ACCEPTANCE OF TRAFFIC SIGN INFORMATION PROVIDED BY AN IN-VEHICLE TERMINAL

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SUMMARY

This study was designed to investigate driver acceptance of traffic sign information provided by an in-vehicle terminal (IVT). Specifically, four message conditions were compared in an on-road field study: (a) visual sign (b) visual sign and auditory message, (c) visual sign and auditory feedback based on driver behaviour and (d) visual sign and complete instruction provided for all subjects after the driver passed a test sign. The main results showed that the subjects accepted the integration of traffic sign information. For example, the subjects assessed that many aspects of the system were useful; they would like to include these aspects in the IVT if purchased; and the IVT information was reported to increase the effect of traffic signs and to improve traffic safety. The most preferred message condition was the visual sign. However, many subjects reported driving problems while using the IVT. The most frequently reported problems included unintentional speed decreases and late detection of another road user, vehicle or obstacle on the road. The main implication of this study is that integration of traffic sign information is a promising approach. Further research is needed to investigate the various effects of this kind of systems on driver behaviour.

INTRODUCTION

When developing new traffic information systems and traffic management systems, an issue to be solved is the integration of information provided by different systems (including several devices and services). It has been suggested, for example, that vehicles should be equipped with in-vehicle terminals (IVT) presenting traffic sign information (visually or audibly). It has also been envisaged that this sort of service could make traditional traffic signs redundant, although another option would be for traffic sign information to be shown in several ways (i.e. traditional signs and in-vehicle signs) each reinforcing the provision of information.

Our own opinions as to these options aside, clearly the introduction of advanced transport technology suggests the research on the effects of in-vehicle traffic sign information on driver behaviour. One concern over IVT has been the resulting increase of mental workload and consequent traffic safety problems. Several studies have shown that IVT information may distract drivers from performing primary tasks (1,2). This concerns both visual and auditory information.

Several aspects should be taken into account when designing optimal traffic sign information. First, only necessary information should be provided and other information

should be avoided. Second, a system should provide information only when needed. Third, a minimum requirement is the consistency of the information. In addition, it may be worthwhile using different information sources to complete and emphasise important information. Fourth, it is widely acknowledged that the current traffic system does not provide enough feedback, which leads to unsafe driving (3). Therefore appropriate feedback would be needed. Fifth, advanced technologies make it possible to monitor driver behaviour efficiently and to provide information based on the collected data. For example, the technology for measuring current speed has been available for a long time, and more advanced technologies enable the scanning movements of drivers' eyes to be measured. Linked to the need for feedback, these monitoring technologies could enable us to design systems that react to improper driver behaviour after passing the traffic sign. Specifically, many warning signs seek implicitly to boost the observation behaviour of other road users and to increase safety margins by decreasing the driving speed. In addition, regulatory speed limit signs explicitly inform drivers to use the driving speed adjusted to the current speed limit.

This study was designed to investigate driver acceptance of traffic sign information provided by an IVT. Specifically, four message conditions were compared in an on-road field study.

METHOD

TASKS

The primary task was to drive five times along a 10 km route normally, following the instructions given by the IVT. The secondary task was to observe the IVT information and assess the system after conducting the driving task.

MESSAGE CONDITIONS

Four message conditions presented by the IVT were evaluated: (a) visual sign (i.e. a pictogram of a warning sign or a legend of a speed limit sign of 40 km/h), (b) visual sign and auditory message (i.e. synthesised speech), (c) visual sign and auditory feedback based on driver behaviour (i.e. speed behaviour and/or glances indicating search for pedestrians/cyclists) and (d) visual sign and complete instruction provided for all subjects after the driver passed a test sign (e.g. a message "slow down and watch out for children").

SITE

The route consisted of suburban main roads in the Helsinki capital area. The posted speed limit ranged from 40 km/h to 50 km/h. Drivers drove a practice route of 10 km to familiarise themselves with the car.

EQUIPMENT

The instrumented vehicle used in the tests was a 1999 Toyota Corolla sedan with manual transmission. The vehicle was equipped with a PC-based hidden measuring

system and differential GPS receiver. Data collection frequency was 5 Hz. Measured variables in this study were time, distance, speed and position. The data were transmitted to the computer in the trunk.

The IVT shown in Figure 1 was located on the right side of the steering wheel such that the visual angle from the centre of the normal fixation site on the road ahead to the centre of the IVT was approximately 28° horizontally and 28° vertically. The eye-screen distance was approximately 85 cm for a driver about 180 cm tall. The width of the IVT was 190 mm and the height 150 mm. The dimensions of the display (TFT flat screen) were 130 mm and 95 mm, respectively. The controls (push buttons) were not used in this study.

The measuring system and traffic sign display application took care of both data acquisition and timing of traffic sign information. The application also provided navigation information. The timing of traffic sign information and navigation information were determined by the distance travelled from fixed points. The distance counter was set to a predefined value at fixed points when the experimenter pressed a button.

SUBJECTS

Totally, 20 paid subjects participated in the study. All the subjects were licensed drivers who volunteered for the study. However, the final data included 19 subjects because one (elderly male) subject was excluded due to technical problems resulting in insufficient data. Ten subjects were aged between 18 and 23 years (mean 20.2 years) and nine between 59 and 86 years (mean 68.3 years). There were five females and five or four males in each age group. In the following the number of subjects is 19 unless otherwise indicated.

The kilometrages during the last 12 months varied between 500 km to 30,000 km, the mean value being 9,315 km. The mean value was smallest for the young male group (3,200 km) and largest for the old male group (17,625 km). Five subjects were familiar with the test route before participating in the test; the majority were not.

DESIGN

There were 20 trials for each subject, including four trials each for every message condition. Three trials included a warning sign (children, bicyclists and children) and one included a speed limit sign of 40 km/h. The subjects did not know in advance that their behaviour would be measured, nor were they informed about the information types.

(a)

(b)

(c)

Figure 1. The information display showing (a) a symbolic children sign and speed limit sign, (b) a symbolic cyclists sign and speed limit sign and (c) a turn-arrow and speed limit sign.

PROCEDURE

The subjects participated in the experiment individually. They were told that this study looked at how drivers assess IVT information, as they had purchased such a system for their own vehicle.

The test route was driven five times. However, the first two runs included the same message conditions so that the subject got used to the route and route guidance system before any data collection. The characteristics of the message conditions are given in Table 1.

Table 1. Message conditions.

Sign	**Visual sign**	**Visual sign and auditory message**	**Visual sign and feedback**	**Visual sign and complete instruction**
Symbolic children sign	Visual sign "children"	Visual sign + auditory message "children"	Visual sign and, depending on driver behaviour, one of the auditory messages *)	Visual sign + auditory message "slow down and watch out for children"
Symbolic cyclists sign	Visual sign " cyclists "	Visual sign + auditory message "cyclists"	Visual sign and, depending on driver behaviour, one of the auditory messages *)	Visual sign i+ auditory message "slow down and watch out for cyclists"
Speed limit sign, 40 km/h	Visual speed limit sign	Visual sign + auditory message "speed limit"	Visual sign + auditory message "speeding" if speeding	Visual sign + auditory message "driving speed may not exceed 40 km/h"

*) "Slow down" if the subject did not search for pedestrians/bicyclists and the speed was less than 50 km/h or the speed decreased. "Watch out for children" if the speed was 50 km/h or more or the speed did not decrease and the subject searched for pedestrians/bicyclists. "Slow down and watch out for cyclists" if the speed was 50 km/h or more or the speed did not decrease and the subject did not search for pedestrians/bicyclists.

Each subject carried out the runs with different message conditions in the same order indicated in Table 1. It was assumed that this procedure (compared to the balanced design) would make it easier for subjects to compare the characteristics of the system in terms of the message conditions, as the runs created a continuum (4).

Messages were delivered automatically by the computer based on the distance driven. The appearance of a new message was announced by a sound signal (‘beep’). An experimenter sitting in the right rear seat of the test vehicle observed the driver and controlled messages concerning visual search during feedback conditions. The messages concerning speed behaviour (during the two latter conditions) were provided

automatically by the system. In addition, route guidance (i.e. arrows in the IVT preceding every turn), preceding auditory signals and posted speed limit were given throughout the route during each run. The experiment was conducted only in daytime between 08:30h and 16:00h without active precipitation.

After completing runs 2-5, the subjects answered questions concerning mental workload. The questionnaire was based on NASA-TLX with slight modifications. Seven workload factors were investigated on a nine-point scale: control of traffic situations, control of vehicle, time pressure because of simultaneously performed tasks, mental effort, mental demand, attention and concentration, frustration and feeling of safety. After completing the driving, the subjects shared their opinions about the use of the IVT and the messages provided by it. Finally, they were told that their driving behaviour had been recorded during the experiment, and their permission to use the data was requested.

RESULTS

The subjects assessed usefulness (or harmfulness) of the IVT according to a detailed list. The most useful aspects included route guidance, visual sign on the display and signal preceding the visual sign (Figure 2). The same aspects were the most popular when assessing the aspects to be included in an IVT if purchased (Figure 3).

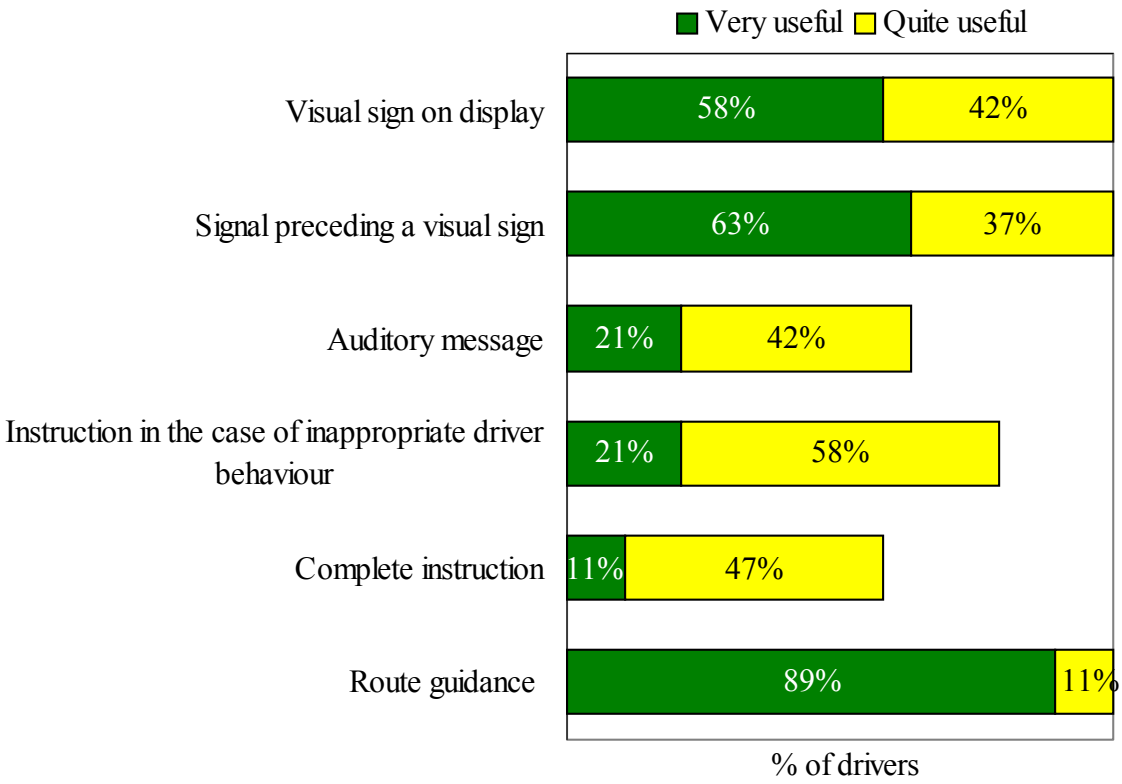

Figure 2. Percentage of drivers indicating the usefulness of given information. The four-point scale ranged from ‘very useful’ to ‘very harmful’.

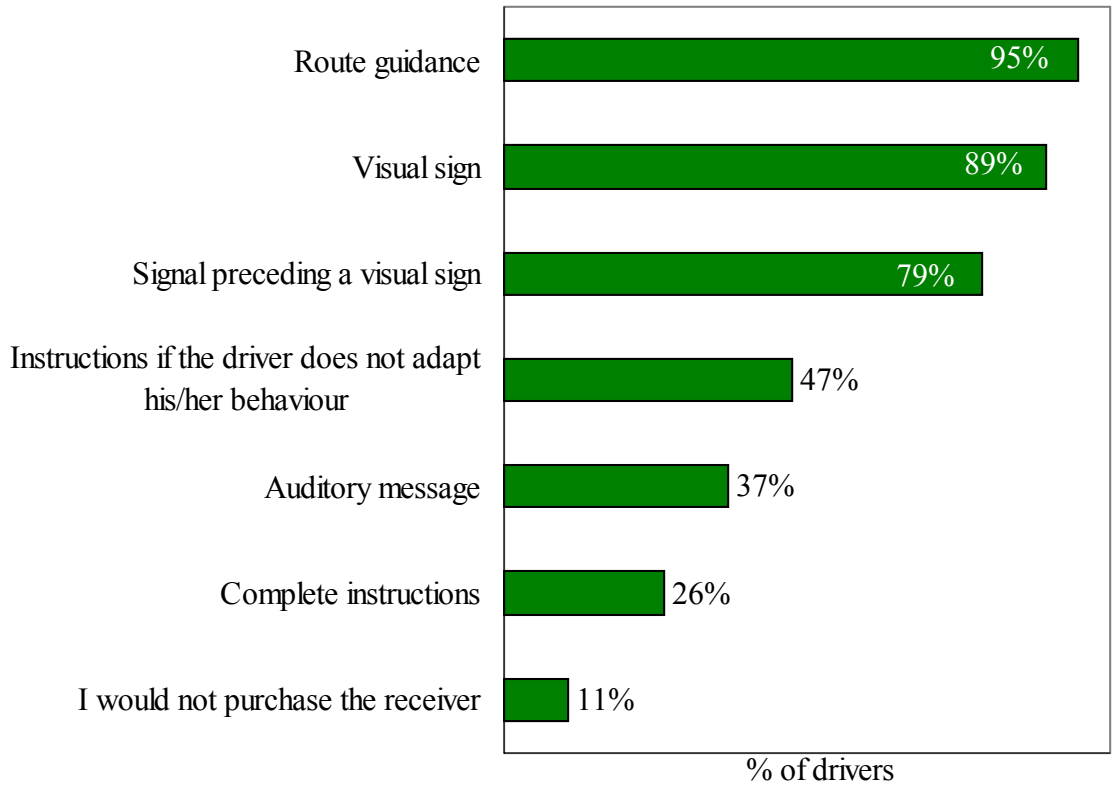

Figure 3. Desirable aspects included in the IVT if purchased.

The least desirable aspects included complete instruction when passing a sign. The auditory messages were considered quite harmful by seven subjects in visual and auditory condition, and by eight subjects in visual and complete condition. In visual and feedback conditions four subjects regarded auditory messages as quite harmful.

There were no age effects in assessments of usefulness except a tendency for older subjects to prefer complete instruction compared with young subjects. Specifically, none of the younger subjects (n = 10) liked to have complete instruction, and only two desired feedback information in the IVT they would purchase. The corresponding figures were five out of nine and seven out of nine for older drivers, respectively.

The females regarded complete instruction somewhat more frequently as quite harmful than men (six out of 10 vs. two out of nine). All male subjects liked to have a signal preceding a visual sign if they purchased an IVT, compared with only six out of 10 females. There were no other gender effects concerning the properties of the IVT.

Overall, the most preferred message condition was visual sign (six subjects), followed by feedback (five subjects), auditory message (four subjects) and complete instruction (two subjects). Two subjects indicated that they did not know.

The following aspects of the human machine interface (HMI) were assessed on a four-point scale from ‘very good’ to ‘very weak’: location of the IVT, ease of route guidance, legibility of traffic signs on the IVT, clarity of vocal messages and timing of

the message. Overall, the HMI assessments were quite favourable. All aspects were assessed to be 'very good' or 'good' except clarity of auditory messages (i.e. synthesised speech) and timing of message, which were assessed to be 'quite weak' by two subjects, and location of the IVT which was considered 'quite weak' by one subject.

The use of visual information provided by the IVT (including visual signs and route guidance) was assessed to be 'easy' or 'very easy' by all subjects, except for one who indicated that the traffic sign information was 'neither complicated nor easy'.

In general, subjects were quite satisfied with various aspects of the information provided by the IVT (Figure 4). Timeliness of information was the only property with which two subjects (out of 17) were 'quite unsatisfied'.

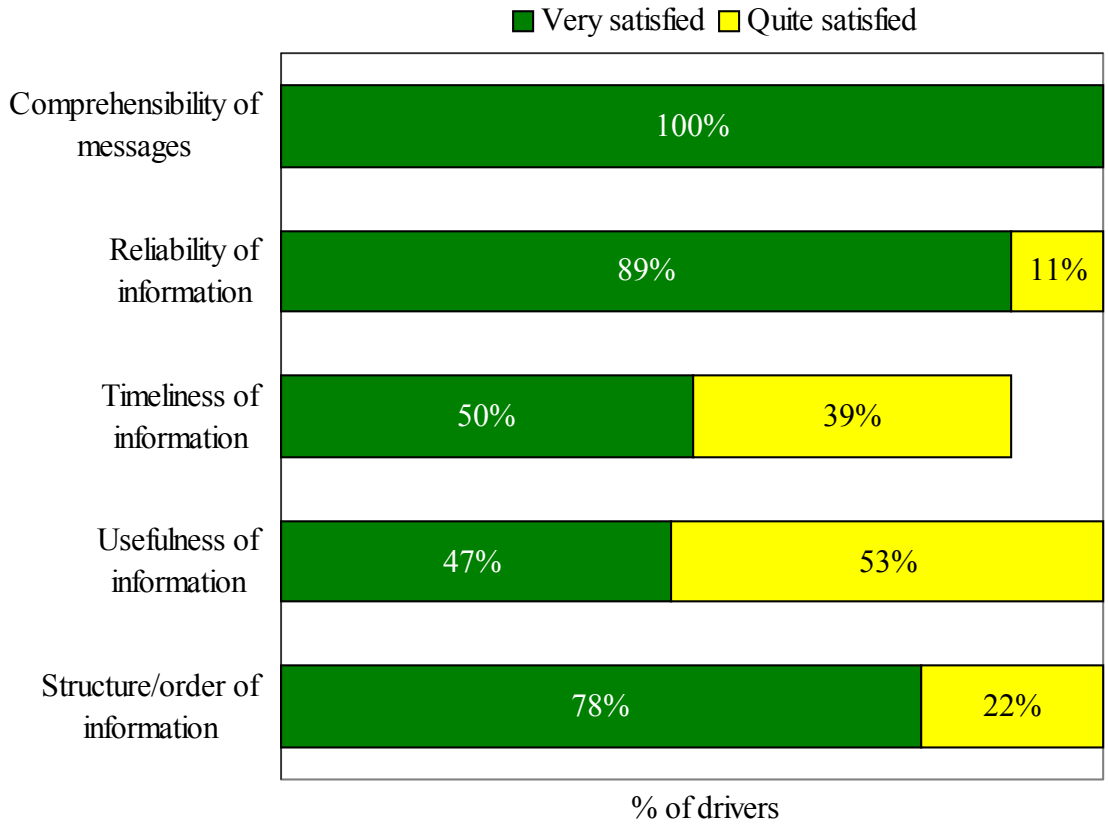

Figure 4. Satisfaction with the IVT assessed on a four-point scale from 'very satisfied' to 'very unsatisfied'.

Subjects also assessed the effects of sign information presented on the IVT compared with conventional traffic signs. Eighty-nine percent of the subjects reported that the IVT information increased the effect of traffic signs and improved traffic safety. In addition, 74% of the subjects indicated that driving comfort was improved as well.

Subjects assessed how much they would be willing to pay to purchase an IVT having the properties they defined as most desirable. The results showed that 14 subjects were willing to pay something. The indicated purchase price ranged from 34 euros to 504 euros, with a mean of 200 euros. Furthermore, older subjects were willing to pay less than younger subjects, and all five subjects who were not willing to pay anything were older subjects.

The results given in Figure 5 show that many subjects reported relatively frequent problems. The most frequently reported problems included unintentional speed decreases and late detection of another road user, vehicle or obstacle on the road.

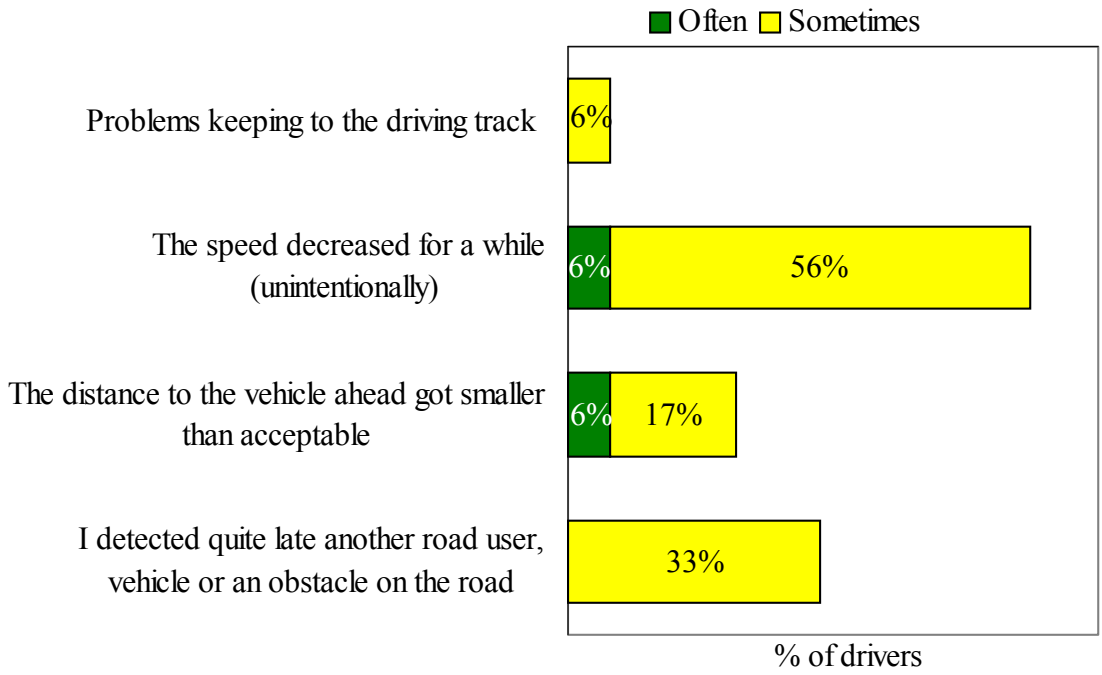

Figure 5. Percentage of drivers indicating problems while using IVT assessed on a three-point scale from 'often' to 'never'.

There were no age effects except a slight tendency for young subjects to report more often than the older ones that the distance to the vehicle ahead got smaller than was acceptable. All subjects who reported this problem were males. The female subjects reported more often than men that their driving speed had decreased unintentionally for a while (seven out of 10 vs. four out of 9).

A modified NASA-TLX based workload assessment was used. The data were collected after each run (four message conditions). Overall, the results did not show any considerable difference by message condition. However, frustration was somewhat high after the runs when feedback or complete instruction was presented.

DISCUSSION

This study was designed to investigate driver acceptance of the integration of traffic sign information provided by conventional traffic signs and an IVT. Specifically, four message conditions were compared in the field experiment carried out by an instrumented vehicle. The message conditions were (a) visual sign, (b) visual sign and auditory message, (c) visual sign and auditory feedback, and (d) visual sign and complete instruction.

The main results showed that the subjects accepted the integration of traffic sign information and the effects of gender and age were in general unremarkable. Specifically, the subjects assessed that many aspects of the system were useful; they would like to include these aspects in the IVT if purchased; and the IVT information was reported to increase the effect of traffic signs and to improve traffic safety. In addition, a vast majority of the subjects was willing to pay for purchasing the IVT that has the properties they defined as most desirable. One reason for many favourable assessments was probably the successful HMI of the IVT, which was also appreciated by the subjects. Overall, the most preferred message condition was the visual sign.

However, there were also a couple of less favourable assessments. First, the subjects did not favour auditory messages. This finding suggests that drivers prefer information but not in the way the instructions were given by the system. Second, many subjects reported driving problems while using the IVT. The magnitude of these problems was somewhat similar to that found in a study investigating the use of a RDS-TMC receiver while driving (5). The most frequently reported problems included unintentional speed decreases and late detection of another road user, vehicle or obstacle on the road. Given that the secondary task was relatively easy, including simple visual and auditory messages and no control tasks, this finding is striking.

The main implication of this study is that integration of traffic sign information is a promising approach. Drivers seem to appreciate many aspects of this sort of system and find that it has many advantages. However, they frequently reported problems with the use of the IVT while driving. Further research is therefore needed to investigate the various effects of this kind of systems on driver behaviour. For example, further research could investigate the optimal characteristics of the IVT with a larger driver sample and with a procedure allowing strong conclusions to be made concerning the efficiency of the system. Another broad issue is how drivers adapt their behaviour to this type of system in the long term. This could be examined with a longitudinal study involving a limited number of drivers who are willing to take part in data collection, including a black box installed in their vehicle which would record their driving behaviour.

ACKNOWLEDGEMENTS

Appreciation is extended to the Finnish Ministry of Transport and Communications and the Finnish National Road Administration (Finnra) for their support of this research. Financial support for the study was also received from the European Union DGVII through the TRAVELGUIDE (Traveller and traffic information systems: Guidelines for

the enhancement of integrated information provision services) project. However, the content of the paper is the sole responsibility of its publishers and it in no way represents the views of the EC.

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