and revocation of the drivers license: a staggering 47% of people answered that it should still be possible to drive under those conditions. Although this large amount will probably have something to do with the perception that drowsiness is not that serious (which it actually is), as open answers noted, we still think this number of people is still way too large and not in accordance with statements by the SWOV about the overall tendency in our society to condemn for instance drunk driving. As said, a result to worry about.

4 IMPACT ASSESSMENT

For the government/European Union it is important to know if the TSSA will increase the traffic safety. When this is not the case, it is not interesting to invest in the development of the TSSA and at a later stage, to subsidize the purchase of the TSSA. In this impact assessment the emphasis lies on the effects of adopted speeds of the driver, due to the TSSA. The results of the user acceptance assessment will be used to calculate the rate of vehicles that will be equipped with the TSSA. First the assessment methodology will be described, due to the CONVERGE method (Zhang, Kompfner, White & Sexton, 1998, September). After this has been done the analysis can be carried out.

4.1 Assessment methodology

4.1.1 Expected impacts

First we have to draw some expectations for the impact assessment. Our expectations are, that when vehicles are equipped with the TSSA device, the traffic safety will increase. The more vehicles are equipped, the safer the traffic situation will be. It is also important that the drivers actually follow the advised speed. When people drive faster than the advised safe speed, traffic safety will decrease.

4.1.2 Indicators

The indicators in this assessment are the speed and the number of injuries and fatalities. A change in speed driven, will have an impact on the number of injuries and fatalities. The number of injuries and fatalities are an indicator for traffic safety.

4.1.3 Reference case

The reference case is the case when driving without the TSSA. Numbers about speed driven and injuries and fatalities must be known. When these numbers are known, a comparison can be made between the injuries and fatalities in the situations with and without the TSSA implemented.

4.1.4 Data collection

The numbers for injuries and fatalities can be found in the Cognos database that can be found via www.swov.nl. Numbers about the average speed on different types of roads can be found on web pages from public institutions, like provinces or the department of traffic and water management.

4.1.5 Conditions of measurement

The measurement will be carried out in a quantitative way, using a macroscopic model.

4.1.6 Statistical considerations

The numbers that will be used for the impact assessment should be reliable. This means that the numbers used should come from confidential authorities.

4.1.7 Measurement plan

First all the necessary data need to be collected. Then calculations can be made on the expectance of the increase in traffic safety. Based on this calculations some conclusions can be drawn.

4.2 Data collection

The first and most important thing we need to know is how much cars are equipped with the TSSA. This can be calculated using the results of the questionnaire from the previous chapter, imagine a price level for the TSSA and the distribution of drivers looking at the age of the drivers. From the Cognos database (SWOV, 2007) we can get some numbers about the total amount of kilometres driven by car for different age categories. These numbers are from the year 2007.

Age group	Total number of kilometres driven (*billion)	Part in total (%)
0-17	15,3	11
18-24	9,5	7
25-39	39	28
40-59	54,9	39
60-74	17,1	12
75+	3,8	3
Total	139,6	100

The price level of the TSSA is set at €150. The willingness to pay is €150 and we assume that this is a credible value for the TSSA. From the results of the questionnaire we can calculate which part of each age group is willing to buy the TSSA at a price level of €150.

Age group	Willing to buy the system (%)	Part in total (%)	Part in total with TSSA (%)
0-17	0	11	0
18-24	16	7	1,12
25-39	12	28	3,36
40-59	16	39	6,24
60-74	20	12	2,4
75+	0	3	0
Total		100	13

From this table can be seen that when the price level for the TSSA is set at €150, 13% of all cars will be equipped with the TSSA.

From the Cognos database (SWOV,2007) also the number of fatalities and injuries can be found. In the year 2006 (not all numbers for 2007 were available) there were 730 traffic fatalities and 28.559 injuries.

The latest information that is necessary is the average speed driven on different types of roads. On most highway sections the speed limit is at 120 km/h. On some other parts the speed limit is 100 km/h. The average speed driven on these road sections is respectively 114,4 km/h and 101,4 km/h. The percentage of drivers that is exceeding the limit is respectively 35% and 54% (Mathijssen, 2001).

On provincial roads in Overijssel where the speed limit is 80 km/hour, the average speed driven is also 80 km/hour. For roads where the speed limit is 100 km/hour, the average speed driven is 91 km/hour. The percentage of drivers that is exceeding the speed limit is respectively 43% and 18% (Dikken, 2006).

In the questionnaire respondents could fill in if they would follow the advised speed of the TSSA. In the table below can be seen about how much of the respondents would follow the speed advise.

Age group	Max. 120 km/hour TSSA 130 km/hour	Max. 120 km/hour TSSA 100 km/hour	Max. 100 km/hour TSSA 120 km/hour	Max. 100 km/hour TSSA 90 km/hour
18-24	92%	40%	75%	59%
25-39	91%	49%	70%	58%
40-59	75%	66%	56%	70%
60-74	100%	88%	78%	75%
Age group	**Max. 80 km/hour TSSA 90 km/hour**	**Max. 80 km/hour TSSA 70 km/hour**	**Max. 50 km/hour TSSA 30 km/hour**	
18-24	87%	47%	30%	
25-39	87%	57%	40%	
40-59	73%	70%	48%	
60-74	90%	38%	50%	

4.3 Assessment

Impact on number of injuries and fatalities

In an article from Marchau, van der Heijden and Molin (2005) two equations are presented which can calculate the expected number of injuries and fatalities due to a change is average speed driven. The equations are:

$$\frac{i_{new}}{i_{old}} = \left(\frac{v_{new}}{v_{old}}\right)^3 and \frac{f_{new}}{f_{old}} = \left(\frac{v_{new}}{v_{old}}\right)^4$$

In these equations the *i* stands for the number of injuries, *v* for average speed driven and *f* for the number of fatalities. The notations new and old refer to the cases in which the TSSA is implemented (new) and the cases without the TSSA (old).

The number of fatalities on highways in 2006 is 119. The number of injuries on highways is 3.122 in the same year. (SWOV, 2007) The average speed driven is 114,4 km/hour on places where the maximum speed is 120 km/hour. We assume that the average speed calculated by the TSSA is 100 km/hour. When 13% of all vehicles is equipped with the TSSA, a total of 8% will follow up the speed advice (this percentage is calculated with the use of the tables above). This means that 92% percent still drives with an average speed of 114,4 km/hour and 8% drives with an average speed of 100 km/hour. The total average speed in the new situation is: 92% * 114,4 km/hour + 8% * 100 km/hour = 113,3 km/hour.

We are now able to calculate the number of injuries and fatalities for the situation where the TSSA is equipped in 13% of the cars and a total of 8% that follows up to the speed advice.

$$\frac{i_{new}}{i_{old}} = \left(\frac{v_{new}}{v_{old}}\right)^3 = \frac{i_{new}}{3122} = \left(\frac{113{,}3}{114{,}4}\right)^3 \quad i_{new} = 3032$$

$$\frac{f_{new}}{f_{old}} = \left(\frac{v_{new}}{v_{old}}\right)^4 = \frac{f_{new}}{119} = \left(\frac{113{,}3}{114{,}4}\right)^4 \quad f_{new} = 114$$

From these calculations can be seen that when 13% of all cars are equipped with the TSSA and a total of 8% of all road users adapts his/her speed to the TSSA advise (100 km/hour), there will be 90 injured and 5 fatalities less compared to the situation where no car is equipped with the TSSA.

The statistic value of a life is €2,2 ± 0,3 million (SWOV, 2007). When the TSSA will be implemented, there are 5 fatalities less (only on highways). This means that in total 5 * €2,2 million = €11 million will be saved, only due to the reduce in traffic fatalities on highways. We think, looking only at these numbers, it is wise to do further investigation on implementing the TSSA.

When 50% of the cars are equipped with the TSSA (e.g. people are willing to buy the system when it is subsidized), the reduction of injuries and fatalities will be much higher. When 50% of the cars are equipped with the system, 32% of all highway users will follow up the speed advice of 100 km/hour. The average speed will be in that case: 0,68 * 114,4 km/hour + 0,32 * 100 km/hour = 109,8 km/hour. Calculating the numbers of injuries and fatalities again:

$$\frac{i_{new}}{i_{old}} = \left(\frac{v_{new}}{v_{old}}\right)^3 = \frac{i_{new}}{3122} = \left(\frac{109{,}8}{114{,}4}\right)^3 \quad i_{new} = 2760$$

$$\frac{f_{new}}{f_{old}} = \left(\frac{v_{new}}{v_{old}}\right)^4 = \frac{f_{new}}{119} = \left(\frac{109{,}8}{114{,}4}\right)^4 \quad f_{new} = 101$$

The reduces in injuries and fatalities is much higher, respectively 362 and 18. The money saved, only due to the fatalities is 11 * €2,2 million = €24,2 million. This is a large amount of money, so it is valuable for the government/European Union to invest in the development of the TSSA. In a later stage can be looked at subsidizing the purchase of the TSSA.

Impact on traffic flow

To give an idea of the impact of the TSSA on the traffic flow, some simple calculations can be carried out using the techniques from the notes of the course 'Verkeer' (van Maarseveen, Zuidgeest, & van Zuilekom, 2005). The capacity of one lane on the highway is 2400 vehicles/hour (van Maarseveen, Zuidgeest, & van Zuilekom, 2005). In this calculation we assume that the highway has two lanes, so the capacity is 4800 vehicles/hour. The following equation will be used: q = u * k, whereby the *q* stands for intensity [vehicles/hour], *u* stands for free flow speed [km/hour] and *k* stands for density [vehicles/km]. We assume that the average speed driven before the implementation of the TSSA is 114,4 km/hour and the intensity is 2500 vehicles/hour, so the density can be calculated: k = q / u → k = 2500 / 114,4 = 21,9 vehicles/km. After the TSSA is implemented the average speed driven is 113,3 km/hour so the density will be: k = 2500 / 113,3 = 22,1 vehicles/km. The density on the highway is increased. When more vehicles are equipped with the TSSA, the average speed will further decline, so the density will increase. When the traffic flow on a highway already is reaching capacity, the capacity will not be high enough in the situation where much cars are equipped with the TSSA. The effects of the TSSA on traffic flows on the highway will be negative. The traffic safety will increase, so the discussion will be what is more important.

5 RISK ANALYSIS

During the design and implementation process of the TSSA, a lot of problems can occur. It is necessary to make an inventory of these risks, so they can be prevented. The method that can be used for this is the RAID method which is discussed in the paper of the European Commission (Berghout, et al., 1999). The RAID method contains three steps, which will be discussed in this chapter. The first step is to describe the deployment scenario. Based on this, the risks for the implementation of the TSSA can be described. The last step is to determine the mitigation actions for the risks. Each risk will be classified with a color. The color given to a risk is based on the probability of occurrence and the level of impact. In table 5 can be seen which color should be used due to the level of probability of occurrence and the level of impact.

		Probability of occurrence		
		Low	Medium	High
Level of impact	Low	Blue	Green	Yellow
	Medium	Green	Yellow	Orange
	High	Yellow	Orange	Red

Table 5: Risk rating scheme

Because the threat of the risks is different, only the highest risks (red and orange) will be treated extensively. For these risks the mitigation actions will be determined.

5.1 Deployment scenario

In this paragraph the deployment scenario for the TSSA will be described. The subjects which will be discussed are the geographical scope, the ITS development, level of cooperation and the time horizon. The risks will be based upon this deployment scenario.

5.1.1 Geographical scope

The geographical scope for the TSSA will be the Dutch network. The reason for this is that the system does have many optional layers, so it will be difficult enough to implement the TSSA only on the Dutch network. When the TSSA is implemented successfully in the Netherlands, the scope can be widened to whole Europe. This can be done in a later phase, so Europe is not the scope for the risk analysis.

5.1.2 ITS development

The scope of the TSSA is to give a save speed advice. As mentioned before this speed advice can be based upon the condition of the vehicle, user profile, driver status, circumstances (road/weather) and traffic conditions. All components are variable, so information on these points need to be updated and sometimes real-time information is needed. The device on which the speed advice is displayed is an in-car display, which can be built in the car itself or it can be portable, so the device can be used in several cars. The device should detect the car itself, so user input is not necessary. The device should give an advice speed, but it can also be that the advised safe speed should be controlled. Because of this, the TSSA should be able to display the safe speed, but should also control the speed, so the driver cannot exceed the safe speed advice.

5.1.3 Level of cooperation

The TSSA is a project from a combination between public and private parties. The private parties that are involved are the European and National government. This because of the information on the open layer that should be the same in all different countries (at the end). Also because these governmental organizations can subsidize the purchase and/or use of the TSSA by the road users. The public parties that are involved in the development of the TSSA are the manufacturers of the system, the car manufacturers, but also the information providers of all different layers. At last a communication provider is needed, so real time information can be used to calculate an accurate safe speed.

5.1.4 Time horizon

The time horizon for the TSSA is set at ten years after implementation. The aim is that every car is equipped with the TSSA within ten years after implementation. The reason for this is that the TSSA will work optimal when all cars are equipped. This is the desired situation. This situation could be achieved, looking at the implementation of navigation systems. At this time most of the cars are equipped with a navigation system.

5.2 Mitigation actions

In Appendix C all risks that are threatening for the TSSA project are described. In this paragraph only the red/orange risks are described. For these risks mitigation actions will be described, so the effects of the risks can be avoided or controlled. The red and orange risks for the TSSA are:

Number	Threat description	Threat consequences	Probability of occurrence	Level of impact	Risk rating scheme
9	The price of the TSSA is (relative) high	- Fewer consumers. - Costs exceeds the benefits. - No profit for manufacturer.	Medium	High	Orange
12	People are not willing to buy the system, because they do not see the advantages of the TSSA	- A few people are buying the TSSA. - Great losses for all parties involved in the development and deployment of the TSSA.	Medium	High	Orange
13	The costs of the development and implementation are much higher than planned	- Great losses for the parties involved in the development and implementation phase of the TSSA.	Medium	High	Orange
17	Not enough funds found to invest in the TSSA	- Delay in development of the TSSA. - When there are no funds at the end, the TSSA never will be developed and implemented.	Medium	High	Orange
20	Telecommunication systems for communication between the open layer and the TSSA become obsolete	- The communication systems for the communication between the TSSA and the open layer have to be adapted to the newest communication technologies. - The TSSA devices that were already sold should be adapted to the new system.	Medium	High	Orange
24	Advice speed above speed limit not legislated by law	- Benefits of having the system are lower than supposed. - TSSA system becomes less attractive to potential buyers of the system. - Less systems sold.	High	Medium	Orange
42	After the TSSA system becomes available for selling, some faults in the system are detected	- The wrong TSSA devices needs to be sent back, and the problems must be solved. - Unsatisfied users. - Great losses.	Medium	High	Orange

43	The user does not like the system	- Hardly no TSSA systems sold. - Great losses.	Medium	High	Orange

For all these risks mitigation actions can be described:

Number	Actions	By whom	Type
9	- Lower the selling price of the TSSA - Subsidize the purchase of the TSSA - Manufacture the TSSA in another way, so the costs for making the TSSA are lower	- Manufacturer - Government/EU - Manufacturer	- Avoidance - Avoidance - Avoidance
12	- Make a campaign to promote the TSSA - Let people test the system so they see the advantages of the system - Carry out an user acceptance assessment	- Manufacturer/Govern-ment/EU - Manufacturer/Car selling companies -Developer	- Avoidance - Avoidance - Avoidance
13	- Let the Government subsidize the TSSA project - Sell the TSSA for higher prices	- Government - Manufacturer	- Control - Control
17	- Make a good analysis of the costs and benefits of the TSSA project with as less uncertainties as possible - Define the risks for every stakeholder as good as possible, so the stakeholder knows exactly what his/her responsibilities are and how they must cope with the project when it does not work	- Developer - All stakeholders together	- Avoidance - Avoidance
20	- Get information about projects from future communication methods and make it possible that the TSSA device later can be adapted to this newer communication method	- Manufacturer	- Avoidance
24	- Try to make it happen that driving above the speed limit is legislated by law - Use test results from tests with the TSSA to convince the law makers, that driving with the TSSA is safer. This implicit that driving above the speed limit does not lower the safety level of the road users.	- Developer - Developer	- Avoidance - Avoidance
42	- Test the TSSA system thoroughly, so the chance that there are faults in the TSSA system is very low.	- Manufacturer	- Avoidance
43	- Make sure that the HMI of the TSSA is attractive to the user. - Test the TSSA system thoroughly, and ask the testers if they like the system. - Let people test the system so they see the advantages of the system - Carry out an user acceptance assessment	- Manufacturer - Manufacturer - Manufacturer/Car selling companies -Developer	- Avoidance - Avoidance - Avoidance - Avoidance

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