Cooperative Vehicle-Infrastructure Systems

D.DEPN.4.1b	Assess user acceptance by small scale driving simulator research

Sub-project No.	1.3	Sub-project Title	DEPN
Topic No.	4	Topic Title	Utility, usability and user acceptance
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Dissemination level PU/PP/RE/CO		PU	
File Name		DEL_DEPN_4.1b_Simulator Study_V1.5	
Due date		15 January 2008	
Delivery date		09 April 2008	

Abstract	This deliverable describes the small scale driving simulator study that was performed to asses the acceptance and workload from the end user's perspective of a number of important CVIS scenarios.

	Project supported by European Union DG INFSO IST-2004-2.4.12 eSafety – Cooperative systems for road transport
Project reference	FP6-2004-IST-4-027293-IP
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Control sheet

Version history			
Version	**Date**	**Main author**	**Summary of changes**
1.0		Jasper Pauwelussen	1st version
1.1		Jasper Pauwelussen	2nd version
1.2		Jasper Pauwelussen	3rd version
1.3		Marika Hoedemaeker	4th version
1.4		Jasper Pauwelussen	5th version
1.5	20-03-2008	Marika Hoedemaeker	After internal review
	Name		**Date**
Prepared	Marika Hoedemaeker		December 2007
Reviewed	Julie Castermans		February 2008
Authorized	Monica Schettino		April 2008
Circulation			
Recipient	**Date of submission**		
European Commission	April 2008		

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Abbreviations and Definitions

Abbreviation	Definition
ANOVA	Repeated measures Analysis of Variance
CFF	Cooperative Fleet & Freight Applications
CINT	Cooperative Interurban Applications
COMO	Cooperative Monitoring
CTA	Cooperative Traveler Assistance
CURB	Cooperative Urban Applications
EDA	Enhanced Driver Awareness
HMI	Human Machine Interface
RSME	Rating Scale for Mental Effort
SP	Sub-project (of CVIS) e.g. COMM, FOAM, CURB…
SUMMITS	Sustainable Mobility Methodologies for Intelligent Transport Systems
TMC	Traffic Management Centre
UC	Use Case
UN	User Need

1. Summary

This deliverable describes the small scale driving simulator study as part of the user acceptance study, Deliverable D.DEPN.4.1.

The goal of this small scale driving simulator study is to asses the acceptance and workload from the end user's perspective of a number of important CVIS scenarios. To design systems that only provide information that the driver considers being useful and informative, different concept designs of the three types of CVIS systems were simulated and analyzed.

The scenarios were:

- Speed advice for green wave at traffic lights
- Routing and rerouting to avoid traffic congestion and optimize traffic throughput
- Infotainment: Auditory messages, e.g. e-mail, hotel reservations etc.

This assessment will be used for the Human Machine Interface (HMI) requirements of CVIS systems in the defined scenarios.

Speed advice for green wave

Before driving in the actual scenario, participants filled in an acceptance questionnaire on how their acceptance was before actually experiencing the system. For the speed advice scenario it was found that before experiencing the dynamic traffic signs or the in-car display the participants provided higher scores on 'usefulness' and 'satisfying' than afterwards. No statistically significant difference was found between the dynamic traffic signs and the in-car display.

The green-wave speed showed on the in-car display was experienced as more personal than the advisory speed showed on the dynamic traffic signs.

The Peripheral Detection Task (PDT) measured the on-line workload. The results show that using dynamic traffic signs resulted in a higher workload than without a system used for green-wave information.

Routing & rerouting

For the routing and rerouting scenario it was found that the rerouting navigation system that allowed the participants to choose an alternative route seemed to be a more useful and satisfying system compared to a conventional navigation system without a rerouting function. For all different navigation conditions it was found that the usefulness and satisfaction was rated positive.

The subjective workload of the system that automatically rerouted and did not provide information and the system that allowed the driver to choose the alternative route was lower than the experienced workload of the conventional navigation system. The average workload for all systems seemed to be low.

Infotainment system

The usefulness of the different message systems was not significantly different and was rated positive for all systems. The satisfaction of the system that provided the message at once when it arrived and of the system that provided the message when the participant touched the button on the display seemed to be higher than the satisfaction of the system that only provided a message if the participant stopped the car. The satisfaction for all systems was positive.

For the overall judgment, before and after the systems were experienced, it was concluded that the message system that forced the driver to stop was the least desired compared to all other systems. The system that provided the message when the participant touched the button on the display seemed to be more desired than the system that provided the message at once when it arrived.

When the subjective workload was considered it seemed that there was no significant difference between the four infotainment designs.

2. Introduction

The simulator study was conducted additionally to a questionnaire study (D.DEPN.4.1a). This questionnaire study provided end user information of a large group of potential end users after they had a short description of the different CVIS scenarios. The participants had to imagine that they were using a certain CVIS system and they were asked how useful such a system would be by rating it from 1 (very useless) to 5 (very useful). The present study provides an insight in the user acceptance and workload of CVIS systems after potential end users have experienced some of the CVIS systems in a driving simulator.

In the simulator study a small group of people experienced three types of CVIS scenarios. These three scenarios were:

- Speed advice for green wave at traffic lights
- Routing and rerouting to avoid traffic congestion and optimize traffic throughput
- Infotainment: Auditory messages, e.g. e-mail, hotel reservations etc.

To design systems that only provide information that the driver considers to be useful and informative, different concept designs of the three types of CVIS systems were simulated. This resulted in the following conditions for every CVIS scenario in the simulator study:

Speed advice for green wave

- The participant drove without a speed advice system. This was the baseline condition
- The participant drove with an in-vehicle display. This display provided green wave speed advice
- The participant drove on a road with dynamic traffic signs. The traffic signs showed the right speed for the green wave

Routing and rerouting system

- The participant drove with a conventional navigation system that did not reroute if a traffic congestion was on the programmed route
- The participant drove with a navigation system that rerouted, but did not inform the participant
- The participant drove with a navigation system that rerouted and informed the participant why he/she was rerouted
- The participant drove with a navigation system that informed the participant

about congestions on the route and asked the participant what alternative route to choose. The participant could also choose to continue the present route with the congestion.

Infotainment messages

- The participant drove with a system that gave an auditory message (e-mail) immediately after this message arrived
- The participant drove with a system that gave an auditory message after the driver pushed the message button on the touch screen display
- The participant drove with a system that gave an auditory message only if the driver stopped the car and pushed the button on the display
- The participant drove with a system that gave an auditory message when the system thought the traffic situation was safe enough for the driver to hear the message

For the speed advice scenario, the experiment setup was different compared to the routing and rerouting scenario and the infotainment scenario. In this virtual environment there were traffic lights implemented. Also other traffic was simulated to correspond with a real traffic light situation at crossroads, where cars stop or cross the road depending on the traffic light sign. For the routing and rerouting scenario and the infotainment scenario, the same virtual environment was used, but different routes. In these scenarios there was no other traffic simulated to prevent that the participants would follow other cars.

The research questions of this study were:

- What is the user acceptance of the three different CVIS scenarios with respect to usefulness and satisfaction? What CVIS system concept design was considered to provide the most useful information? What system concept design did they like best?
- Is there a difference in user acceptance before the systems were actually used in the small scale driving simulator study compared to after they were used?
- What is the workload of the different CVIS systems?
- According to the user acceptance and workload of the different CVIS system, what are the suggestions that could be made about HMI concepts for combined CVIS systems?

The outcome of the small-scale driving simulator study provides an insight of the user acceptance and workload of CVIS systems. This outcome could be used for the HMI requirements.

Chapter 3 describes the three considered scenarios and the driving simulator that was used for the small-scale driving simulator experiment. Also a short description of the methodology is given. Chapter 3 describes the experiment that was conducted for the speed advice to have a green wave at traffic lights. In chapter 4, the results of the second scenario, the routing & rerouting scenario, are shown. Chapter 5 describes the third scenario, the infotainment scenario (sending messages to the driver). In chapter 6, the conclusions and recommendations are drawn.

3. Background

For the study, participants were subjected to three different scenarios related to the three main scenarios as described in D.DEPN.4.1 and rewritten for the experiments.

3.1. The three considered CVIS scenarios

1. Speed advice. In-vehicle display with dynamic traffic signs & speed advice for smooth traffic, green wave information. (scenario based on a Use Cases of CURB & COMO)
2. Routing and Rerouting. Real-time traffic information and route planning with travel time prediction and rerouting (scenario based on Use Cases of CURB, CINT & COMO)
3. Infotainment. Information that is not directly related to the driving or navigation task (scenario partly based on a Use Case of CFF)

Speed advice scenario

The speed advice scenario describes the possibility of having dynamic traffic signs or in-car displays that provide up-to-date information about speed advice for a smooth journey to have a good harmonization with other traffic, the maximum allowed velocity on the driven trajectory and information about oncoming obstacles and road blocks. An example of the speed advice scenario is shown in Figure 1.

Figure 1 Speed advice scenario (Illustrations from Microsoft Powerpoint)

Routing & rerouting scenario

In the routing and rerouting scenario the driver, when connected to the CVIS service, will enter a desired destination in the navigation system. The navigation system calculates the travel time for the fastest route by taking into account all obstacles that are known at that moment. During the journey the system will get real-time information about the situation of the traffic flow and will reroute if necessary. An example of the rerouting scenario is shown in Figure 2.

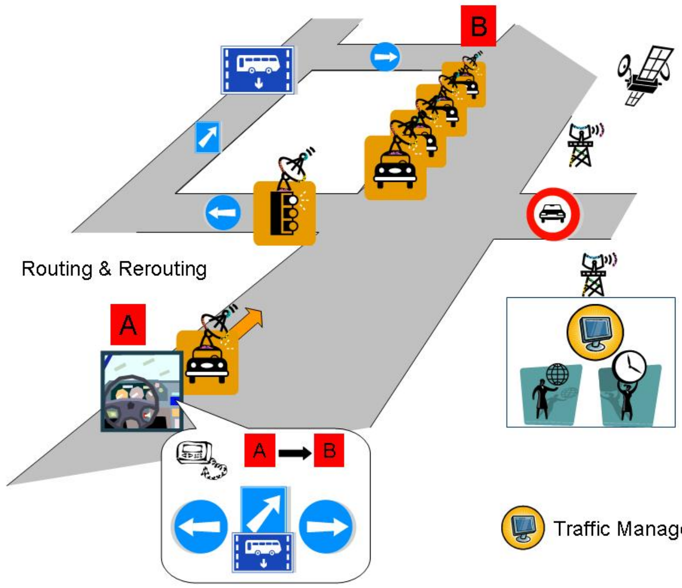


Figure 2 Routing & Re-routing scenario (Illustrations from Microsoft Powerpoint)

Infotainment scenario

The Infotainment scenario considered in-car information that is not directly related to the driving or navigation task but could be useful for the driver. The CVIS system provides different entertainment and information for the driver and the passengers. The system provides internet by the wireless network. The driver has the possibility to make phone calls, listen to music and the passengers can watch videos. The driver and passengers are able to check their e-mail, the news, weather forecast, but also desired facilities that are nearby or on the route like petrol stations, parking spots, restaurants, hotels, maintenance facilities, shops, camping's etc. There is the possibility to make reservations for restaurants, hotels, camping's etc. and the driver is able to book a parking spot near the desired destination. In this experiment the driver will receive messages that are read to him/her by the system. An example of the infotainment scenario is shown in Figure 3.

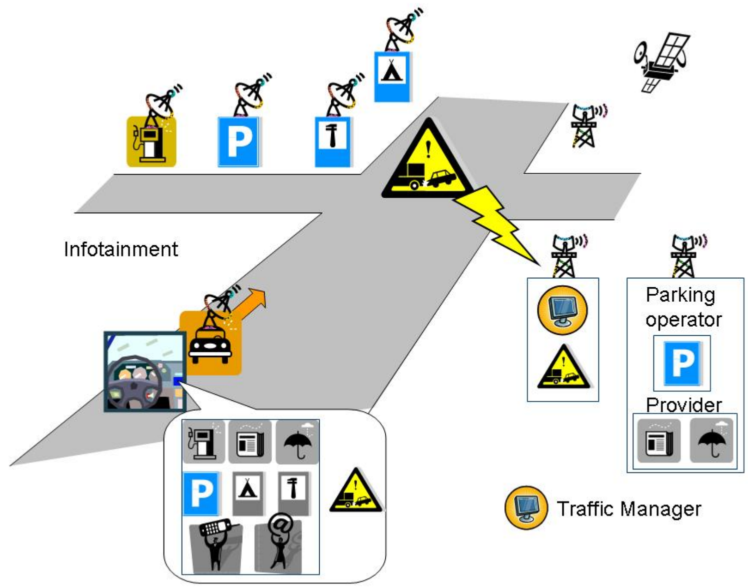


Figure 3 Infotainment scenario (Illustrations from Microsoft Powerpoint)

3.2. Driving simulator

All experiments were conducted in the fixed-base low-cost driving simulator of TNO Human Factors. This simulator contains a Volkswagen Golf 4 mock-up, manual transmission, a steering force feedback by an electrical torque motor. The virtual environment was projected on three large screens (225cm (h) x 300 cm (w)) with a total viewing angle of 180°. For the projection on every screen three Liesegang dv 245 projectors (800x600 dpi, 1400 ANSI Lumen) were used and three Dimension 8400 computers (P4 3.0 GHz P4 HT, 1.0 GB DDR2) with NVIDIA GeForce 5600 GT graphic cards that generated real-time images at a refresh frequency of 30 Hz.

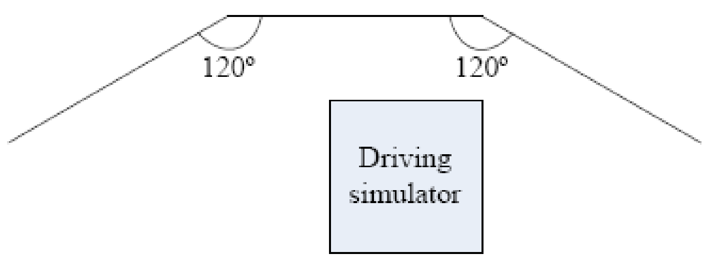


Figure 4 Driving simulator screens

The sound of the vehicle, in-car systems and environment was presented to the driver by speakers that were mounted in the vehicle. It was also possible to communicate with the experimenter that was in the same room behind the control panel.

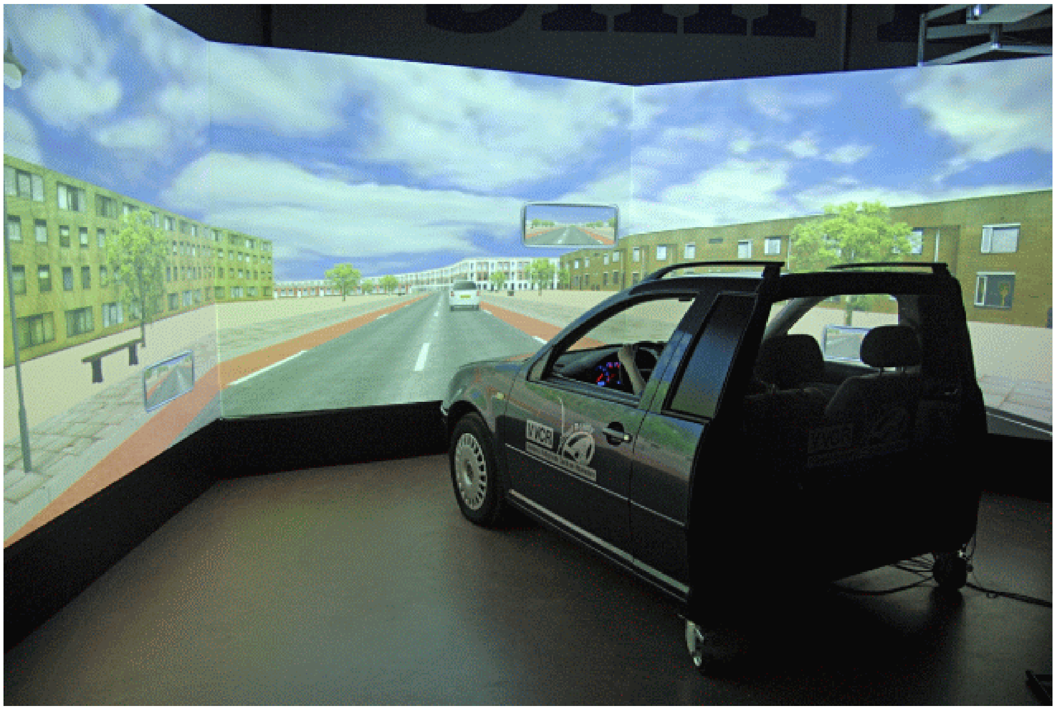


Figure 5 Driving simulator

3.3. *Methodology*

The user acceptance study of the Speed Advice system was done in the SUMMITS research program concerning speed advice systems. The results that were found regarding to the acceptance and workload of the speed advice scenario were included in this report. All results of this study could be found in Duivenvoorden (2007).

For the Routing and Rerouting and e-mail scenarios a new virtual environment was designed for the specific use of the CVIS systems in these scenarios. In contrast to the speed advise scenario, these two scenarios did not contain other traffic.

The fixed-base driving simulator and the software to build up the virtual environment were the same for all three experiments.

3.3.1. Measuring acceptance

The acceptance could be divided into

- The utility or usefulness of the system from the driver's point of view
- The usability of or satisfaction with the system

The utility or the usefulness of the system provides information about the enthusiasm of the people driving with the system towards the support that the system is providing with respect to driving without the system. The usability of or satisfaction with the system describes the amount of comfort when using the system. This focuses more on the design of a certain system with respect to the design of other systems with the same functionality.

For measuring the acceptance of the CVIS systems the Van der Laan Scale (Van der Laan et al., 1997) was used. This scale is dedicated to assess the acceptance of new systems. It contains several questions that were related to the usefulness from the subject's perspective and the satisfaction the subjects had using the new system.

The participants had to indicate on a 5 point rating scale what their opinion was about the items that are listed in Table 1. Items 1,2,4,5,7 and 9 are scored from +2 to -2, the other items (3,6 and 8) are scored from -2 to +2 because the items were mirrored.

Table 1. Van der Laan scale items

#	Dimension	Items
1	Usefulness	Useful – useless
2	Satisfaction	Pleasant – unpleasant
3	Usefulness	Bad – good
4	Satisfaction	Nice – annoying
5	Usefulness	Effective – superfluous
6	Satisfaction	Irritating – likeable
7	Usefulness	Assisting – worthless
8	Satisfaction	Undesirable – desirable
9	Usefulness	Raising alertness – sleep-inducing

Averaging the scores of the usefulness items over all subjects' results in the end-score for usefulness and averaging the scores of the satisfying items results in the end-score for satisfaction.

For the Routing & Rerouting scenario and Infotainment scenario we also asked acceptance related questions in a short questionnaire.

3.3.2. Measuring workload

In addition to user acceptance it is also important to consider how the system affects the driving task. Therefore driver workload was studied.
The workload in the Speed Advice scenario was measured objectively by measuring the performance of the secondary task, the Peripheral Detection Task (PDT), where the subject had to respond to a peripherally presented red light (M.H. Martens & W. van Winsum, 2000). By measuring the reaction time of the driver to the appeared red light and the percentage of missed stimuli, one can determine the increase of the workload due to the speed advice system.

The subjective workload in the Routing & Rerouting and Infotainment scenarios were measured by an RSME (Zijlstra, 1993).

4. Speed Advice experiment

In the speed advice experiment, the driver received a speed advice to have the green wave at the traffic lights trajectory. This means that the drivers that followed the speed advice and therefore had a green wave at the traffic lights did not have to stop for red traffic lights on their route. This will increase the traffic throughput, because the magnitude of the speed fluctuation is less compared with the present situation. Also the emission and noise will be reduced.

The scope of this experiment study was a provincial road in Delft, namely the Kruithuisweg N470. The maximum speed limit was 80 km/h. Only close to the intersections with the traffic lights, the speed limit was 50 km/h. For this experiment a virtual environment was made to simulate the kruithuisweg. In this experiment the values of the advisory speed varied between 60 km/h and 80 km/h. The maximum of the green-wave speed (80 km/h) equaled the speed limit on the Kruithuisweg.

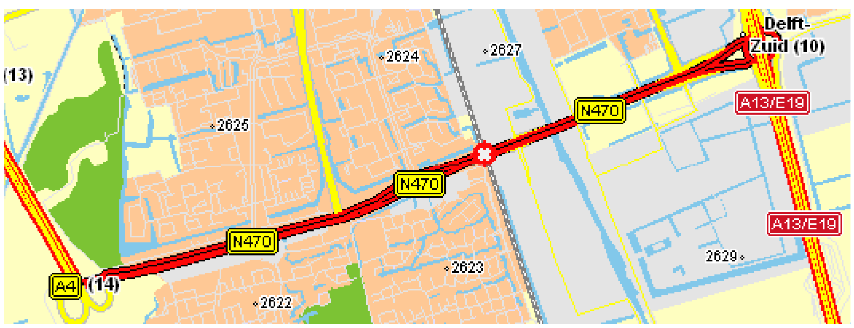
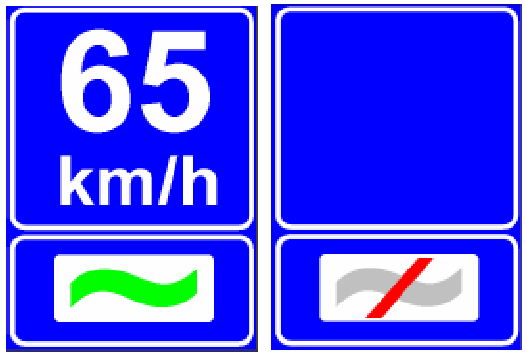


Figure 6 Kruithuisweg (source: www.routenet.nl)

The advisory speed given to the subject depended on the speed of the subject. The green wave speed in the experimental setup was calculated by the time left to the start of the green phase and the distance to a traffic light. The subject only got an advisory speed if the speed that was necessary for the green wave was between 60 and 80 km/h. If the speed was higher or lower, the 'No green wave' sign was showed (Figure 7). To provide a proper real-time speed advice the distance and relative speed of the car in front of the driver should be considered too, even as the detection of possible emergency vehicles or other traffic that drives through a red light.



Green wave **No green wave**

Figure 7 Speed advice signs

In this driving simulator experiment the subjects drove three different conditions. These conditions varied in the system used for presenting the green-wave speed to subjects:

1. Baseline condition. This condition is without a system for giving the subject a green wave speed;

2. Dynamic traffic signs condition. Dynamic traffic signs at the road side are used for giving the subject the advisory speed about the green wave (Figure 8);

3. In-car system condition. Here an in-car display is used for presenting the green wave speed (Figure 9).

Figure 8 The dynamic traffic signs

Figure 9 The in-car display

The experiment was a within-subject design, which meant that in each condition the same subjects were tested. This gave a reduction in error variance associated with individual differences. A within subject design is also called a repeated measurement. This design had more statistical power and took fewer subjects. With a within-subject design it is possible to compare workload and user acceptance between the three different conditions. A comparison between 'without system' and 'with system' could be made but also a comparison between both systems. A disadvantage of a within-subject design is that subjects learn over time, which results in undesirable learning effects. To solve this problem, the sequence of the runs is counterbalanced because of these learning effects.

Two green-wave conditions were introduced in order to avoid learning effects on the green wave speed. These two conditions were:

1. The low reference speed condition 65 km/h;

2. The high reference speed condition 75 km/h.

Driving the low reference speed condition meant that a green wave was guaranteed when driving with an average speed of 65 km/h in the low reference speed condition and 75 km/h in the high reference speed condition. The reference speed condition in the eastern direction differed from the reference speed condition in the western direction. When a subject drove the eastern direction in the low reference speed condition, he/she had to drive the western direction in the high reference speed condition and vice versa.

These two speed values were used to examine the effects of a bigger difference between the speed limit and advisory speed. The subjects were not informed about these two green wave conditions, so they could not anticipate on this. They were only instructed that they could receive an advisory speed for the green wave on the

Kruithuisweg.

When the speed advice for the next traffic light is for example 65 km/h, this meant that driving with an average speed of 65 km/h resulted in green light. A bandwidth of 3 km/h was made round this advice, so driving with an average speed between 62 and 68 km/h resulted in green.

In total, each subject completed three runs in the driving simulator corresponding to the three experimental conditions of systems. A run contained two reference speed conditions by driving the eastern and western direction on the Kruithuisweg. This resulted in six trials, two trials in each run:

1 Without system Low reference speed 65 km/h

2 Without system High reference speed 75 km/h

3 Dynamic traffic signs Low reference speed 65 km/h

4 Dynamic traffic signs High reference speed 75 km/h

5 In-car display Low reference speed 65 km/h

6 In-car display High reference speed 75 km/h

Apart from the participant there were ten other cars driving along with the subject. The other traffic in the experiment did not react on the green-wave advice. It was assumed that this did not influence the subjects. Subjects were able to overtake the other traffic. A run lasted about ten minutes.

4.1. Subjects

Six (2 x 3) different groups of subjects were made to cover all combinations of the three system conditions (without system, dynamic traffic signs and in-car display) and the two reference speed conditions (low and high).

In total sixty subjects were planned to take part in the experiment, for each group ten subjects with a minimum of eight subjects for each group. To select subjects from the TNO subject database the following section criteria were used:

- Age between 23 and 60 years;

- Having a driving license five years or more;

- Driving around 7,000 kilometers a year or more;

- Not having motion sickness in fairground attractions, in a real car and in a simulator.

In the experiment a total of 58 subjects participated, but only fifty (35 male and 15 female) subjects completed the experiment. The eight subjects got motion sick and were left out of the data set.

The average age of the fifty subjects was 44 years (standard deviation 12.9 and range 24-64). Two subjects were older than 60 years (namely 61 and 64 years) but they were still active drivers so it was allowed for them to participate. All the participants had their driving license for more than five years. All subjects, including the motion sick ones, were paid for their participation.

4.2. Independent variables and dependent measures

The independent variables in the analysis of variance are the three different systems: Baseline, Road signs and in-car display.

The dependent workload measures were the average PDT reaction time and the PDT percentage missed signals. The dependent measures for deriving the acceptance were the Van der Laan scale items described in Table 1.

4.3. Results of Speed Advice scenario

Visual analysis of box plots and histograms of the data showed a couple of outliers. According to the notated comments it seemed that in several runs a small traffic jam occurred because of an error of the software. The traffic jam happened when the traffic light was red and when there was traffic in front of the participant. In this case the participants were directed around the traffic by the experiment leader and could continue the run. For the analysis it was assumed that this incident that only occurred at six runs had no influence on the participant's acceptance of the system, but could influence the measured workload. Therefore these were excluded from the measured workload data.

The results with respect to the acceptance of the Speed Advice systems are described in subsection 4.3.1. The workload analysis is described in subsection 4.3.2.

4.3.1. Acceptance of Speed Advice scenario

The user acceptance of the three different system conditions was measured by the questionnaires that had to be filled out by the participants during the experiment. User acceptance concerned two dimensions, namely 'usefulness' and 'satisfying' (Van der Laan et al, 1997). The dimension 'usefulness' was about practical aspects of the dynamic traffic signs and the in-car display used for the green wave. 'Satisfying' reflected the pleasantness of both systems. The dimensions 'usefulness' and 'satisfying' were rated on a 5-point rating scale from -2 to +2.

The experiment was split up in two parts for measuring user acceptance. One third of the subjects had to fill out questions about a hypothetical system for the green wave before they could actually experience the system. These participants (N = 17) started the experiment with the baseline run followed by the runs with systems. This part of the study was called 'baseline first'. In 'system first' subjects (N = 33) had to judge the systems after they were exposed to the systems.

Before computing the scores of the variables ('usefulness' and 'satisfying') for user acceptance and before performing analyses of variance, reliability analyses had to be performed by using Cronbach's alpha (Van der Laan et al, 1997). Table 2 shows the results (α values) of the reliability analyses.

Table 2 Results (α values) of the reliability analyses

	Before measurement		After measurement Dynamic traffic signs		After measurement In-car display	
Study part	Usefulness	Satisfying	Usefulness	Satisfying	Usefulness	Satisfying
Baseline first	0.91	0.89	0.97	0.98	0.97	0.98
System first	-	-	0.98	0.97	0.95	0.94

The determined reliability is sufficiently high ($\alpha > 0.65$) and therefore, the end-scores for each subject could be computed and analyses of variance could be performed.

For both parts, 'baseline first' and 'system first', the usefulness and satisfying scores are shown in Table 3. The relations between the measurements of both study parts are in the same order of magnitude, horizontally and vertically. Therefore, it could be said that there was no sequence effect of the experimental runs.

Table 3 Usefulness scores and satisfying scores for both study parts

	Before measurement		After measurement Dynamic traffic signs		After measurement In-car display	
Study part	Usefulness	Satisfying	Usefulness	Satisfying	Usefulness	Satisfying
Baseline first (N=17)	1.48	1.59	0.76	0.68	0.53	0.10
System first (N=33)	-	-	0.72	0.51	0.56	0.08

Statistical analyses were performed on both study parts. For the study 'baseline first' a significant main effect of 'measurement' in 'usefulness' and in 'satisfying' was found. The statistical results of the main effects are shown in Table 4.

Table 4 Statistical results on usefulness and satisfying for baseline first

Baseline first	F	P	Figure

Usefulness	F(2,32) = 7.48	< 0.01	Figure 10
Satisfying	F(2,32) = 12.39	< 0.001	Figure 11

Figure 10 and Figure 11 show the main results respectively for 'usefulness' and 'satisfying'. Post hoc test of Bonferroni[1] showed that usefulness scored higher in the before measurement than in the dynamic traffic signs condition [$p < 0.05$]. The usefulness in the before measurement also seemed to be significantly higher than in the in-car display condition [$p < 0.01$].

Post hoc test of Bonferroni showed that satisfying scored higher in the before measurement than in the dynamic traffic signs condition [$p < 0.05$]. Also for the in-car display condition the satisfaction of the system seemed to be significantly higher in the before measurement than in the in-car display condition ($p < 0.001$).

The previous described results indicate that the participants expected that the system would be more useful and have a higher satisfaction before they experienced the system than after they experienced the system for the dynamic traffic signs condition and the in-car display condition. These results could be caused because of the simplified representation in the simulator environment. Although the expectations were higher on forehand, the usefulness and satisfying are still positive after the participants experienced them in a simplified environment. This would imply a positive acceptance of the system by the participants.

[1] http://en.wikipedia.org/wiki/Multiple_comparisons

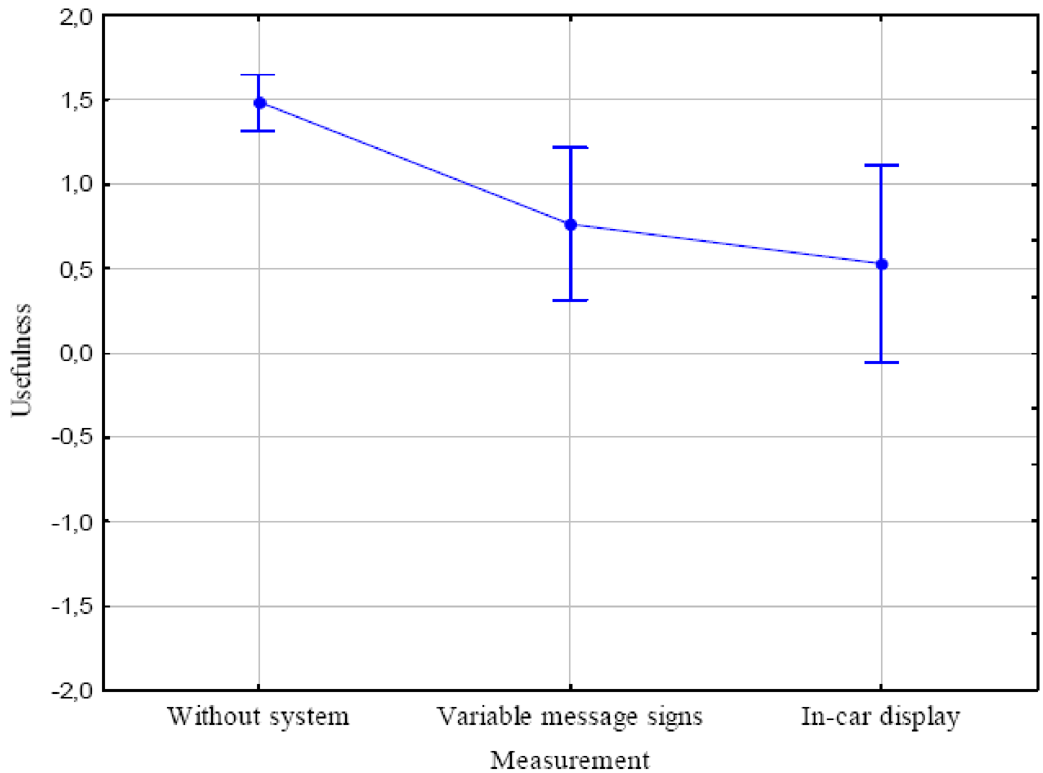


Figure 10 Usefulness as a function of 'measurement'

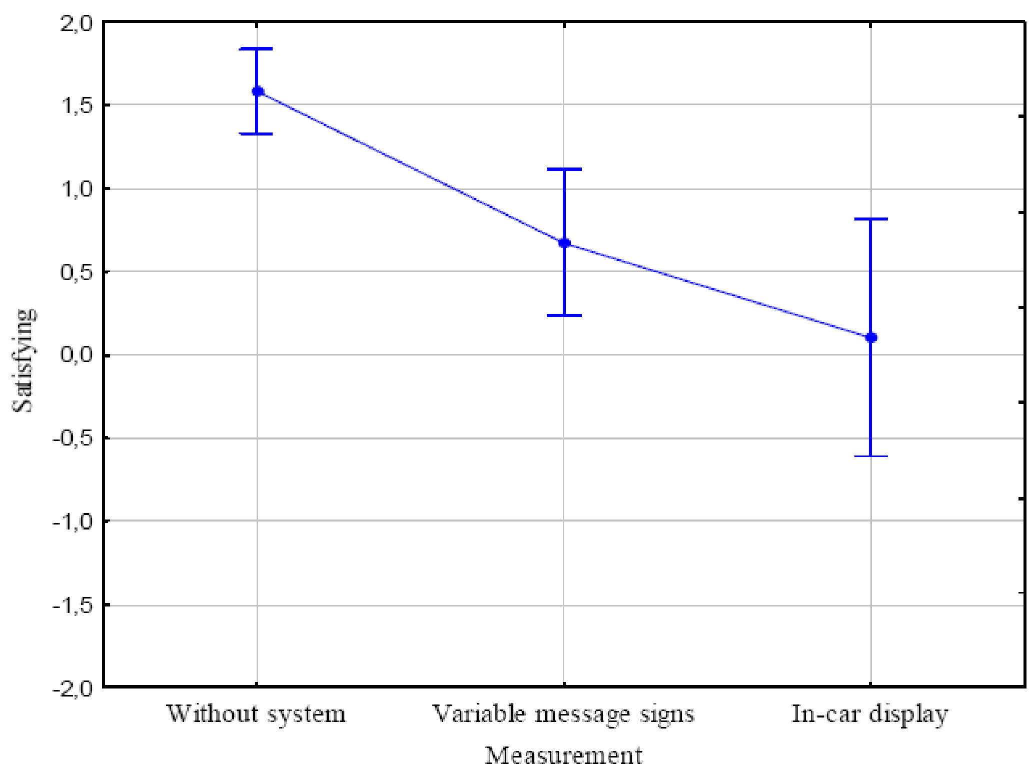


Figure 11 Satisfying as a function of 'measurement'

No statistically significant difference was found for usefulness and satisfying between the dynamic traffic signs and the in-car display.

For the study 'system first', a significant main effect was found of 'measurement' in 'satisfying'. No main effect in 'usefulness' was found. The statistical results of the repeated measures analysis are shown in Table 5.

It is shown in Figure 12 that satisfying scored higher in the dynamic traffic signs condition than in the in-car display condition [$p < 0.05$].

Table 5 Statistical results on usefulness and satisfying for system first

Baseline first	F	P	Figure
Usefulness	$F(1,32) = 0.71$	0.41	
Satisfying	$F(1,32) = 6.72$	< 0.05	Figure 12

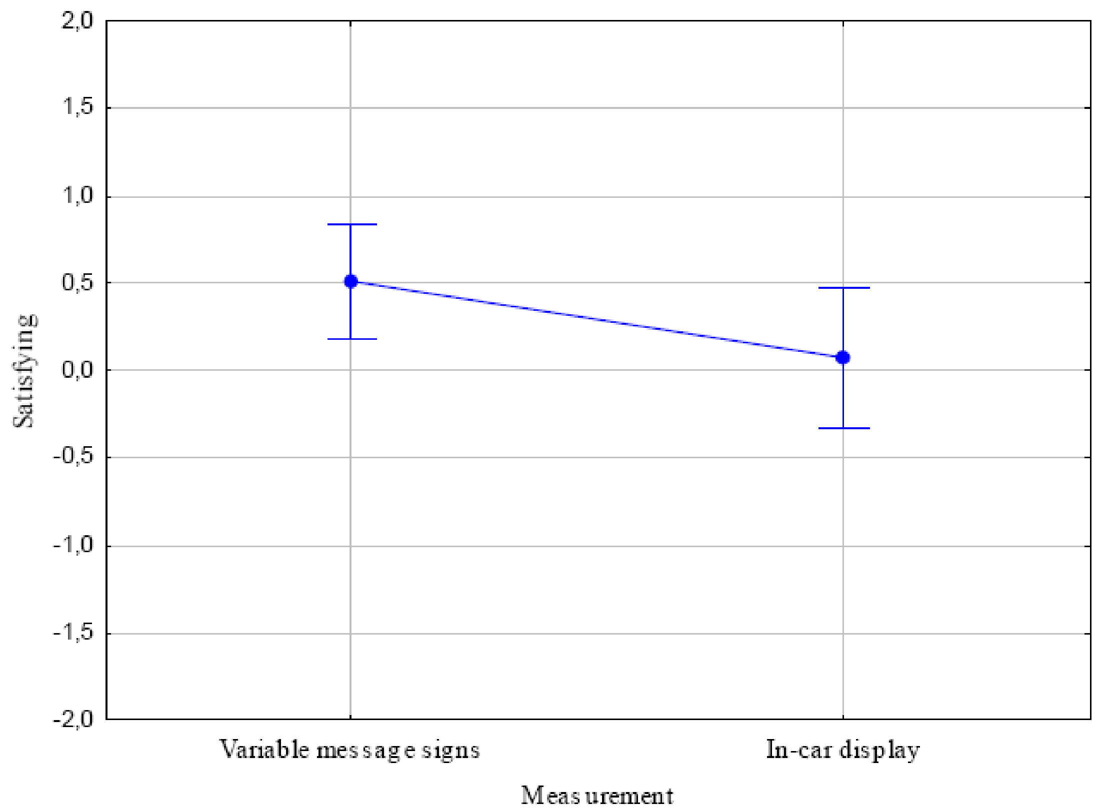


Figure 12 Satisfying as a function of 'measurement' for the 'system first' study

Both study parts together

Table 6 shows the averaged scores for the study parts 'baseline first' and 'system first' together, corrected for the number of participants per study part (N = 17 & N = 33).

Table 6 Usefulness scores and satisfying scores for the whole study

Before measurements (N = 17)		After measurements Dynamic traffic signs (N = 50)		After measurements In-car display (N = 50)	
Usefulness	Satisfying	Usefulness	Satisfying	Usefulness	Satisfying
1.48	1.59	0.73	0.57	0.55	0.09

For both study parts together (a total of 50 subjects), analysis of variance was performed. A significant main effect was found of 'measurement' in 'satisfying'. No main effect in 'usefulness' was found. The statistical results of the repeated measures analysis are shown in Table 7.

Table 7 Statistical results on usefulness and satisfying for both study parts

	F	P	Figure
Usefulness	F(1,49) = 1.38	0.25	
Satisfying	F(1,49) = 10.20	< 0.01	Figure 13

Figure 13 shows the main results respectively for 'satisfying'. It is shown that satisfying scored higher in the Dynamic traffic signs condition than in the in-car display condition [$p < 0.01$].

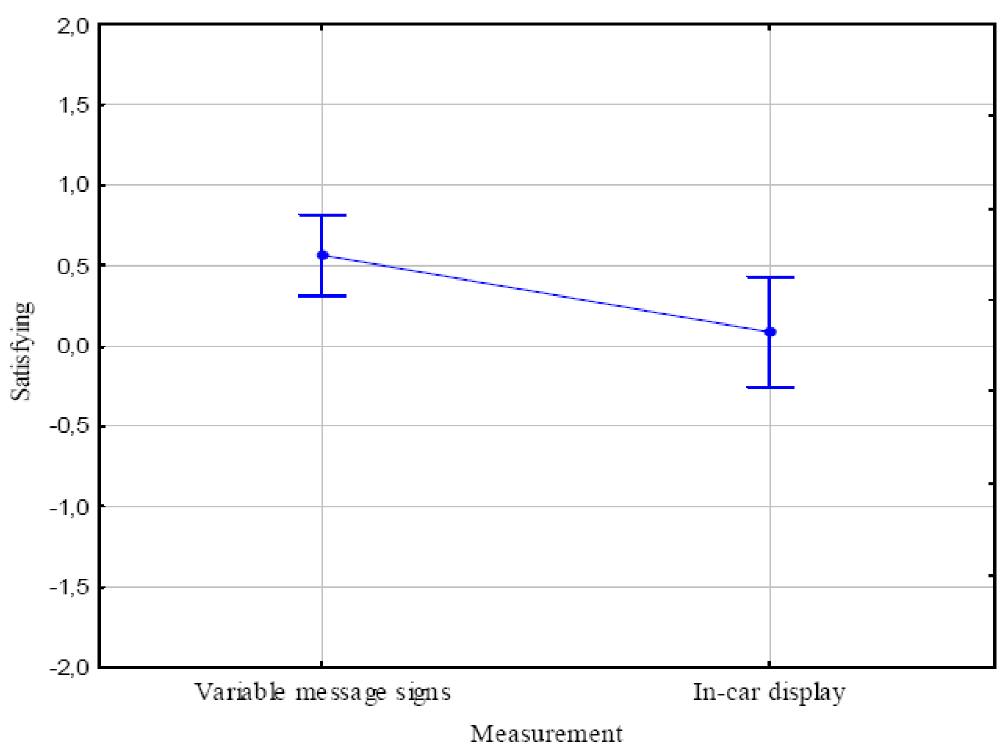


Figure 13 Satisfying as a function of 'measurement'

Figure 14 shows the results of all the subjects for the three conditions 'without system', 'dynamic traffic signs' and 'in-car display'. It can be seen that without experiencing a system for the green-wave speed advice (without system condition), the system is found more useful and satisfying than after experiencing such a system. The scores are however positive for all conditions which imply a positive acceptance.

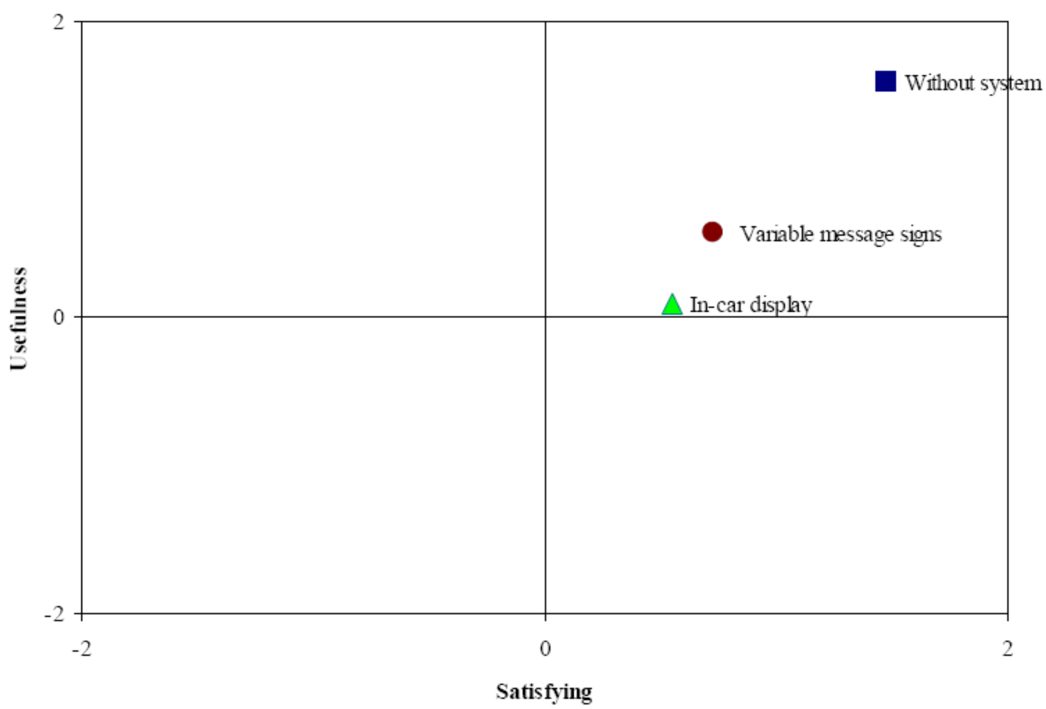


Figure 14 Overview of the scores for the three conditions

Personal messages

After using the dynamic traffic signs and the in-car display, the subjects were asked to judge the given advisory speed shown on both systems about being personal (special meant for you) or common (meant for everyone, not specially for you). The used scale for judging was -2 for not personal to +2 for personal. The dynamic traffic signs scored 0 and the in-car display +0.52. The unpaired Student's t-Test was performed in order to examine statistically significant difference between the dynamic traffic signs and the in-car display. There was found statistically significant difference between the conditions 'dynamic traffic signs' and 'in-car display' [$p < 0.05$]. The green-wave speed showed on the in-car display was experienced as more personal than the green-wave speed showed on the dynamic traffic signs.

4.3.2. Workload of Speed Advice scenario

Average PDT reaction time

There was a significant main effect found of 'system'. No main effect of 'reference speed' and no interaction effect between 'reference speed' and 'system' were found.

The statistical results of the repeated measures analysis on the average PDT reaction time are shown in Table 8.

Table 8 The statistical results of the average PDT reaction time

Effect	F	P	Figure
Reference speed	F(1,41) = 0.07	0.80	
System	F(2,82) = 8.21	< 0.001	Figure 15
Reference speed x system	F(2,82) = 2.01	0.14	Figure 16

Post hoc tests showed that the use of dynamic traffic signs resulted in a higher reaction time than without a system used for green wave information [p < 0.001] which can be seen in Figure 15. This indicates that the workload was higher when subjects were driving with the dynamic traffic signs. No statistically significant difference was found between the dynamic traffic signs and the in-car display. Figure 16 shows the average PDT reaction time as a function of 'system' and 'reference speed'.

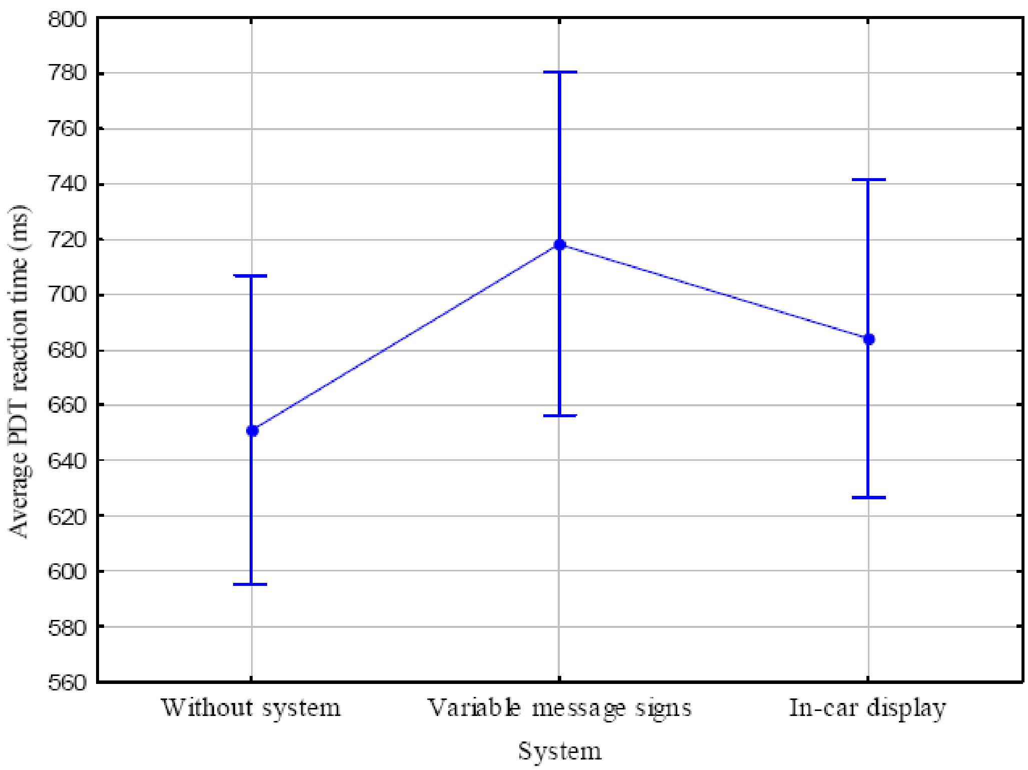


Figure 15 Average PDT reaction time as a function of 'system'

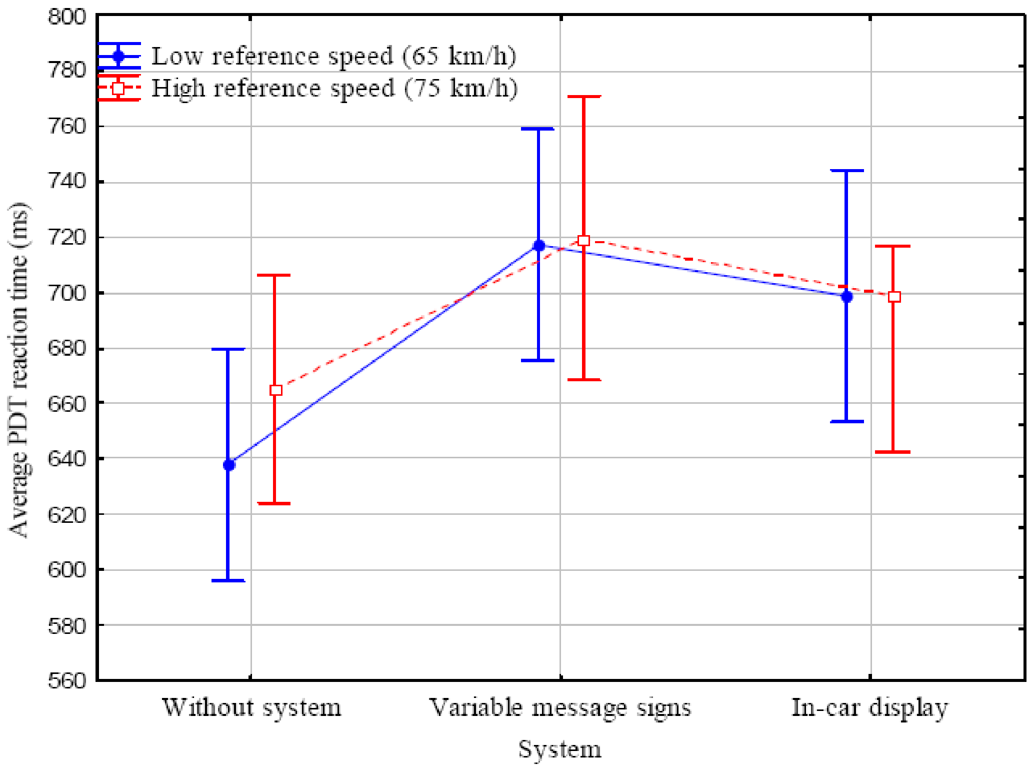


Figure 16 Average PDT reaction time as a function of 'system' and 'reference speed'

Percentage missed PDT signals

There was a significant main effect found of 'reference speed' and 'system'. The statistical results of the repeated measures analysis on the percentage missed PDT signals shown in Table 9.

Table 9 Statistical results on percentage missed signals

Effect	F	P	Figure
Reference speed	$F(1,41) = 4.57$	< 0.05	Figure 17
System	$F(2,82) = 84.91$	< 0.01	Figure 18
Reference speed x system	$F(2,82) = 0.27$	0.76	Figure 19

It seemed that the average PDT reaction time in the low reference speed condition had a larger percentage of missed signals than in the high reference speed condition [$p < 0.05$]. The results are shown in Figure 17.

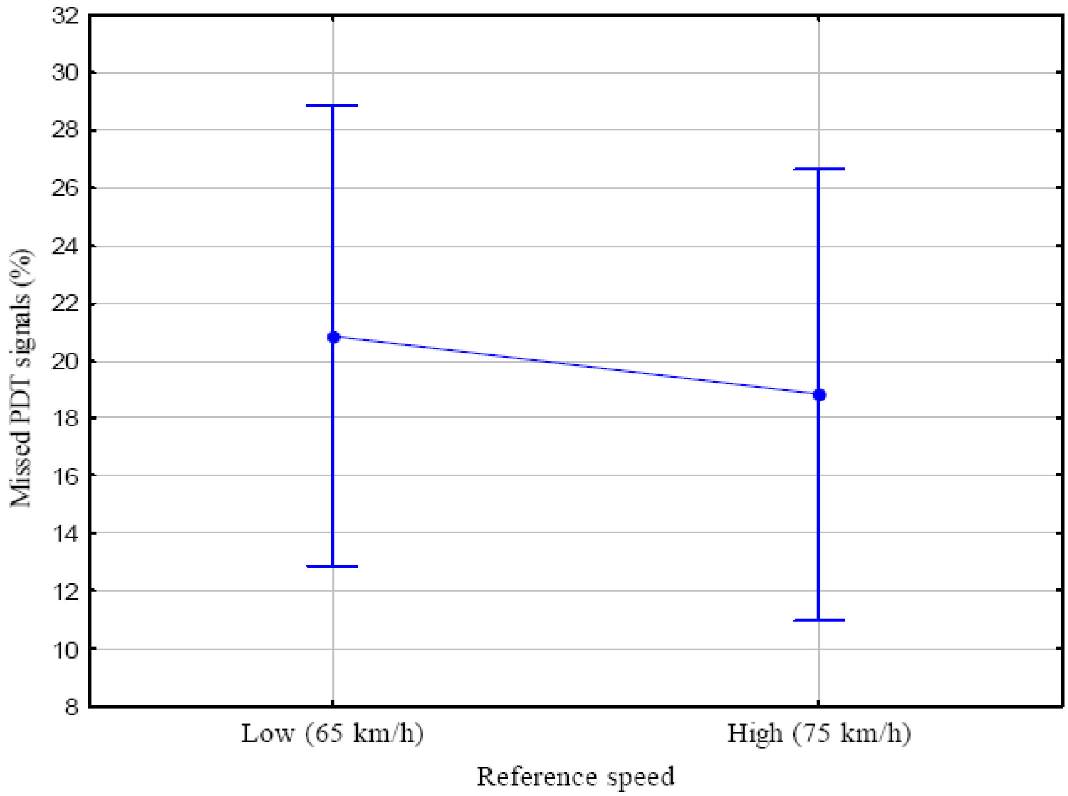


Figure 17 Percentage missed PDT signals as a function of 'reference speed'

Post hoc tests showed that when using dynamic traffic signs the percentage missed signals was higher than without a system [$p < 0.05$], see Figure 18. This indicates that the workload was higher when subjects were driving with dynamic traffic signs compared to driving without a system. No statistically significant difference was found between the dynamic traffic signs and the in-car display. There was also no statistically significant difference found between in-car display and driving without the green wave speed advice system. Figure 19 shows the percentage missed PDT signals as a function of 'system' and 'reference speed'.

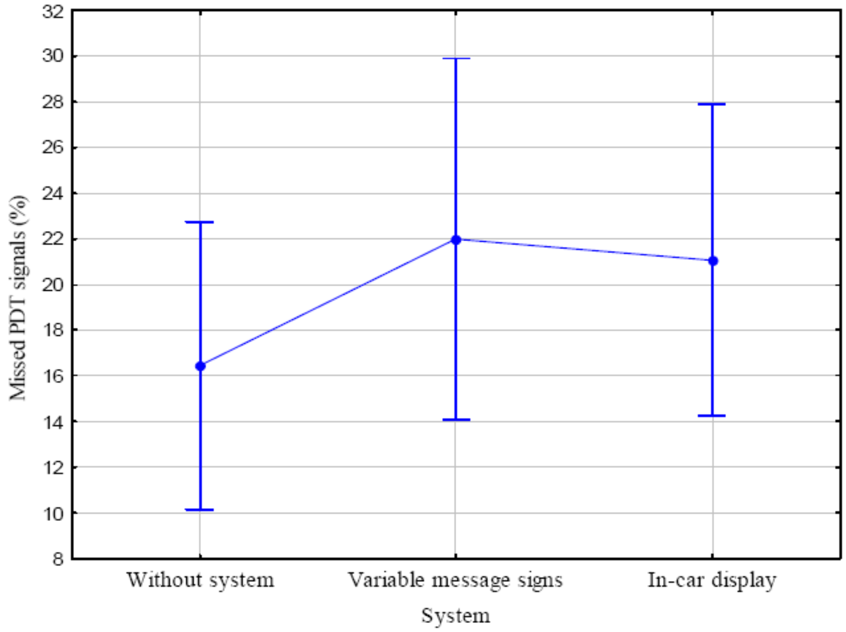


Figure 18 Percentage missed PDT signals as a function of 'system'

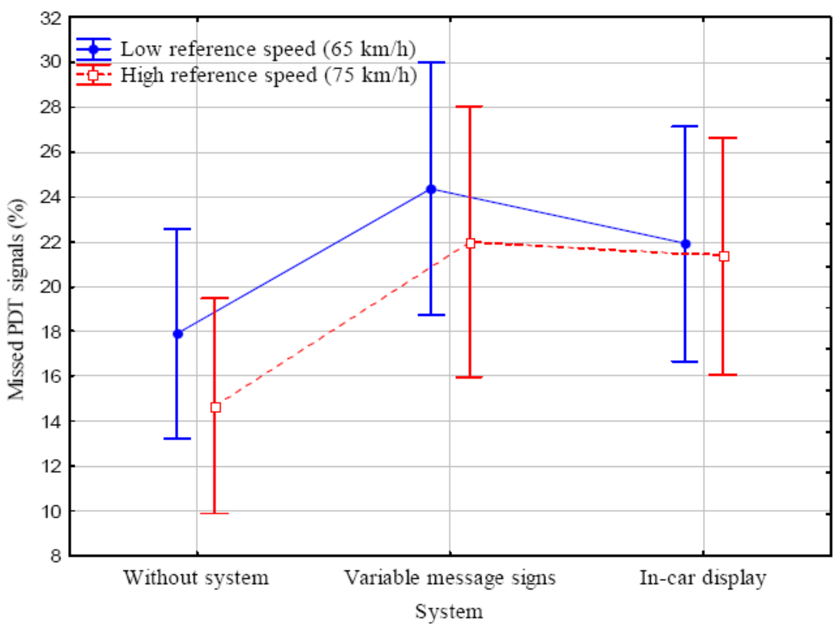


Figure 19 % missed PDT signals as a function of 'system' and 'reference speed'

4.3.3. Remarks of the subjects

Beside the questionnaires subjects always had the possibility to write down comments or remarks on the questionnaires. In this section the most frequently comments are shown.

General

Most subjects said they liked driving at the Kruithuisweg and experiencing the dynamic traffic signs and the in-car display for the green wave. Some subjects found it really nice driving the simulator. Most subjects wrote down they drove like they normally did.

Variable signs or in-car display

In the before measurement of ‘baseline first’ most of the subjects (12 out of 17 subjects) preferred the dynamic traffic signs. Five out of 17 subjects preferred the in-car display. After completing the experiment, the preference shifted to fifty-fifty. Nine subjects chose the dynamic traffic signs and eight the in-car display.

For ‘system first’, 15 out of 33 subjects chose after completing the experiment for the dynamic traffic signs. Eight subject chose the in-car display and nine preferred the driving without a system for the green wave. One subject did not answer.

Several reasons were given by multiple subjects when choosing for dynamic traffic signs:

- Dynamic traffic signs are easier to realize at the road side, because there is no need to make adjustments to cars;
- Dynamic traffic signs are like normal traffic signs, so drivers know what to do;
- Dynamic traffic signs are less distractive than the in-car display;
- It is a common way of giving information;
- Dynamic traffic signs are accessible for everyone, even for foreign drivers;
- Not everyone has an in-car display;
- There are already too many things on the control panel.

Subjects chose for the in-car display because of the following reasons. Multiple subjects gave these reasons:

- There are already too many traffic signs at the side of the road;
- It is a personal way of giving information;
- The in-car display is easier to monitor because it is always present.

When subjects did not prefer a system for the green wave the following reasons were given. They rather drive without a system, because they are more capable themselves to adjust their speed to the situation or they never act on advisory speeds.

Acting on the green-wave speed

One of the reasons for choosing to act on the green-wave speed was that they could continue driving at the intersections, which was pleasant and saved fuel. Sometimes the other traffic made it impossible to act on the green wave by causing a traffic jam. One subject rather preferred a fixed green-wave speed and another one preferred dynamic traffic signs above the road. Two subjects would rather get speech message next to the visual messages. Traffic lights changed to green a little too late according to a few subjects.

Driving simulator

About the simulator, a frequently made comment was that it was difficult to keep the right speed because of the missing feedback forces on the acceleration pedal and sound of the engine. Due to the missing feedback on motion of the mock-up, a few subjects found it difficult to brake. Several subjects missed a cruise control and radio in the driving simulator. Some subjects found it difficult to see the status of the traffic lights and the dynamic traffic signs from a distance. Only close to the traffic lights and signs it was possible to see which light or signal was shown. This can be explained because of the low resolution of the projectors.

PDT

A few subjects found it more difficult to use the micro switch of the PDT when driving faster, passing or in driving a curve. Because of some happenings, a subject pushed the micro switch as a reflex. For example, when the traffic light changed the light or when the subject passed other cars.

Scenarios

Driving the baseline condition, two subjects missed the variable signs or the in-car display. Apparently they expected the systems to be there. One subject collided with another car because that car suddenly braked which he/she apparently did not notice in time. Another subject mentioned a car drove through him after passing an intersection.

This can be explained because at that moment the software was not able to detect the position of the other car and the subject. Another subject liked the virtual environment of the Kruithuisweg because of the nice cars. Finishing the second run, one subject was surprised he/she had to drive the same route for a second time.

4.3.4. Chapter conclusions

Acceptance

Before experiencing the dynamic traffic signs or the in-car display the subjects provided higher scores on 'usefulness' and 'satisfying' than when they actually experienced both systems. No statistically significant difference was found between the dynamic traffic signs and the in-car display. In case of only an after measurement, 'satisfying' scored higher when using dynamic traffic signs than when using the in-car display.

The green-wave speed showed on the in-car display was experienced as more personal than the advisory speed showed on the dynamic traffic signs.

Workload

Using dynamic traffic signs resulted in a higher reaction time on the PDT stimuli than without a system used for green-wave information. Driving with dynamic traffic signs also resulted in a higher percentage missed PDT signals. This indicates that when subjects were driving with dynamic traffic signs the workload was higher compared to driving without a system. In the low reference speed condition the percentage missed PDT signals was higher than in the high reference speed condition.

5. Routing & Rerouting experiment

In this experiment the Routing and Rerouting scenario was simulated. The routing and rerouting system is a navigation system that is able to guide the driver to an alternative route in case of roadblocks or accidents.

The participants drove four different conditions of this Routing and Rerouting scenario in this simulator study. These four conditions concerned the navigation system for different amount of automation. The control condition was using a conventional navigation system with no routing and rerouting system implemented [Conventional_Nav]. In the three other conditions the system continually calculated the fastest route and could provide alternative routes when obstacles occur. One of these conditions contained a system that provided an alternative route without providing any information about the rerouting to the driver [Reroute_NoInfo]. The system automatically took the decision of rerouting the vehicle, because of obstacles on the previous calculated route. Another condition provided an alternative route and provided information about the rerouting to the driver [Reroute_Info]. The driver could decide to take the advice of following the new route that was provided or not to follow the alternative route but continue on the old route and meet obstacles on this route. The last condition provided alternative routes with some additional information about the travel time, information about the rerouting and asked the driver to take action in order to choose the route they preferred. If the driver would not choose an alternative route he/she would take the conventional route and would meet throughput inconveniences on the route. In this case the participant would encounter a roadblock. The participant could choose an alternative route (route A or B) by using the buttons on the (touch-screen) display [Reroute_Choice]. See

Figure 20 (Distance between 5 and 8 km).

The goal of this experiment study was to analyze the user acceptance of the routing and rerouting system and what information, presented by the different system designs, the participants considered as most relevant.

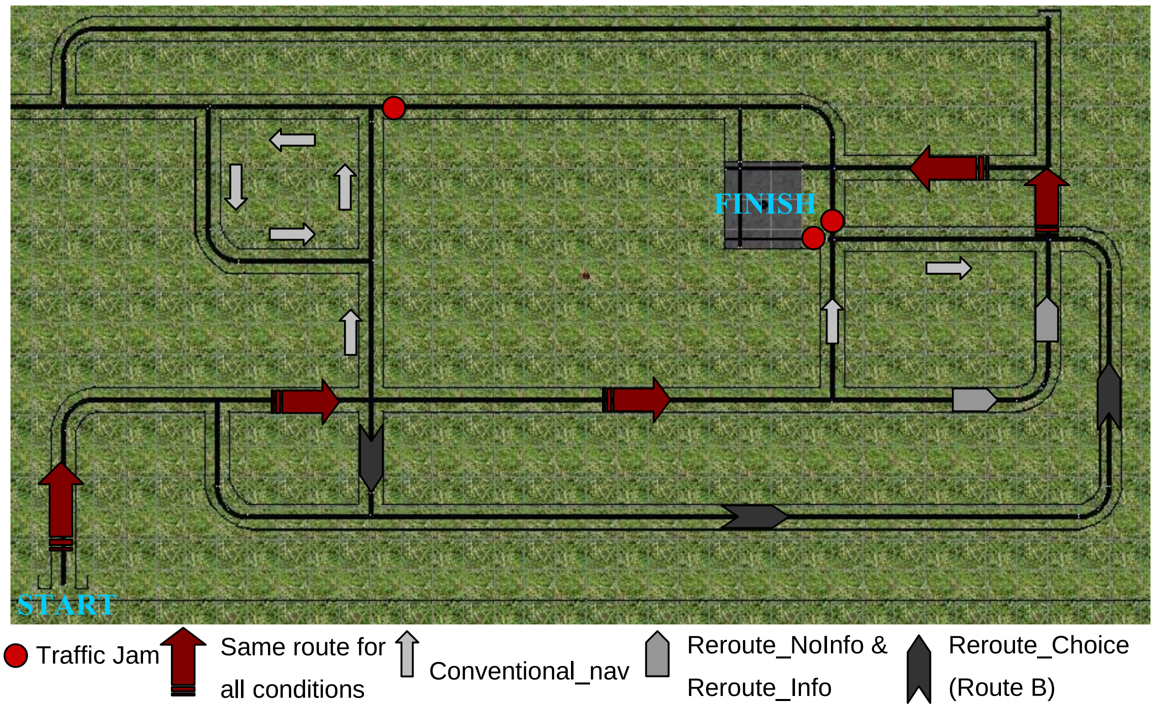


Figure 20 Top view of different rerouting conditions

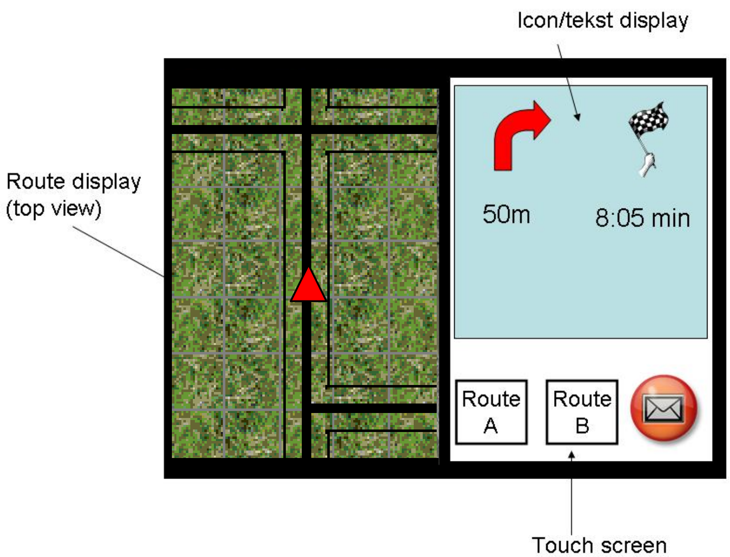


Figure 21 Schematic representation of the touch screen in-car display

In the driven scenarios there was no other traffic modeled to prevent that the participants would follow other cars. On forehand, the participants did not know what condition they were going to drive.

5.1. Subjects

In total twenty subjects were planned to take part in the experiment. Every subject drove the 4 different conditions. The experiment design was a within-subject design where the order of the conditions was balanced to avoid order effects. The selection criteria that were used for the subjects were that they needed to have some experience with a navigation system and that they drove at least 5000 kilometers or more.

In the experiment 17 of the 20 planned subjects participated in the experiment. Three of the subjects canceled the planned experiment and one of the subjects got motion sick during the experiment. Therefore, the data of 16 participants was analyzed. The average age of the 16 participants that completed the experiment was 48.8 years. The standard deviation was 15.8 years. All subjects were paid for their participation.

5.2. Independent variables and dependent measures

The independent variables in the analysis of variance are the four different systems: Conventional navigation system [Conventional_Nav], rerouting navigation system no_info [Reroute_NoInfo], rerouting navigation system info [Reroute_Info] and the rerouting navigation system with route choice [Reroute_Choice].

The dependent measures were the acceptance measures: The Van der Laan scale items described in Table 1 and the comparison ratings for the four different systems before and after the participants experienced the systems. The dependent workload measures were the RSME ratings.

5.3. Results of Routing & Rerouting scenario

Before computing the scores of the variables (‘usefulness’ and ‘satisfying’) for user acceptance and before performing analyses of variance, reliability analyses had to be performed to consider if what is measured is truly what is supposed to be measured. For this internal consistency of the measurement scale the Cronbach’s alpha was analyzed (Van der Laan et al, 1997). Table 10 shows the results (α value) of the reliability analyses.

Table 10 Results (α values) of the reliability analyses

Conventional Navigation System		Rerouting - No notification		Rerouting - Information to driver		Rerouting - route chosen by driver	
Usefulness	Satisfying	Usefulness	Satisfying	Usefulness	Satisfying	Usefulness	Satisfying
0.82	0.92	0.81	0.89	0.78	0.95	0.79	0.79

The determined reliability is sufficiently high ($\alpha > 0.65$) and therefore, the end-scores for each subject could be computed and analyses of variance could be performed.

5.3.1. Acceptance of Routing & Rerouting scenario

The participants had to follow the instructions that were given by the navigation display. The maximum allowed speed was 80km/h. The acceptance of the four rerouting systems was measured by questionnaires that had to be filled out by the participants after driving a condition. The questionnaire contained questions with respect to the usefulness and the satisfaction of the system described by the Van der Laan scale (Van der Laan et al, 1997). The participants were also asked to compare the four different message conditions and arrange the systems in a sequence in terms of best overall judgment. The system that was rated 1 was considered to be the best system to have according to the participant and the least desired system was rated 4. The four systems were rated before and after they had experienced the systems. The questionnaire can be found in the Appendix A

To provide some insight in the understanding of the system by the participants and their opinion towards the design, the participants were asked if they understood the system, if they had a clear idea about the use of the system and the system design.

To get an idea of what the system should cost, the last six participants of the experiment were asked what they would pay for the CVIS system.

Understanding, purpose and design of the different systems

For the conventional navigation system without the rerouting function 12 participants indicated that comprehensibility of the system was good. 2 of the participants answered that it could be better and 2 participants expected to have a rerouting system and thought therefore that there was an error in the systems' rerouting function. 15 of the 16 participants indicated that the driving simulator experiment provided a good understanding of the use of the system.

The comprehensibility of the navigation system that rerouted automatically without providing information to the driver was good according to all 16 participants. 15 of the 16 participants replied that the driving simulator experiment provided a good understanding of the use of the system.

The comprehensibility of the navigation system that rerouted automatically with providing information to the driver was good according to 12 of the participants and 4 said it was not.. 15 of the 16 participants said that they had a good understanding of the system in the driving simulator.

15 of the 16 participants indicated that the comprehensibility of the navigation system that had drivers choose the alternative route was good. 15 of the 16 indicated that the driving simulator experiment provided a good understanding of the use of the system.. One remark about the design of this system was that the participant wanted to have a confirmation about the route he had chosen to check if the route was selected by the system.

Utility of the system – Van der Laan Scale

The participants were asked to rate the following items for the systems on the Van der Laan 5-point rating scale:

- Useful/Useless

- Bad/Good
- Effective/Superfluous
- Assisting/Worthless
- Raising alertness/Sleep-inducing

The average of the scores presented the usefulness of the system. The results for all participants for the four different navigation conditions are shown are Figure 22. Repeated measures Analysis of Variance (ANOVA) was used to consider significant differences of the usefulness per condition.

It turned out that the main effect of the usefulness of the different systems was significant [$F(3,45) = 3.85$, $p<0.05$].

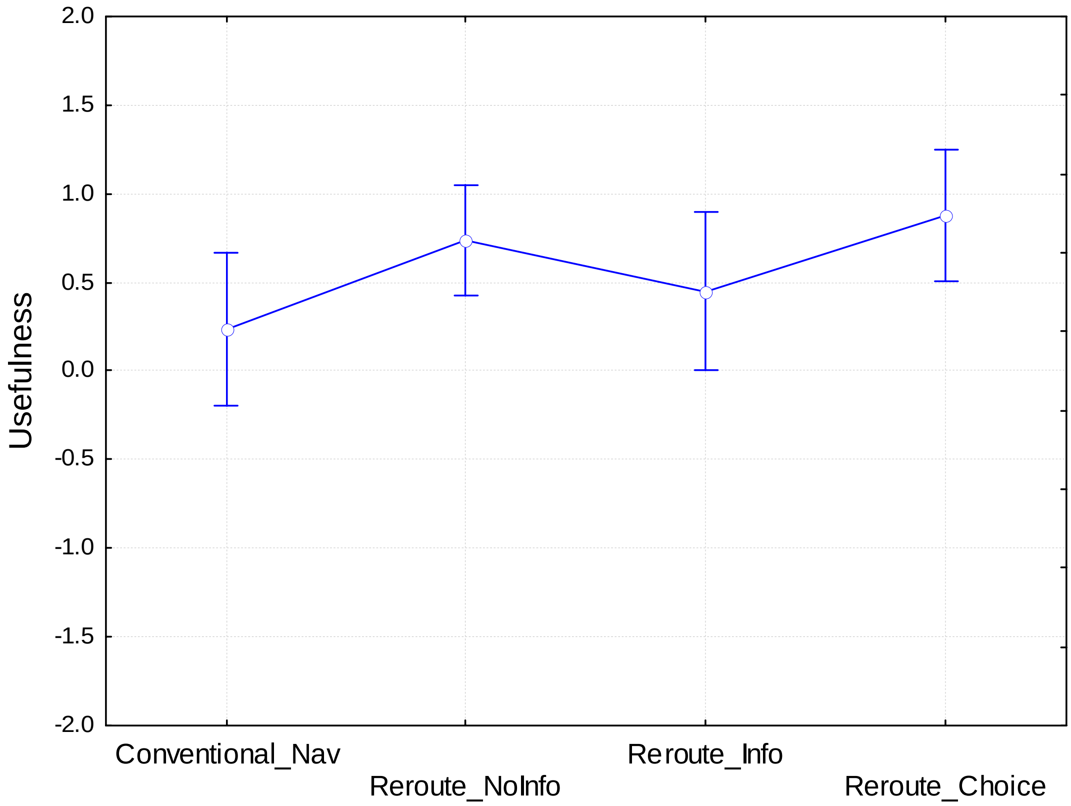


Figure 22 Usefulness of the four different navigation systems. The vertical bars indicate the standard deviation errors

The effect of the different systems was determined by the post-hoc Bonferroni test. This resulted in a significant effect for the [Reroute_Choice] with respect to the [Conventional_Nav] [$p<0.05$]. It could therefore be concluded that the participants considered the rerouting navigation system that provided alternative routes including travel time information from which they had to choose their desired route as more useful with respect to the conventional navigation system without rerouting function.

There was no significant difference between the two other rerouting navigation systems, [Reroute_NoInfo] and [Reroute_Info], with respect to the [Conventional_Nav] and [Reroute_Choice]. It is shown in Figure 22 that the usefulness of the [Reroute_NoInfo] and [Reroute_Info] was rated positive.

Satisfaction of the system – Van der Laan Scale

The participants were asked to rate the following items for the system on the Van der Laan 5-point rating scale:

- Pleasant/Unpleasant
- Nice/Annoying
- Irritating/Likeable
- Undesirable/desirable

The results of the combined average scores for all participants for the four different navigation conditions are shown in Figure 23. Repeated measures Analysis of Variance (ANOVA) was used to analyze any satisfaction differences between conditions.

It turned out that the main effect of the satisfaction of the different systems was significant [$F(3,45) = 5.00$, $p<0.01$].

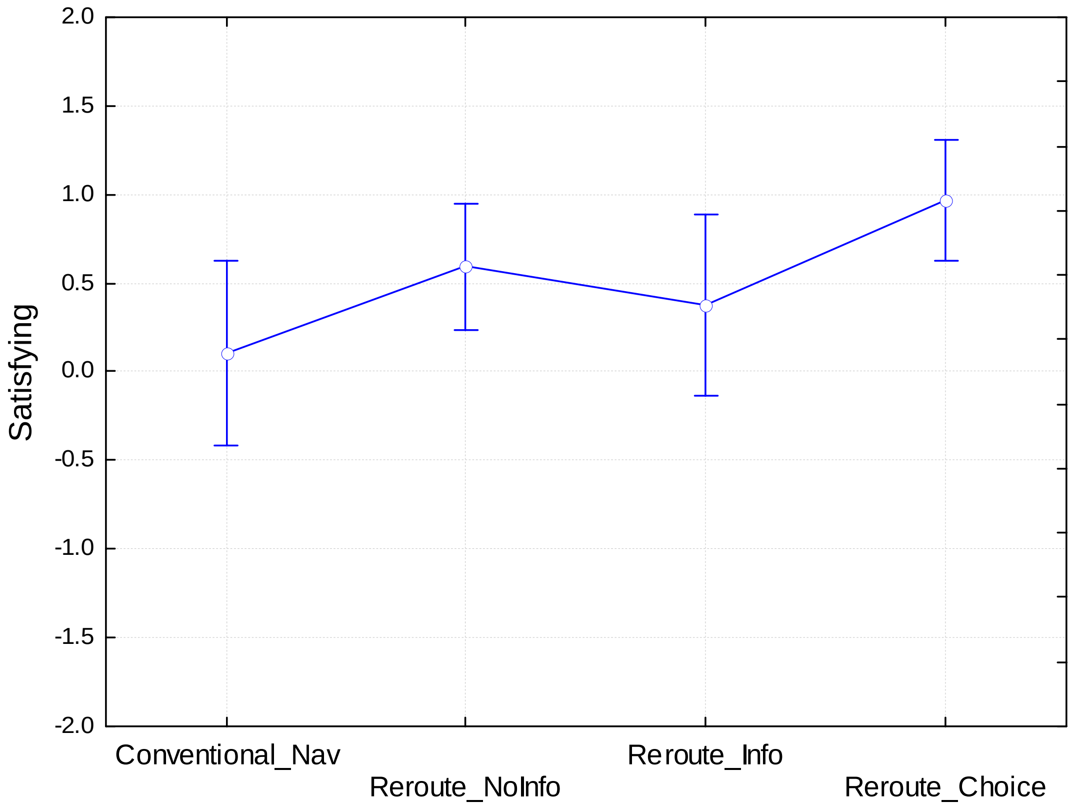


Figure 23 Satisfaction of the four different navigation systems. The vertical bars indicate the standard deviation errors

The effect of the different systems was determined by the post-hoc Bonferroni test. This resulted in a significant effect for the [Reroute_Choice] with respect to the [Conventional_nav] system without rerouting function [p<0.01]. There was no significant effect found for the two other rerouting navigation systems with respect to the [Conventional_nav] and the [Reroute_Choice].

The usefulness and satisfaction of the four CVIS navigation conditions are shown in Figure 24. It is shown that all conditions were on average rated positive for the usefulness as well as for the satisfaction. The best accepted system seemed to be the rerouting system that provided information about the congestion and alternative routes with travel time information from which the driver was able to choose his/her desired route.

No significant differences were found for the navigation condition where no information was provided when the system automatically rerouted and the condition where this information was provided, compared with the [Conventional_Nav] and [Reroute_Choice].

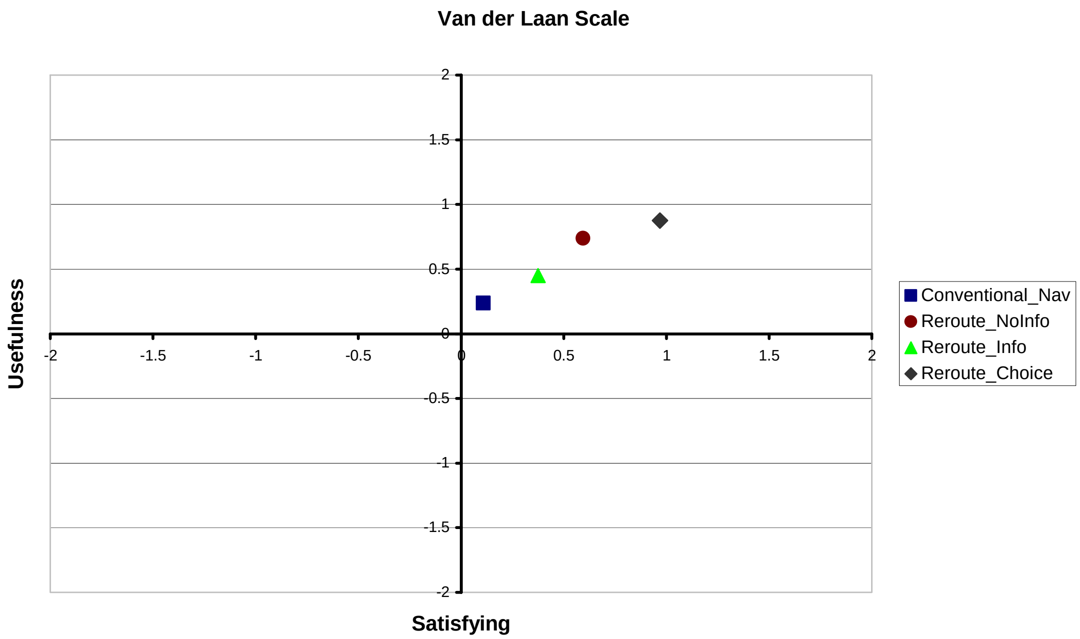


Figure 24 Overview of the scores for the four navigation conditions

Overall judgment

The participants were also asked to compare the different conditions and rate them in order to an overall judgment with the rating scale of 1 (best) to 4 (worst). They had to rate the systems before they experienced the systems and after they experienced the systems. The ratings are shown in Figure 25.

An ANOVA (before and after ratings together) showed marginally effect of system [$F(3,45) = 2.78$, $p<0.05$]. However, a post-hoc Bonferroni test did not show any significant differences.

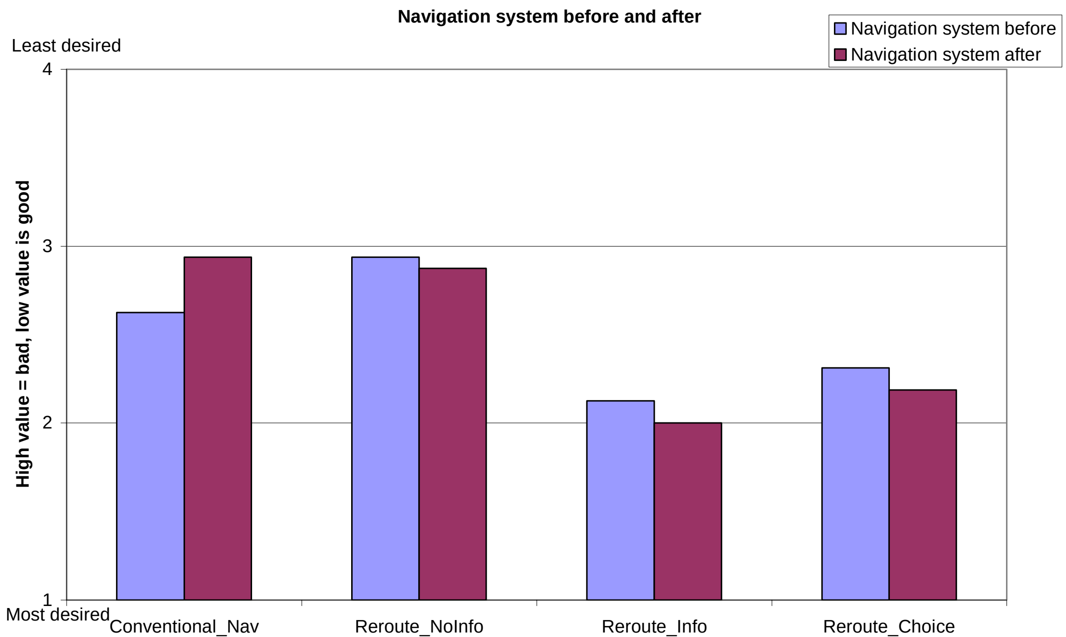


Figure 25 Average ratings of overall judgment

For the 2-way interaction of the different systems and the before and after ratings, no significant differences were found. This implies that the participants seemed to have quite a good impression of the usefulness of the different navigation systems before they had experienced it. One could also say that the Human-Machine Interface (HMI) did hardly influence the impression of the systems the participants had beforehand. If Figure 25 is considered it seems that the [Reroute_Info] had the best overall judgment, then the [Reroute_Choice], the [Reroute_NoInfo] and the worst rated overall judgment was the [Conventional_Nav]. This seems a bit different when it is compared to the outcome of the Van der Laan scale. However the overall judgment ratings did not differ significantly between systems.

System price and monthly service costs

As was mentioned before, the last six of the participants were also asked what price they were willing to pay for a rerouting navigation system and what the monthly costs for the service should be, assumed that the rerouting system works properly and that it fulfils the driver's expectations. The plots of the mean and standard deviation of the indicated prices for the conventional navigation system and for the rerouting navigation system are shown in Figure 26. It seemed that the participants were willing to pay more for the rerouting navigation system compared to the conventional navigation system. Figure 27 shows the monthly costs for the services (updating maps and rerouting). It seemed that on average the desired monthly service costs are the same for both systems. However, the standard deviation seemed to be higher for the rerouting navigation service costs.

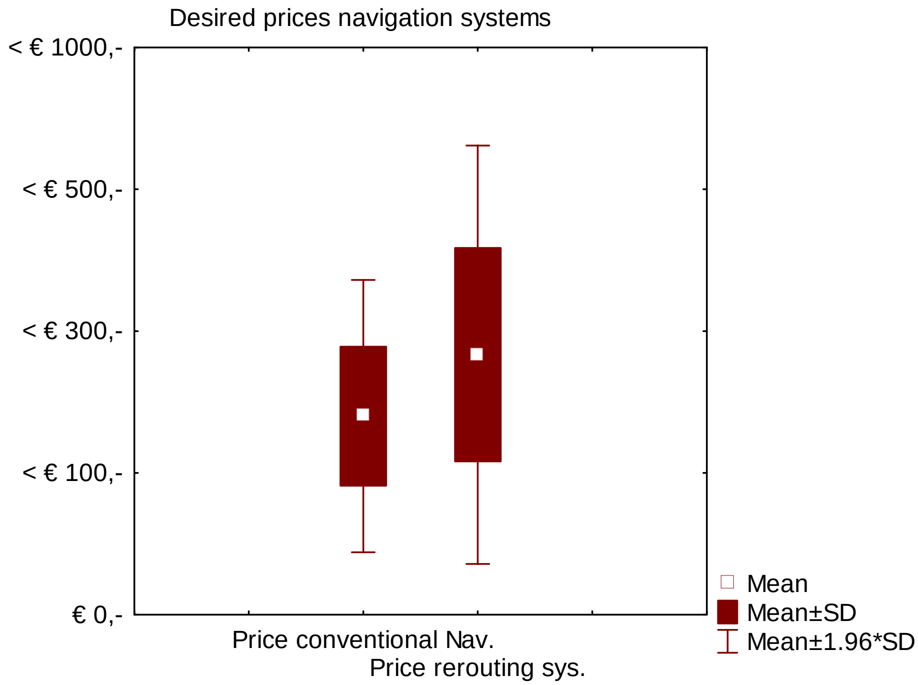


Figure 26 Desired price for navigation system

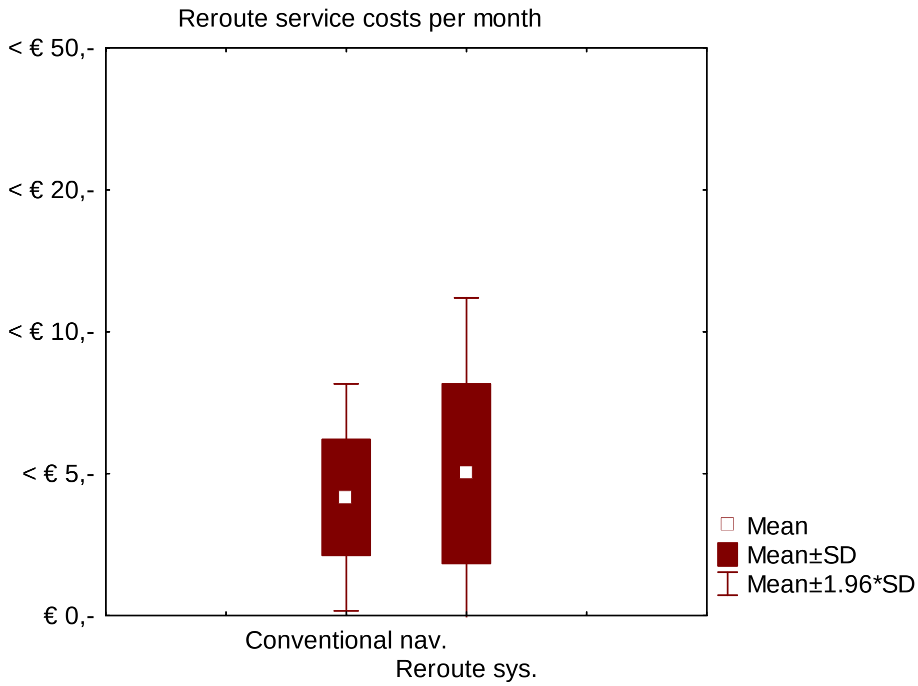


Figure 27 Desired monthly costs navigation system

5.3.2. Workload of Routing & Rerouting scenario

After the participants drove with a system they were asked to indicate the effort on the Rating Scale for Mental Effort (RSME). An example of this RSME is shown in the appendix (Zijlstra, 1993). This subjective workload measure for all four navigation conditions is shown in Figure 28.

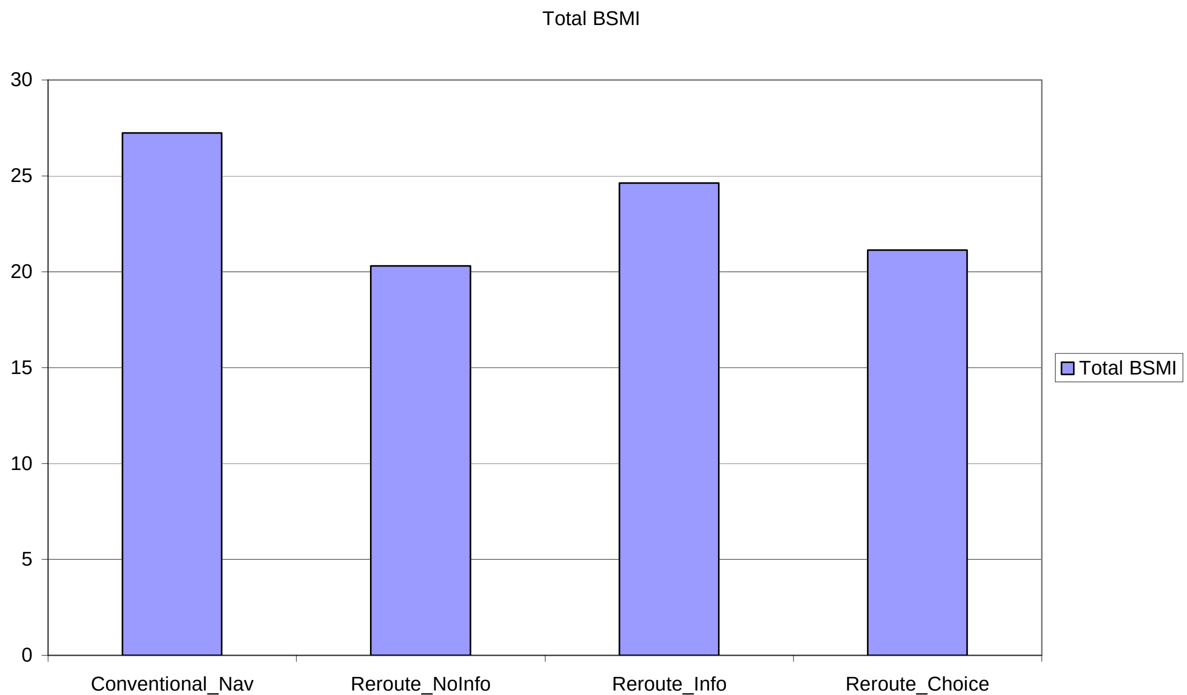


Figure 28 Subjective workload (RSME) rerouting systems

The repeated measures ANOVA showed that the subjective workload differed significantly for the four different navigation conditions [$F(3,45) = 5.31$, $p<0.01$].

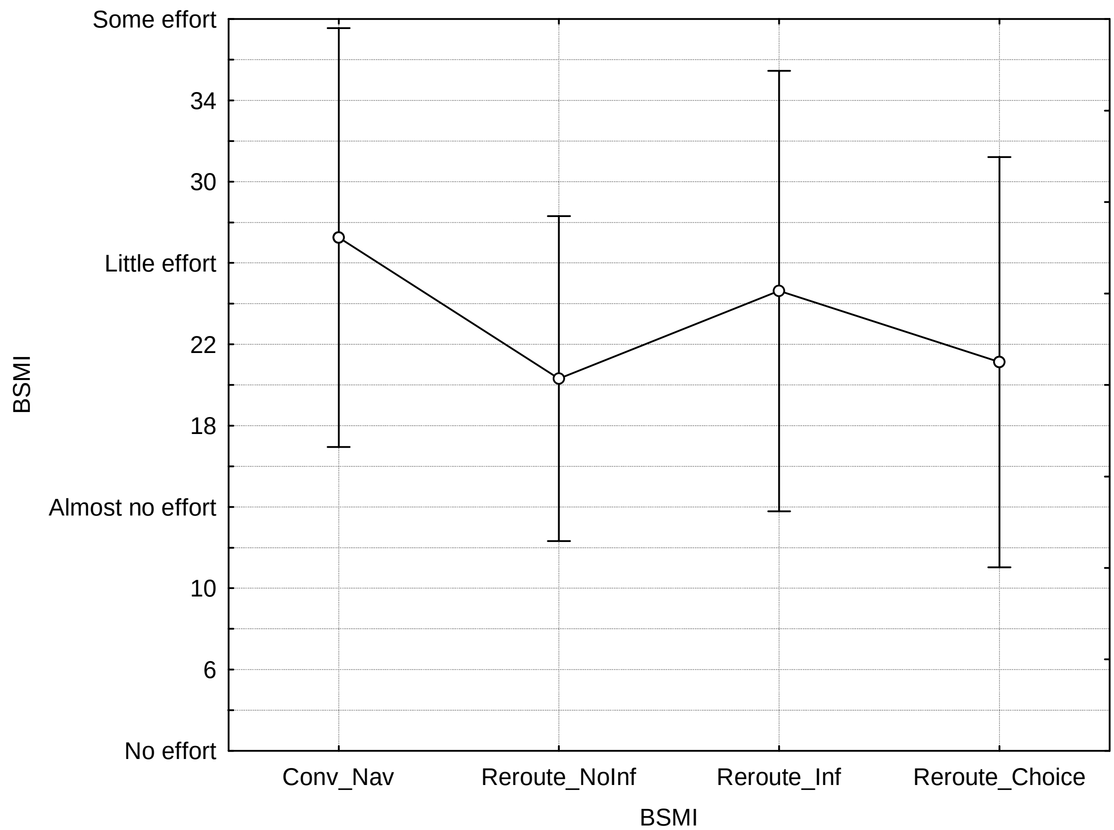


Figure 29 Average subjective workload (RSME) rerouting systems

The Bonferroni post-hoc test showed that subjective workload of the [Reroute_NoInfo] was significantly lower than the subjective workload of the [Conventional_Nav] [$p<0.01$]. Also the subjective workload of the [Reroute_Choice] was significantly lower than the subjective workload of the [Conventional_Nav] [$p<0.05$]. Although the subjective workload for the conventional navigation system seemed higher compared to two of the rerouting condition, the workload is still low. It should however be kept in mind that in the driven scenarios no other traffic was modeled that could increase the overall workload.

6. Infotainment experiment

The participants drove in four different conditions. One condition contained a message service that provided the driver his/her new incoming message as soon as it arrived [Message_at_once]. This means that the system did not take the current traffic situation and the current workload of the driver into account. Another condition contained a message service that only presented an icon when a new message arrived. The driver could choose whether he/she would like to hear it or not. If the driver touches the button on the touch-screen display, the driver hears the message [Message_at_touch]. A third condition that was driven by the participants contained a message service that presented the message only when the system decided that the situation is safe for the driver to take notice of the content of the message [Message_at_safespot]. The last condition contained a message service that only provided the message when the driver stopped the car [Message_at_stop]. This meant that the participant had to stand still on the side of the road and touch the button on the display to hear the message. In the driven scenarios there was no other traffic modeled. A top view of the route that was driven is shown in

Figure 30. The total distance was around the 5 kilometers. There was a navigation system that told the participant how to drive the route.

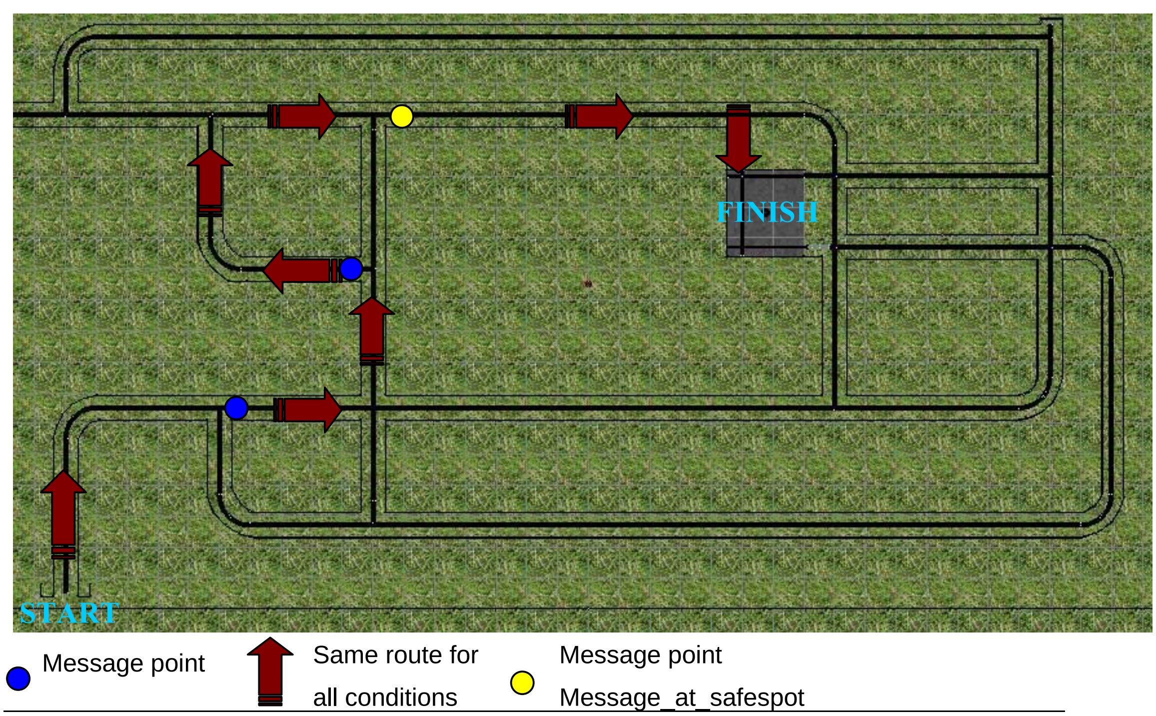


Figure 30 Top view of different rerouting conditions

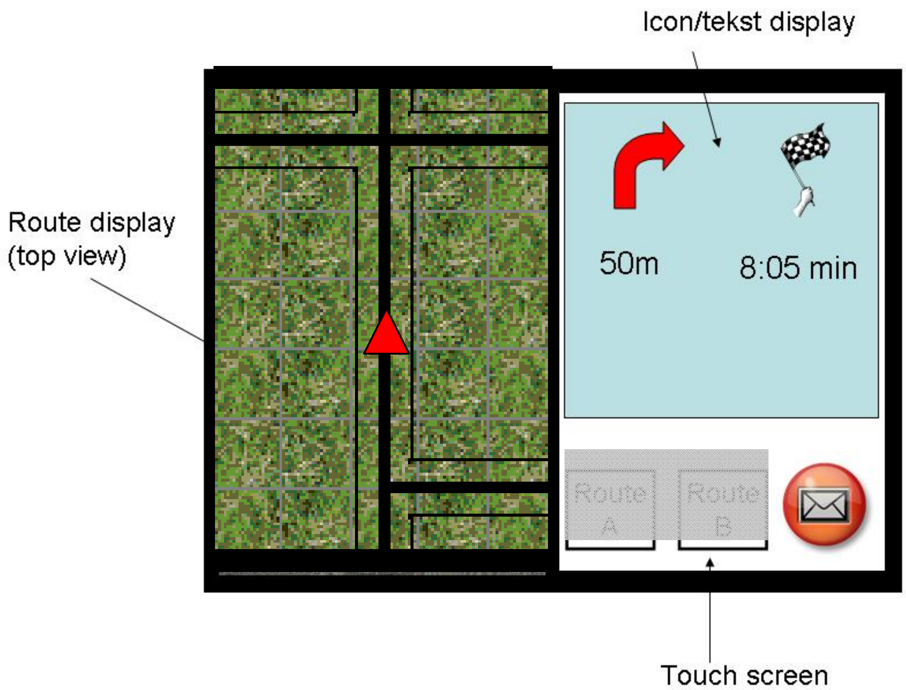


Figure 31 Schematic representation of the touch screen in-car display

6.1. Subjects

The same subjects participated in this experiment as the routing & rerouting experiment.

6.2. Independent variables and dependent measures

The independent variables in the analysis of variance are the four different systems:

1.) The message system that presented the message when it arrived [Message_at_once],

2.) the message system that presented the message when the participant pushed touched the message button on the touch screen [Message_at_touch],

3.) the message system that presented the message when the traffic situation was safe enough (according to the system) [Message_at_safespot] and

4.) the message system that presented the message when the participant pushed touched the message button on the touch screen, but only when the participant was not driving [Message_at_stop].

The dependent measures were acceptance measured by the Van der Laan scale items described in Table 1 and the comparison ratings for the four different systems before and after the participants experienced the systems. The dependent workload measures were the RSME ratings.

6.3. *Results of Infotainment scenario*

Before computing the scores of the variables (‘usefulness’ and ‘satisfying’) for user acceptance and before performing analyses of variance, reliability analyses had to be performed by using Cronbach’s alpha (Van der Laan et al, 1997). Table 11 shows the results (α value) of the reliability analyses.

Table 11 Results (α values) of the reliability analyses

Message - At once when received		Message - After touching display		Message - At safe spot		Message – After display touch at stop	
Usefulness	Satisfying	Usefulness	Satisfying	Usefulness	Satisfying	Usefulness	Satisfying
0.84	0.90	0.80	0.87	0.78	0.85	0.86	0.94

The determined reliability is sufficiently high ($\alpha > 0.65$) and therefore, the end-scores for each subject could be computed and analyses of variance could be performed.

6.3.1. Acceptance of Infotainment scenario

The acceptance of the four message systems was measured by questionnaires that contained questions with respect to the usefulness and the satisfaction of the system described by the Van der Laan. The participants were also asked to compare the four different message conditions and arrange the systems in a sequence in terms of best overall judgment. The system that was rated with 1 was considered to be the best system to have according to the participant and the least desired system was rated with 4. The four systems had to be rated before and after they had experienced the systems.

The participants were also asked if they understood the system, if they had a clear idea about the use of the system in the driving simulator and what they thought about the system design.

To get an idea of what the system should cost, the last six participants of the experiment were asked what they would pay for the CVIS infotainment system and what the monthly costs for the service should be.

Understanding of the different systems

For the [Message_at_once] system 15 participants indicated that comprehensibility of the system was good. 16 participants indicated that the driving simulator experiment provided a good understanding of the use of the system.

The comprehensibility of the [Message_at_touch] system was good according to 15 participants. All 16 participants had a clear picture about the use of the system in the driving simulator.

The comprehensibility of the [Message_at_safespot] system was good according to all 16 of the participants. All 16 participants replied that the driving simulator experiment provided a good understanding of the use of the system..

15 of the 16 participants indicated that the comprehensibility of the [Message_at_stop] system was good. All 16 participants also got a good picture about the use of the system in the driving simulator. One remark about the design of this system was that they liked the system, but they also wanted to be able to respond to the messages.

Utility of the system – Van der Laan Scale

The participants had to rate the following items for the system on the Van der Laan 5-point rating scale:

- Useful/Useless
- Bad/Good
- Effective/Superfluous
- Assisting/Worthless
- Raising alertness/Sleep-inducing

The average of the scores presented the usefulness of the system. The results for all participants for the four different message conditions is shown is Figure 33.

Repeated measures Analysis of Variance (ANOVA) was used to consider significant differences of the usefulness per condition. It turned out that there was no significant effect of the usefulness of the different systems. However, the average rating of the usefulness per condition was positive (~ +0.5) and thus considered useful.

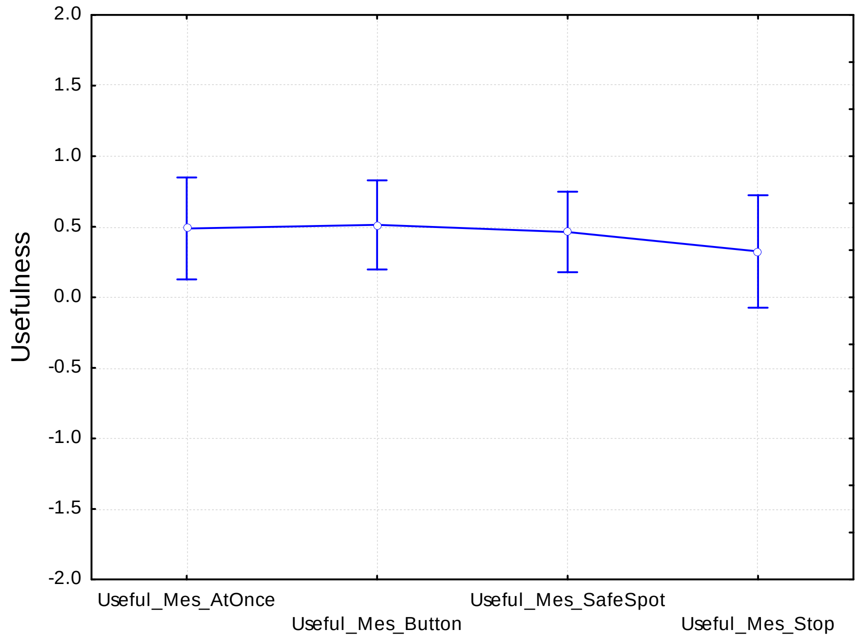


Figure 32 Usefulness of the different message systems

Satisfaction of the system – Van der Laan Scale

For the satisfaction of the systems the participants had to rate the following items for the system on the Van der Laan 5-point rating scale:

- Pleasant/Unpleasant
- Nice/Annoying
- Irritating/Likeable
- Undesirable/desirable

The results of the combined average scores for all participants for the four different message conditions are shown in Figure 33. Repeated measures Analysis of Variance (ANOVA) was used to consider significant differences of the satisfaction per condition. It turned out that the main effect of the satisfaction of the different systems was significant [$F(3,45) = 3.58$, $p<0.05$].

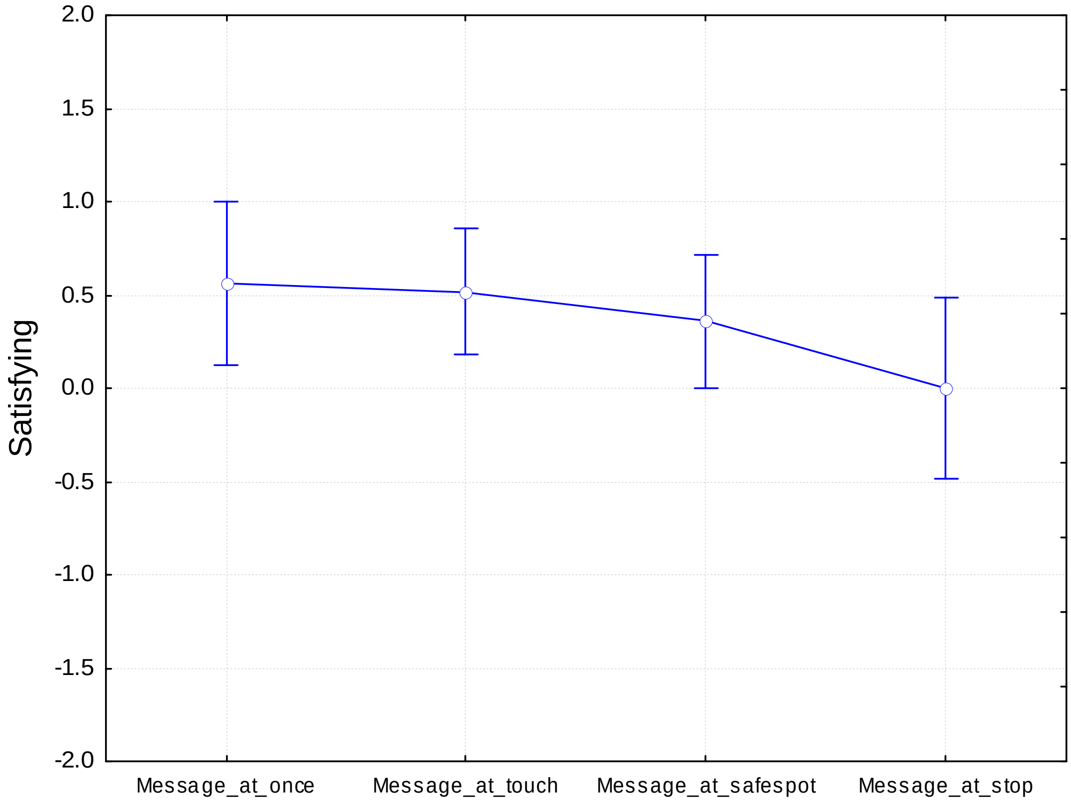


Figure 33 Satisfaction of the different message systems

The effect of the different systems was determined by the Bonferroni test. It seemed that the [Message_at_once] system was more satisfying than the [Message_at_stop] [$p<0.05$]. Also the satisfaction of the [Message_at_touch] system seemed to be higher than the [Message_at_stop] system. This effect was borderline significant [$p=0.058$].

The usefulness and satisfaction of the four CVIS message conditions are shown in Figure 34. It is shown that all conditions were on average rated positive for the usefulness as well as for the satisfaction. The best accepted systems seemed to be the message system that provided the message immediately after it arrived and the message system where the participant had to touch the display to hear the message. The least accepted message system was the system where the participant had to stop the car to listen to the message. The usefulness of this [Message_at_stop] condition was the same as the other three conditions, but the satisfaction was rated lower compared to the [Message_at_once] and the [Message_at_touch] conditions. No significant differences were found for the [Message_at_safespot] condition compared to the other three message conditions.

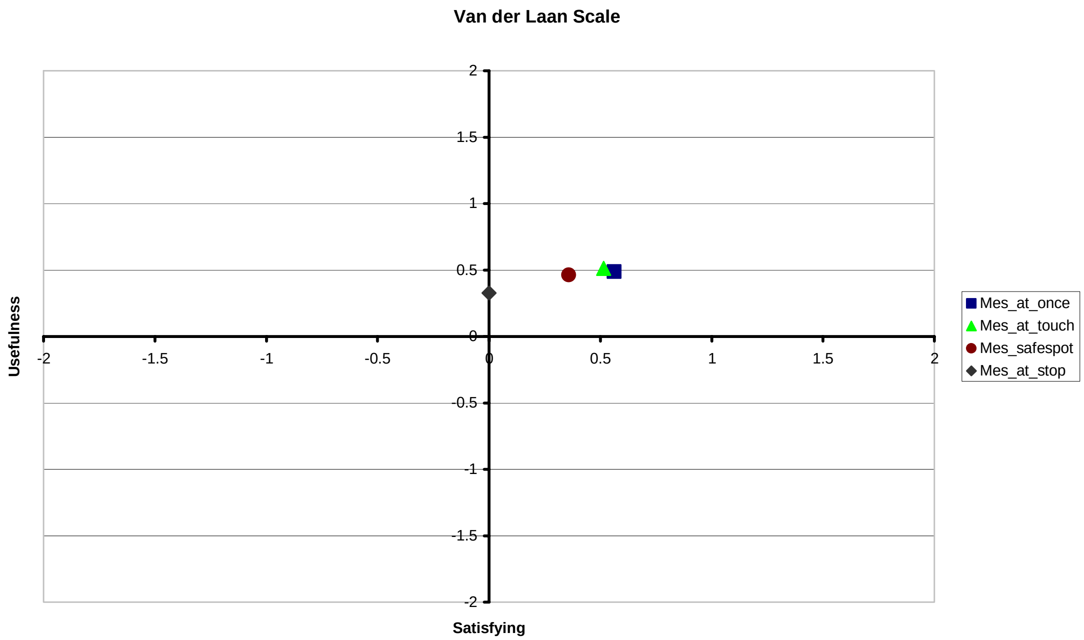


Figure 34 The usefulness and satisfaction of the four CVIS message conditions

Overall judgment

The participants were also asked to compare the different message conditions and order them on a scale of 1 to 4. This was done before and after they had experienced the message systems. The results are shown in Figure 35.

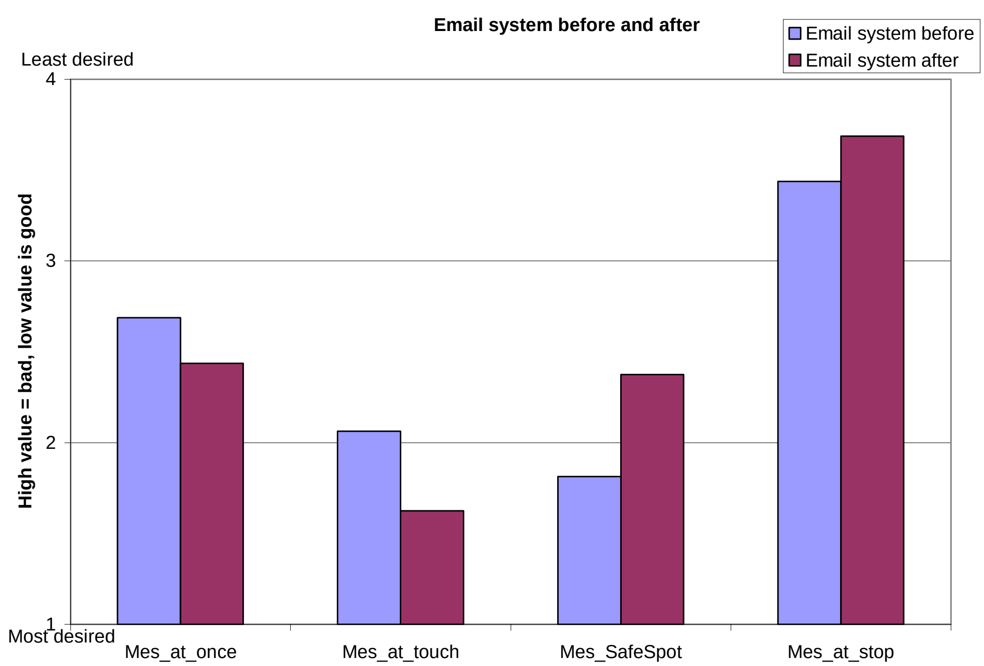


Figure 35 The overall judgment of the four message systems

The main effect for the different systems was highly significant [F(3,45) = 16,85, $p < 0.001$]. The means and standard deviations for the different message systems are shown in Figure 36.

According to a post-hoc Bonferroni test it seemed that the [Message_at_stop] condition was least desired compared to the [Message_at_once], [Message_at_touch] and [Message_at_safespot] conditions, respectively [$p<0.01$], [$p<0.001$] and [$p<0.001$]. There was no significant difference between the [Message_at_once] and [Message_at_touch] condition with respect to the [Message_at_safespot] condition. This implies that the acceptance of a system that automatically chooses a safe situation to provide messages seems also quite high. The difference between the [Message_at_once] and [Message_at_touch] condition was close to significant [$p < 0.06$]. This implies that the [Message_at_touch] condition was more desired than the [Message_at_once] condition

For the 2-way interaction of the different systems and the before and after ratings were no significant differences found.

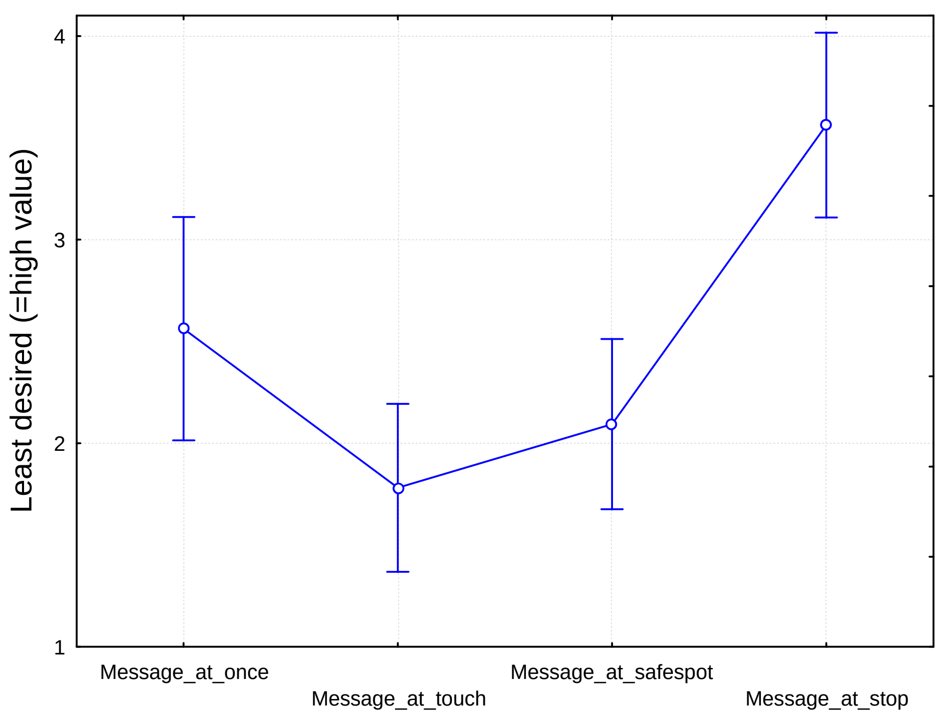


Figure 36 The average overall judgment of the four message systems

System price and monthly service costs

The last six participants of the experiment were also asked what price they were willing to pay for a message/infotainment system and what the monthly costs for the service should be, assumed that the message system worked properly and that it fulfilled their expectations. The plot of the mean and standard deviation of the indicated prices for a general message/infotainment system is shown in Figure 37.

It seemed that the six participants were willing to pay around the € 300,- for a message/infotainment system.

Figure 38 shows the monthly costs for the messaging services. It seemed that on average the monthly service costs were around the € 5,-. It should however be kept in mind that this is only the average of six participants.

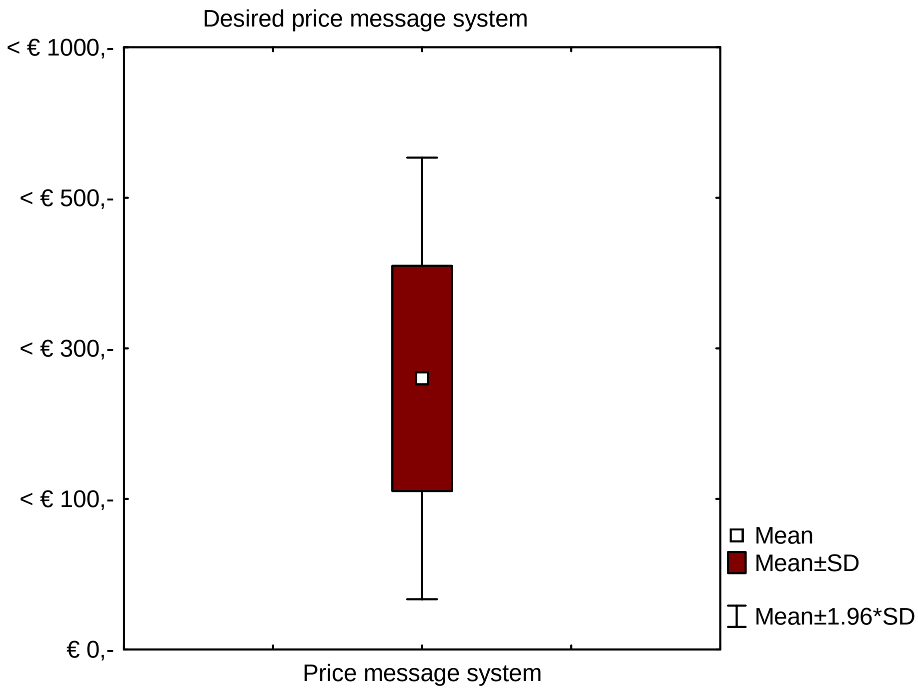


Figure 37 Price for the message system

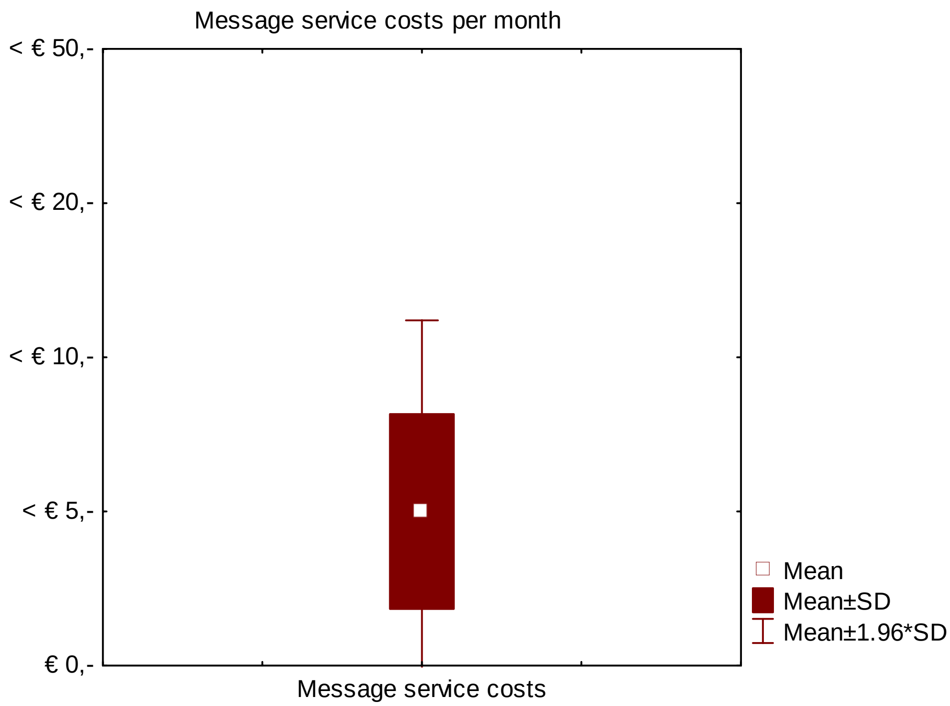


Figure 38 Monthly costs for message service

6.3.2. Workload of Infotainment scenario

After the participants drove a condition they were also asked to indicate the effort on the Rating Scale for Mental Effort (RSME) (Appendix A). This subjective workload measure for all four message conditions is shown in Figure 39.

To consider any significant differences for the four message conditions, an ANOVA was determined. According to the repeated measures ANOVA the subjective workload did not differ significantly for the four different message conditions. The average experienced effort was also quite low (little effort).

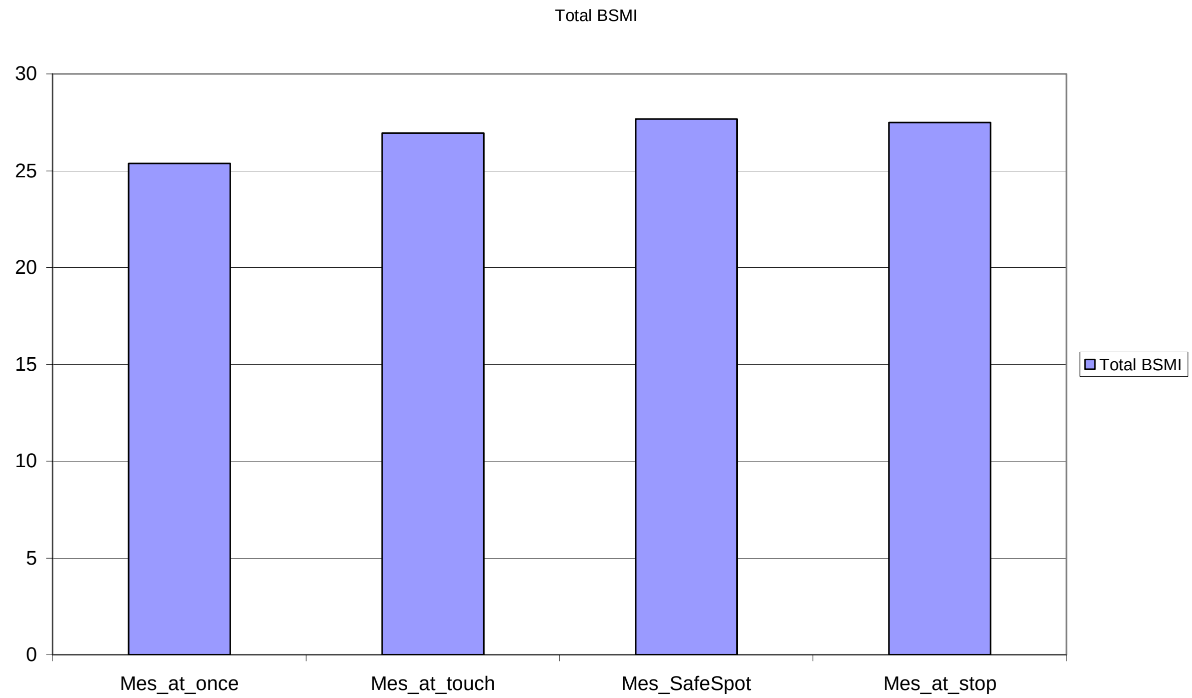


Figure 39 Subjective workload (RSME) for the four message systems

7. Conclusions and recommendations

In this study, the user acceptance for three different CVIS scenarios was examined. These scenarios summarise some of the important use cases that were defined for the CVIS applications: CURB, CINT, CF&F and COMO. The scenarios were speed advice for green wave via dynamic traffic signs and an in-car display, four different conditions for a routing & rerouting navigation system and four types of an infotainment system that provided messages to the driver. The green wave scenario provided speed advice to have a green wave at the traffic lights. In this experiment 50 subjects participated. The routing & rerouting scenario provided in three of the four conditions alternative routes to bypass the congestions/traffic jams. In this experiment 16 subjects participated. These subjects also participated in the infotainment experiment. In this scenario, the participants received messages that were read to them by the system.

7.1. User Acceptance

Green wave speed advice system

After experiencing both systems used for the green-wave speed support, both systems were found less useful and satisfying than the systems were expected to be. However, both systems still scored positive. The dynamic traffic signs were found more satisfying than the in-car display. The green-wave speed advice on in-car display was experienced as more personal than the ones shown on the dynamic traffic signs.

Routing & rerouting system

It was concluded that the participants found the rerouting navigation system where they had to choose an alternative route a more **useful** system compared to a conventional navigation system without a rerouting function. For all different navigation conditions it was found that the usefulness was rated positive.

The rerouting navigation system where the participants had to choose an alternative route was also considered as the more **satisfying** system compared to a conventional navigation system without a rerouting function. Again all different conditions were rated positive for the satisfaction of the system.

The participants were also asked to give their overall judgment about the systems, before they drove the systems and in the end after they had completed all the experiments. In order to provide an idea about the system's function before actually using them, the systems were shortly described. In this overall judgment beforehand it seemed that the participants considered the rerouting navigation system that automatically rerouted and provided the information to the driver as well as the rerouting system where the driver had to choose the alternative route as the best systems. However, the different ratings for the different systems did not seem to be significant. Although there was no significant difference between the ratings before the participants experienced the system and after they had experienced the systems, there seemed to be a difference in the outcome of the most desired system when the overall judgment is compared to the acceptance by the Van der Laan scale. In both cases the rerouting system where the driver has to choose the route showed good results. The usefulness and satisfaction of the system that rerouted automatically but did not provide information, seemed to be high too (not significant), however when the overall judgment was concerned for all four systems it was rated as least desired system (not significant). The opposite was found for the rerouting system that rerouted automatically and provided information. This could be caused by the fact that in the overall judgment the participants decide after reading the provided descriptions of the different systems that they prefer to be informed about a reroute instead of rerouted automatically without a notification. This could indicate that the acceptance of the different systems does not seem to be very predictive on forehand.

Six of the participants were asked to name a price for a rerouting navigation system and for the rerouting service. It seemed that on average the six participants were willing to pay €300,- for a general system that reroutes if a congestion occurs on the route. The standard deviation was around €150,- and the average costs fort the service was about €5,- (SD of around €2,-).

Infotainment system

The usefulness of the different message systems was not significantly different and was rated positive for all systems. The satisfaction of the system that provided the message at once when it arrived and of the system that provided the message when the participant touched the button on the display seemed to be higher than the satisfaction of the system that only provided a message if the participant stopped the car. The satisfaction for all systems was positive.

For the overall judgment, before and after the systems were experienced, it was concluded that the message system where the driver had to stop was the least desired compared with all other systems. The system that provided the message when the participant touched the button on the display seemed to be more desired than the system that provided the message at once when it arrived (borderline significant).

It seemed that the six participants were willing to pay around the €300,- for a message/infotainment system (SD around the €150,-). The monthly service costs were on average around the € 5,- (SD around the €3,-).

7.2. Workload

Green wave speed advice system

Speed support using the dynamic traffic signs resulted in a higher workload for the drivers compared to when no system was used. Following the advice on the dynamic traffic signs can be defined as a small secondary visual task. Compared to the baseline condition, using the in-car display did not result in a higher workload. The workload of the in-car display did not significantly differ from the workload of the dynamic traffic signs.

Routing & rerouting system

The subjective workload of the system that automatically rerouted and did not provide information and the system where the driver had to choose the alternative route was lower than the workload of the conventional navigation system. The average workload for all systems seemed to be low.

Infotainment system

The workload for all different message systems did not differ significantly.

7.3. Recommendations for combined CVIS scenarios

The participants were positive about speed advice for green wave. Considering the acceptance and the workload, the participants seemed to prefer the dynamic traffic signs instead of the in-car display for green wave, but the dynamic traffic signs also seemed to give a higher workload than driving without a speed advice. To consider which speed advice system is the best system further research seems to be needed.

For the rerouting system the system where the driver chooses the alternative route seemed to be most preferable, but also the system that rerouted automatically and did not provide information seemed to have a positive acceptance and low workload. The system that rerouted automatically and provided information was also well accepted. The least desired system was the conventional navigation system. For the combined CVIS scenarios it is recommended to ask the driver to choose an alternative route if the traffic situation is “simple”. In a “complex” traffic situation navigation information is not the main priority and it is not recommended to reroute. In that case the driver will get the opportunity to choose an alternative route if the traffic situation is “simple” again. Another option could be that the system could automatically choose the fastest route in a more complex situation. This condition where the system rerouted automatically without (or with) information was also accepted and showed low workload. This could however influence the driver behaviour in such way that the traffic safety will decrease, e.g. changing lanes at the last minute. To verify this further research is needed.

For the message system the system where the participant had to touch the display to hear the message seemed to be most preferable. Also the message at a safe spot seemed to be highly accepted. In a “complex” traffic situation, the messages could be stored and presented in a more “simple” traffic situation.

A schematic presentation of the previous recommendations is shown in Figure 40.

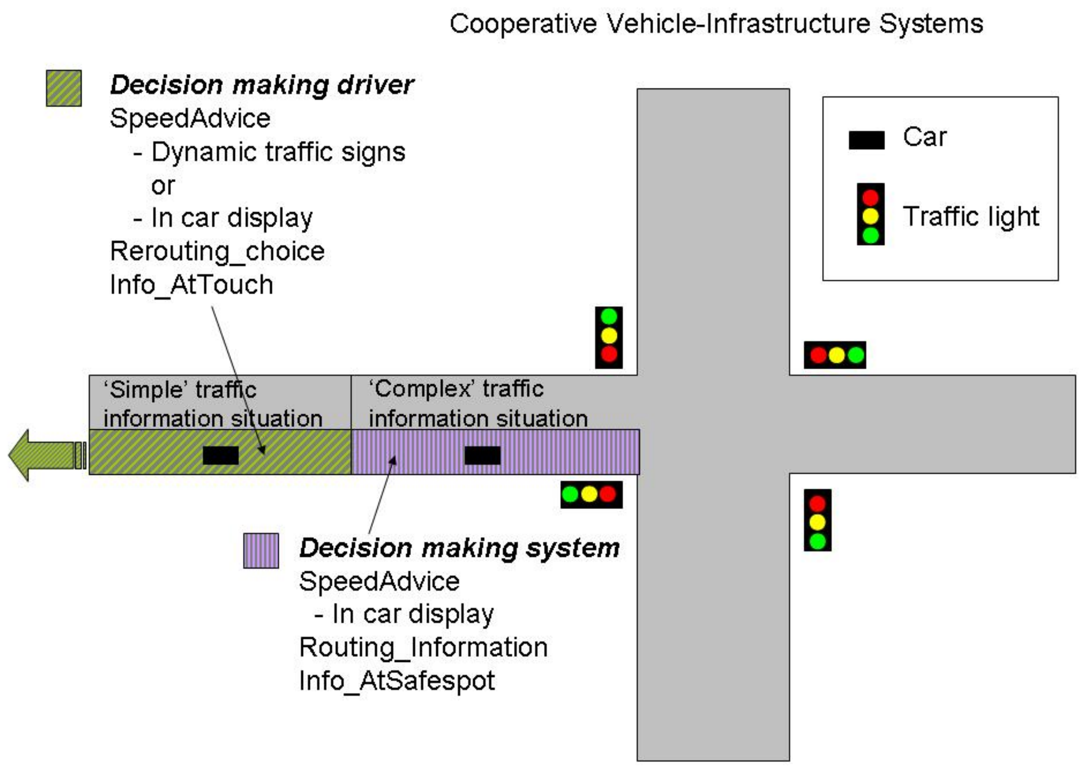


Figure 40 Schematic presentation of HMI for combined CVIS scenarios

Appendix A: References

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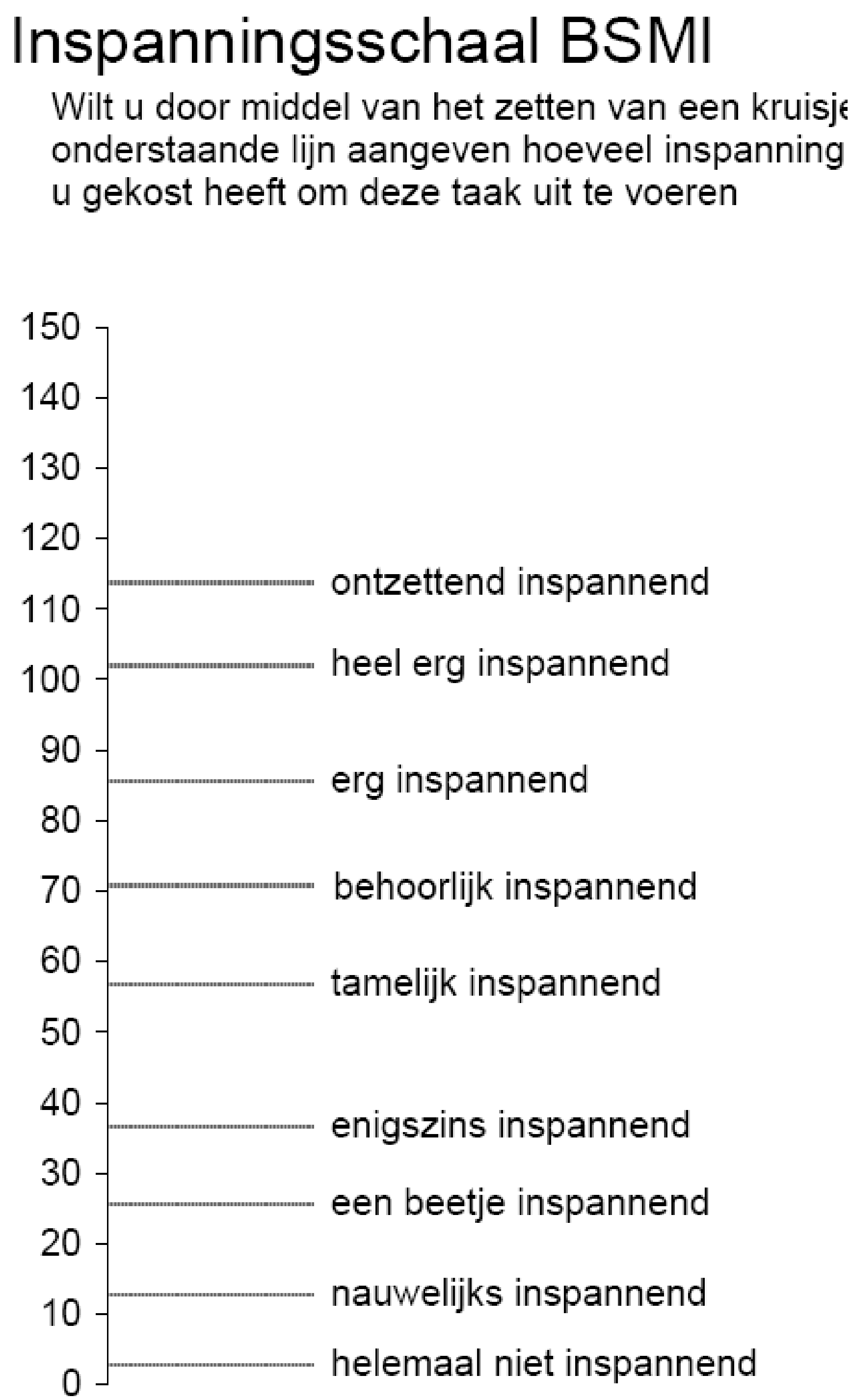
Appendix B: Questions



Tijdens de rit vond ik het systeem

Nuttig						Zinloos
Plezierig						Onplezierig
Slecht						Goed
Leuk						Vervelend
Effectief						Onnodig
Irritant						Aangenaam
Behulpzaam						Waardeloos
Ongewenst						Gewenst
Waakzaamheidverhogend						Slaapverwekkend

Questions per system (scenarios: Routing & rerouting, Infotainment)

Wat vond u van de begrijpelijkheid van het systeem?

O goed

O slecht

O anders, namelijk ……..

Eventueel uw toelichting

……………………………………………………………………………………………
……………………………………………………………………………………………
…………

Gaf het rijden in de rijsimulator u een goed beeld van het systeem?

O Ja

O Nee

O Anders, namelijk ……

Eventueel uw toelichting

……………………………………………………………………………………………
……………………………………………………………………………………………
…………

Wat is uw mening over het ontwerp van het systeem?

…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………
………………

Eenmalige vragen alle 4 de condities vooraf:

Welke van de systemen denkt u het prettigst te vinden?

Wilt u door middel van de cijfers 1 t/m 4 aangeven in welke rangorde u ze zou plaatsen (1= het prettigst, 4= het minst prettig)

… Standaard navigatie

… Navigatie met omleiding zonder toelichting

… Navigatie met omleiding met toelichting

… Navigatie waarbij omleiding alternatieven worden voorgelegd aan de bestuurder

Graag uw toelichting

…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………
………………

… E-mail voorlees systeem waarbij de e-mail direct wordt voorgelezen als de mail binnenkomt

… E-mail voorlees systeem waarbij de e-mail wordt voorgelezen als u aangeeft dat u de mail wilt horen

… E-mail voorlees systeem waarbij de e-mail wordt voorgelezen wanneer het systeem denkt dat de situatie daar veilig genoeg voor is

… E-mail voorlees systeem waarbij de e-mail wordt voorgelezen als u aangeeft dat u de mail wilt horen, maar waarbij de auto wel stil moet staan.

Graag uw toelichting

…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………
………………

Eenmalige vragen na alle 4 de condities:

U heeft zojuist met 4 verschillende navigatie systemen gereden.

Heeft u verschil gemerkt?

O Ja

O Nee

O Anders, namelijk ……

Eventueel uw toelichting

……………………………………………………………………………………………
……………………………………………………………………………………………
…………

Zo ja, welke van de systemen vond u het prettigst?

Wilt u door middel van de cijfers 1 t/m 4 aangeven in welke rangorde u ze zou plaatsen (1= het prettigst, 4= het minst prettig)

… Standaard navigatie

… Navigatie met omleiding zonder toelichting

… Navigatie met omleiding met toelichting

… Navigatie waarbij omleidings alternatieven worden voorgelegd aan de bestuurder

Graag uw toelichting

……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
………………

Eenmalige vragen na alle 4 de condities:

U heeft zojuist met 4 verschillende e-mail voorlees systemen gereden.

Heeft u verschil gemerkt?

O Ja

O Nee

O Anders, namelijk ……

Eventueel uw toelichting ………

Zo ja, welke van de systemen vond u het prettigst?

Wilt u door middel van de cijfers 1 t/m 4 aangeven in welke rangorde u ze zou plaatsen (1= het prettigst, 4= het minst prettig)

… E-mail voorlees systeem waarbij de e-mail direct wordt voorgelezen als de mail binnenkomt

… E-mail voorlees systeem waarbij de e-mail wordt voorgelezen als u aangeeft dat u de mail wilt horen

… E-mail voorlees systeem waarbij de e-mail wordt voorgelezen wanneer het systeem denkt dat de situatie daar veilig genoeg voor is

… E-mail voorlees systeem waarbij de e-mail wordt voorgelezen als u aangeeft dat u de mail wilt horen, maar waarbij de auto wel stil moet staan.

Graag uw toelichting

……

Welk bedrag zou u willen betalen voor dergelijke systemen waarmee u gereden heeft? Geef het bedrag aan doormiddel van het plaatsen van een kruis in het betreffende vakje.

Het systeem (de display in de auto)	€ 0,-	< € 100,-	< € 300,-	< € 500,-	< € 1000,-
Standaard navigatie					
Navigatie met omleiding als er op uw route een verkeersopstopping is					
E-mail voorlees systeem					
De service (bedrag per maand)	€ 0,-	<€ 5,-	<€ 10,-	<€ 20,-	<€ 50,-
Standaard navigatie					
Navigatie met omleiding als er op uw route een verkeersopstopping is					
E-mail voorlees systeem					

Wanneer zou u eventueel meer willen betalen voor het systeem en/of de service?

Navigatie systeem

………………………………………………………………………………………………
………………………………………………………………………………………………
………………………………………………………………………………………………
………………

E-mail systeem

………………………………………………………………………………………………
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………………