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Impacts of a cooperative safety-related traffic information system

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Abstract

NordicWay has implemented a cooperative safety-related traffic information system based on hybrid communication using a mainly cellular network. In this paper, we present NordicWay's Finnish Coop project evaluation results on driver behaviour impacts and user acceptance of the system. The evaluation was based on a field test involving more than a thousand test users from May 2016 to April 2017. The results showed the high acceptance by the users. The system was the first source of information in many occasions and the implications it had on driver behaviour were positive (increased attention, speed reduction, less overtaking, etc.). As a main conclusion, the results indicate that a cooperative safety-related traffic information system in mobile phones has positive impacts on driver behaviour. The results also show that road users would be willing to use this kind of system. Almost all users who had longer experience with the system would have been willing to continue using the application.

Keywords: cooperative systems, impact assessment, safety-related traffic information, driver behaviour, user acceptance

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Nomenclature

CEF	Connecting Europe Facility
C-ITS	Cooperative intelligent transport system

1. Introduction

1.1. Background and purpose of the paper

NordicWay is a CEF (Connecting Europe Facility) corridor from Finland to Sweden, Denmark and Norway. A pilot on cooperative ITS (C-ITS) services was conducted along the corridor, where these services were deployed using hybrid communication on a mainly cellular network. In the Finnish part of the corridor, road safety-related minimum universal traffic information services (Commission Delegated Regulation EU No 886/2013) were provided to road users with the 'HERE DTI' mobile phone application as follows: Warnings of

- obstacle on the road
- unprotected accident area
- temporary slippery road
- reduced visibility
- exceptional weather conditions
- short-term roadworks.

Both the traffic management centre and the road users could receive warnings. The traffic management centre could send all the warning types, but road users could only send warnings of obstacles on the road, reduced visibility and slipperiness.

The benefits of the system were assessed in an evaluation study. The purpose of the project was to assess the technical feasibility of the system and the information it provides as part of a cooperative traffic information system, its readiness for wide-scale implementation, and its commercial potential and ecosystem model. Another purpose is to gain knowledge on cooperative services as a channel for providing safety-related information, and on their impacts on driver behaviour and traffic management. Specifically, the aim of the corridor project was to assess how the warnings affect driver behaviour, user acceptance of this kind of system (i.e. provision of road safety-critical information via mobile phone app), and how effective the system is from a traffic management point of view. A socio-economic assessment was made to complete the evaluation.

In this paper, we present the results related to driver behaviour and user acceptance. More detailed results including the outcomes of the safety, efficiency and socio-economic assessment and the assessment of the effectiveness for traffic management are available in the Evaluation Outcome Report by Innamaa et al. (2017).

1.2. Short literature review

DRIVE C2X project assessed in Field Operational Tests the impact of eight Day-1 cooperative systems which were primarily focused on improving road safety. These systems included weather warning, roadworks warning, obstacle warning and car breakdown warning. When warned of obstacle, roadworks or car breakdown, drivers showed an improved hazard awareness by slowing down close to the roadwork site or broken car, conducted fewer sudden manoeuvres, and became more alert aborting non-driving related secondary tasks. The field test results did not demonstrate a clear effect on speed for weather warning. The conclusion was that drivers only followed the warning by reducing speed, if they perceived the warning as reliable and relevant, i.e. if they found indications for risky conditions which matched the warning received. Instead, the results suggested that drivers did not follow the warning if vehicle speed was at a reasonable level and weather situation is not severe. (Malone et al., 2014)

The C-ITS Platform assessed the socio-economic impacts of Day-1 and Day 1.5 cooperative services for Europe. In their scenario A where the deployment of all safety based V2V services start on all roads and traffic information & smart routing is deployed on TEN-T corridors and core roads first and initially for passenger cars only. The safety-based services included hazardous location notification, roadworks warning and weather conditions warning on motorways (in addition to other services). The socio-economic effectiveness was assessed for different scenarios for period 2015–2030. According to that annual cost-benefit ratio for this scenario A would increase up to 2.7 by 2030 for the Europe. (C-ITS Platform 2016)

2. Method

2.1. Field test

The cooperative safety-related traffic information system was tested along the Finnish part of the NordicWay corridor: Road E18 from Helsinki to Turku, including Ring Road I and Ring Road III in the Helsinki Region. To ensure a larger number of recorded events, the service was made available also on Road 3 between Helsinki and Tampere, Road 4 between Helsinki and Lahti, and the Tampere Ring Road and Coastal Road of Tampere.

The field test lasted from May 2016 to April 2017. During that period, a total of 1009 test users successfully completed the registration procedure and downloaded the app (HERE DTI). No specific incentives were given. 83% of the test users were men, 8% women and 9% did not wish to reveal their gender. 15% of the test users were professional and 85% non-professional drivers. The most typical range of annual kilometres driven was 20 000 – 50 000 (42% of test users) and the most common vehicle type a passenger car (84%).

The field tests were conducted along the principles of a naturalistic driving study, i.e. the driving of test users was logged as part of their everyday life, and the hazard warnings they received were real; thus, no controlled driving tests or fake warnings were used.

2.2. Data

The study design was such that the impacts on driver behaviour were assessed from logged GPS data, supported by questionnaires (subjective data). Anonymised GPS tracks data of other HERE customers formed the baseline for GPS data analysis of driver behaviour impacts. Questionnaires also covered user acceptance and use of the system.

Specifically, the logged data on mobile phones included mainly messages shown by the HERE DTI app, timestamps for communicated messages, and the GPS log, obtained while driving on the test roads. To support driver behaviour analysis, HERE provided anonymised baseline data logged by their customers while using HERE’s navigation apps in the area where warnings had been sent or received. Naturally, the potential use of other traffic services among the baseline drivers could not be known.

First, log data was collected onto a server by HERE. The dataset was then made available to VTT for analysis. VTT imported the data into a PostgreSQL database, where information from several sources was combined. In addition to data queries, numerous indicators were calculated from the database with VTT’s LogPro toolkit, developed over a period of 10 years to analyse data from field tests.

2.3. Impact assessment methods

The nature of the deployed functions is to warn drivers of rare, hazardous situations, which seldom occur. Hence, any warning-related locations make up only a small part of an entire journey. Even roadworks, which last longer, only account for a small fraction. Therefore, the impact of the support system on driving was assessed by comparing driving behaviour near a hazardous location, at the same time, between drivers who received a warning and those who did not. This is called event-based analysis.

Log data analysis was supplemented with user questionnaires. The First Impression Questionnaire was sent roughly once a month to participants who had received their first warning(s). Personalised links were sent by email to the survey with the Questback Essentials online tool. In total, 177 invitations to the questionnaire were sent and 93 responses were received between September 2016 and March 2017. The survey included questions relating to a specific event when a warning was received, such as the news value (novelty of information) and quality (location accuracy and object of warning) of the information provided, and self-assessment of the driver’s reaction to the warning (speed, overtaking, gap, attention, secondary tasking, comfort).

To assess the overall acceptance of the service and the longer-term impression of its impacts, a Final Questionnaire was sent out to all participants in May 2017. There were two different versions: one for the most experienced ones w.r.t. application use (use of the software for at least 2 months, at least four received warnings; 104 persons in total) and another for those with less experience in using the application (1 166 persons). In total, 56 responses were received from the most experienced users and 200 from the others.

3. Results

3.1. Benefits as source of information

In the Final Questionnaire, experienced users were asked about the novelty of the information provided during the pilot. For obstacles on the road (80%, N = 15) and accidents (46%, N = 39), HERE DTI was 'always or in most cases' the first source of information. For poor visibility, it was 'always or in most cases' the first source of information for 33% (N = 9) of drivers, and 'never' for another 33%. For roadworks, the responses varied substantially (N = 33).

In the First Impression Questionnaire, 88% of drivers who had an additional source of information (N = 32) found the information in the warning from the test app to be consistent with that from the other source. For 56% (N = 27), the warning from the test app did not provide additional information compared to the other source. However, 30% of respondents felt that the location information from the test app was more accurate, and 15% stated that the test app correctly identified the hazard type.

3.2. Driver behaviour impacts

Experienced users were asked in the Final Questionnaire to assess the impacts that the warnings and information provided had on their driving behaviour by warning type (Fig. 1). All the warning types were considered to affect speed choice for at least 30% of the users. Another common reaction was that the warnings/information had an impact on the focus of attention in traffic (at least 39% of users). An alternative route was often considered when there was an obstacle on the road, an accident or roadworks (at least 40% of users). Distance to the vehicle ahead was affected most by a poor visibility warning (44% of users). Overtaking behaviour was affected most (33% of users) for obstacles on the road and accidents. An impact on driving comfort was reported by a few users only (at most 11%). Warnings of poor visibility had no impact on driving behaviour for 33% of users, roadworks warnings for 15%, and accident warnings for 11%.

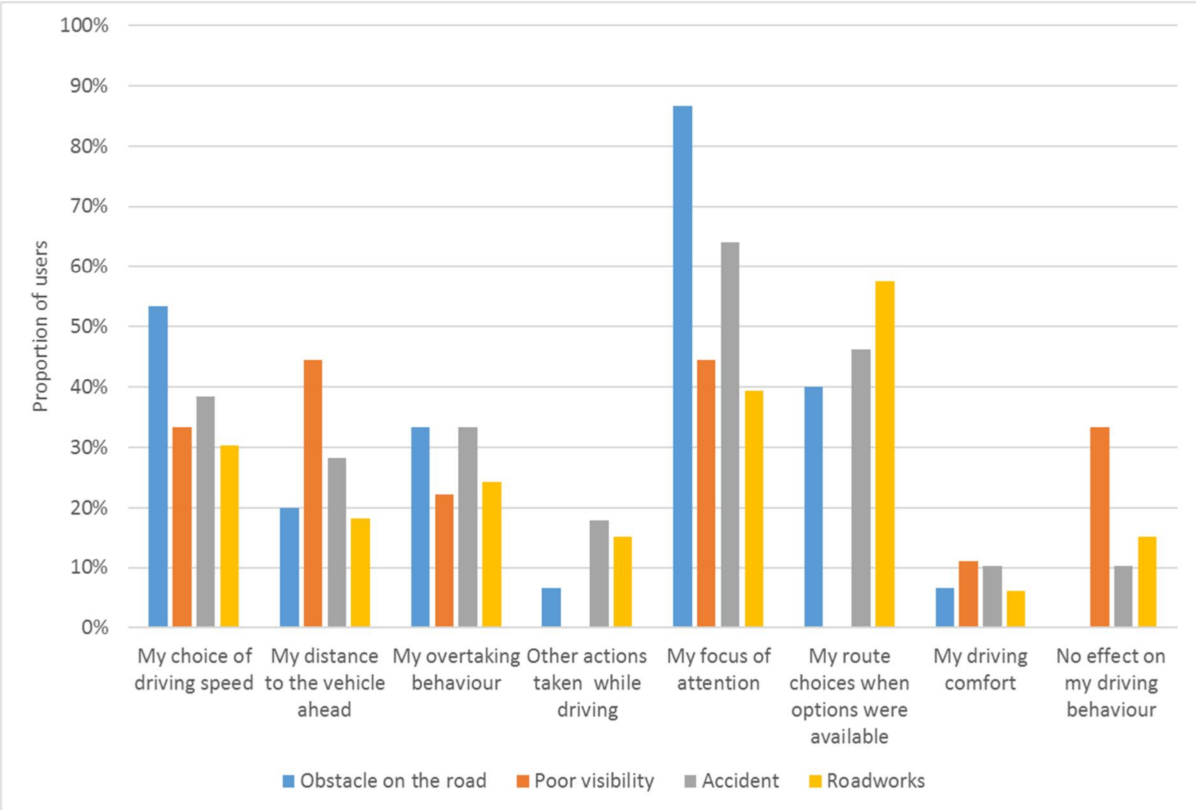

Fig. 1 Impacts on driving behaviour, Final Questionnaire, experienced users; multiple choice allowed, question answered to all warning types experiences; N = 15 for warnings on obstacle on the road, N = 9 for poor visibility, N = 39 for accidents and N = 33 for roadworks

The impact on speed patterns was studied using average spot speeds in the vicinity (±1200 metres) of a warned incident among drivers who received the warning (not initiated by the driver). Events were filtered out from the analysis if they did not have full spot-speed series for the area, or if the closest logged GPS was more than 50 metres from the location of a warned incident.

As an example of results specific to warning type, the impacts of accident warnings are presented below. The spot-speed pattern following an accident warning is shown in Fig. 2. On average, the warning was given 2 048 metres before the location of the incident. There was a statistically significant (p = 0.044) decrease of 1.9 km/h in the average speed between spots 250 and 200 metres before the incident location.

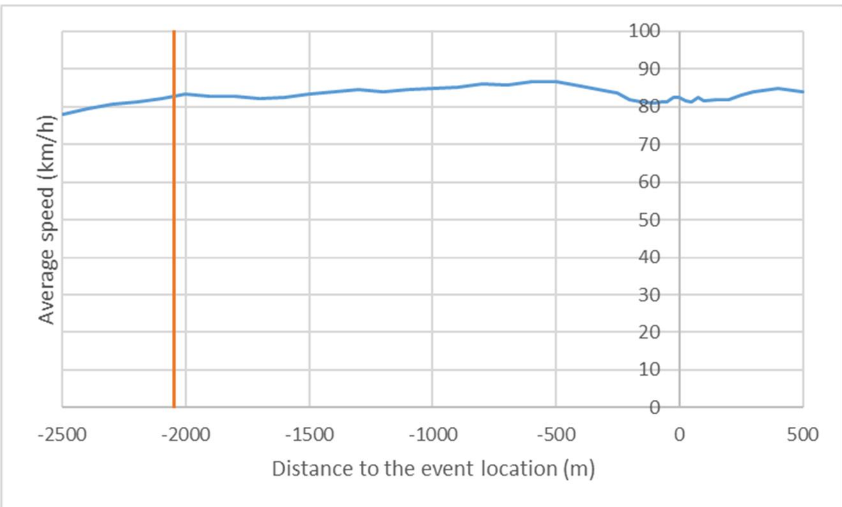

Fig. 2 Average spot speeds (blue line, N = 19) of drivers given an accident warning, and average distance to the location of the incident when the warning was received (red line)

A comparison of the speed pattern was made with baseline data to see whether the reaction of warned drivers came earlier than for others. Here the time-wise closest observation in the same location in the baseline data was used as comparison. The number of samples with good quality baseline observation(s), i.e. with a full speed pattern, was small (N = 5). If the speed patterns were scaled to start from the same level, the speed reduction was seen to be stronger for warned drivers than their baseline (Fig. 3).

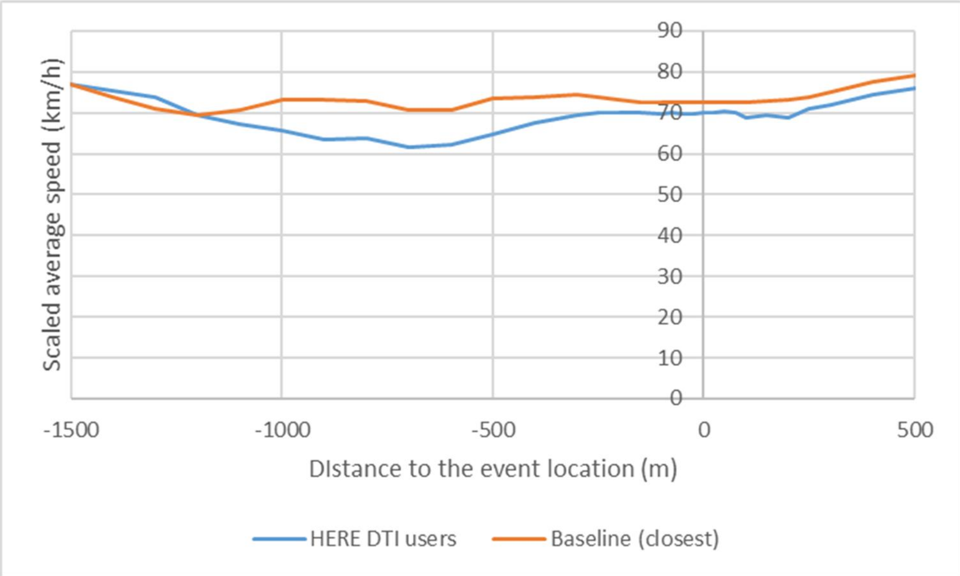

Fig. 3 Average spot speeds (N = 5 for both) of warned and baseline drivers (closest match) scaled to start from the same level, accident warning

In the Final Questionnaire, of those who considered accident warnings to have affected their speed choice (38%, N = 39), 75% (N = 12) stated that they started driving below the speed limit, and 8% (N = 12) that they had stopped speeding. One user reported having kept to the traffic flow and having slowed down when approaching the incident site.

Of those who considered accident warnings to have affected their distance to the vehicle ahead (28%, N = 39), 75% (N = 8) reported having kept a slightly greater distance and 25% (N = 8) a far greater distance than usual. Naturally, the speed reactions affect the distance to the vehicle ahead, thus, these impacts are linked the the impact above although only part of the users reported both impacts.

Of those who considered accident warnings to have affected their overtaking behaviour (33%, N = 39), 80% (N = 10) had avoided overtaking, 20% (N = 10) had overtaken more seldom, and 10% (N = 10) had been more careful when overtaking (respondents could select multiple options).

Of those who considered accident warnings to have affected other actions while driving, such as using the radio, mobile phone, or other device (18%), 50% (N = 6) said they had avoided these actions, 50% followed the app more carefully, and 33% switched the radio on, raised the volume or sought another channel for more information.

Of those who considered accident warnings to have shifted their focus of attention (64%), everyone (N = 14) said they had observed the traffic ahead more closely; 64% had focused more on traffic conditions; 36% said they had paid equal attention to the vehicle ahead and traffic behind; and 7% said they had focused more on controlling their vehicle.

In the Final Questionnaire, experienced users were asked about any driving errors they had noticed from using the app. Most (77%, Fig. 4) had not noticed any. The most common errors reported were accidentally lowering the driving speed (16%) or a delay in noticing another road user or obstacle (7%).

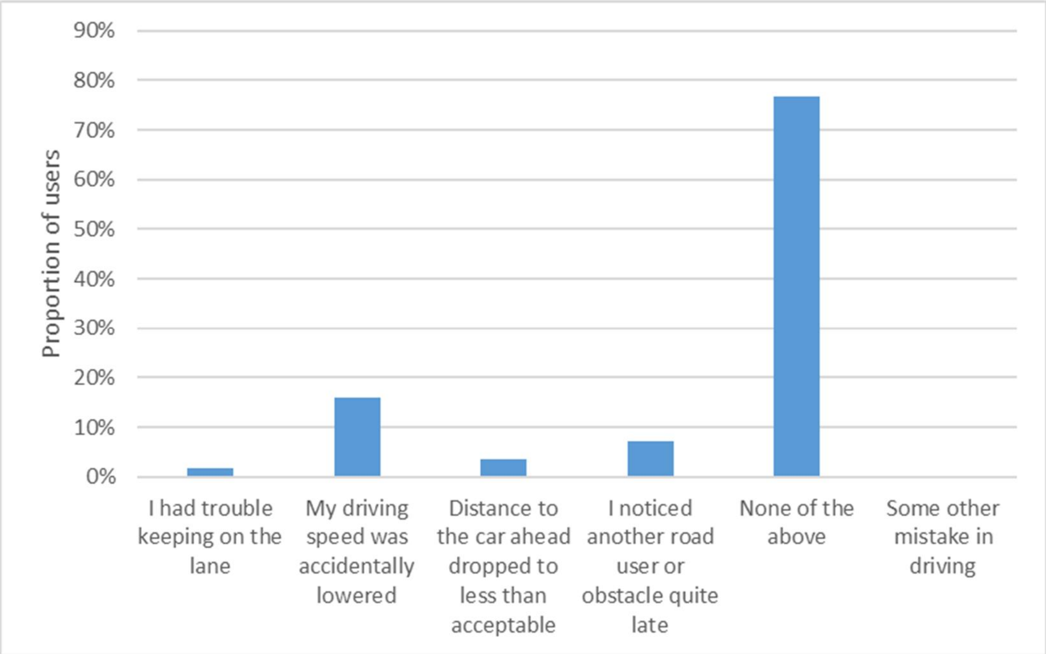

Fig. 4 Driving errors from using the test app, Final Questionnaire, experienced users (N = 56)

3.3. User acceptance

In the First Impression Questionnaire, most users found the test app useful. The commonest reasons were that it provides a means of warning other drivers of hazards on the road (83%, Fig. 5Fig. 5 Overall usefulness of the test app; several alternatives could be selected, First Impression Questionnaire, N = 93

) and that it improves traffic safety (60%) and fluency (49%). Dissatisfaction pertained mostly to the limited functionalities of the prototype app or to the small penetration of users in traffic (and therefore events).

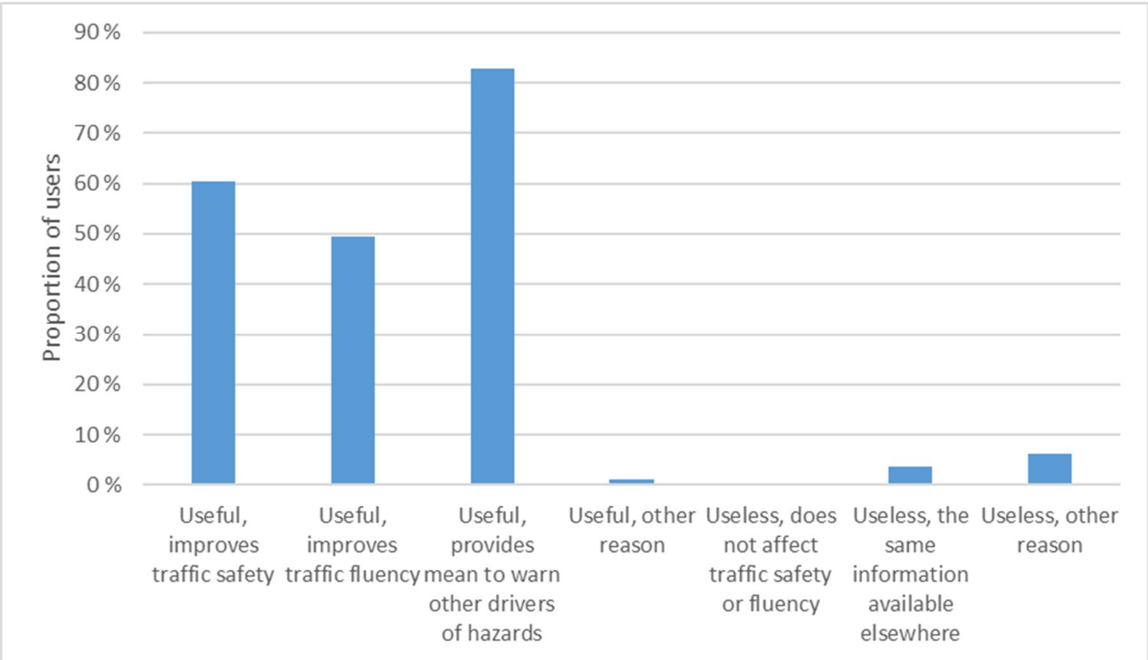

Fig. 5 Overall usefulness of the test app; several alternatives could be selected, First Impression Questionnaire, N = 93

In the Final Questionnaire, the respondents were asked about the additional value the tested service gave them. The three options chosen the most were that HERE DTI gave a more specific location of the disturbance (57%,

Fig. 6), only referred to disturbances close to the vehicle (45%), and gave information on disturbances that the user had not heard about from other sources (45%). Part of the corridor is covered by variable message signs that may also be used to inform the drivers of hazards on the road. Another source available to (practically) all is radio which frequently reports abnormal situations on the road. Only 11% felt that the app brought no additional benefit, and 4% chose 'I cannot say'.

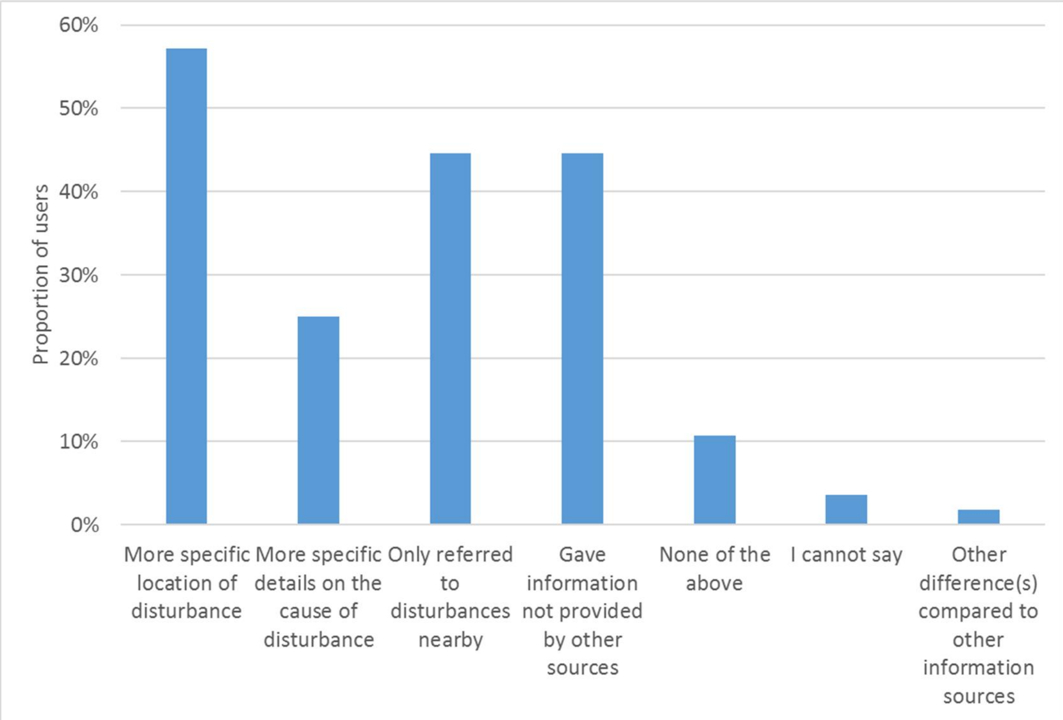

Fig. 6 Assessment of the additional value of the tested service, Final Questionnaire, experienced users (N = 56)

In the Final Questionnaire, the respondents were asked to rate the priority of the warning types on a scale of 1 for the most important, 2 for the second most important, etc. Both user groups gave the highest priority for warnings of accidents and obstacles on the road. Poor visibility was rated the lowest priority (Fig. 7).

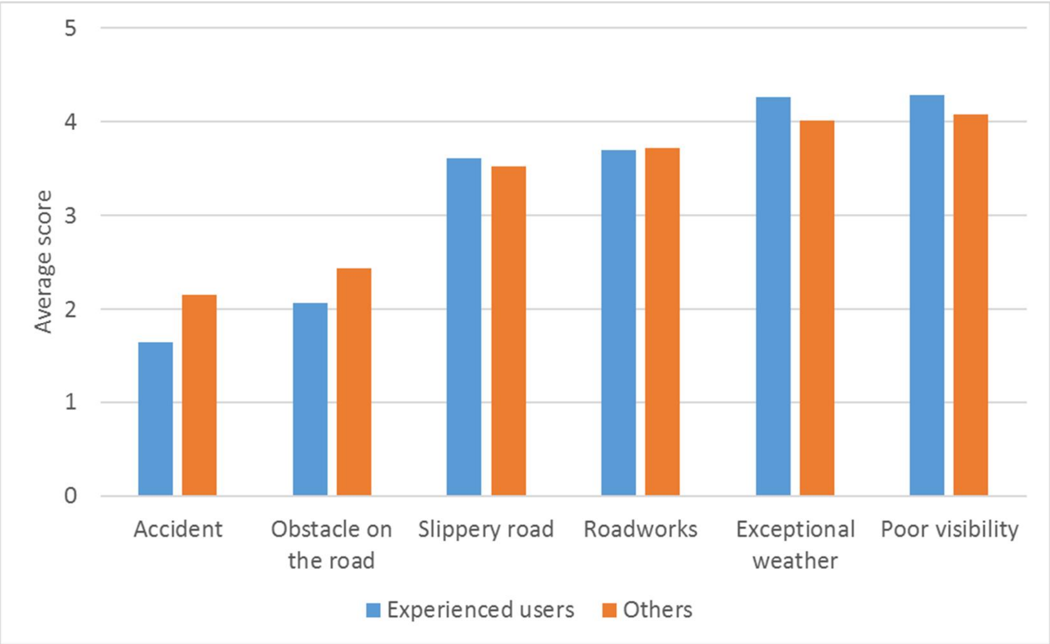

Fig. 7 Priority of warning types: 1 = most important, 2 = second most important, etc., Final Questionnaire, N = 56 for the experienced users and N = 200 for others

In addition to the hazard types currently in the test app, the users favoured including warnings for

- traffic jam
- moose/elk, reindeer, other animals on the road
- driver behaviour abnormally
- damaged road
- police, traffic cameras
- special transport.

They also suggested that the app would show alternative routes in cases of blocked roads or severe congestion.

In the Final Questionnaire, the users were asked whether they would be willing to continue using the app. 95% of experienced users said they would, compared with 86% of less experienced users (Fig. 8). The commonest answer was 'Yes, as part of smartphone navigator' (54% of experienced users and 45% of the others). Only 2% of experienced users and 8% of the others would not be willing to use the app, and 4% and 7%, respectively, selected 'I cannot say'.

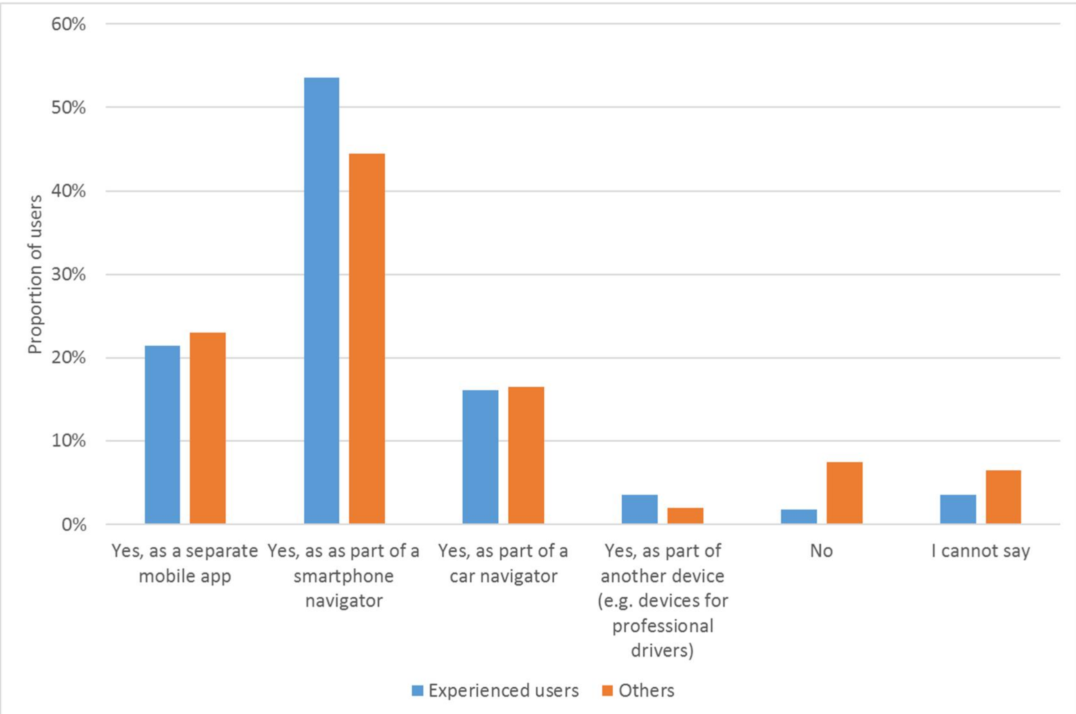

Fig. 8 Willingness to continue using the HERE DTI app if it were launched, Final Questionnaire, N = N = 56 for the experienced users and N = 200 for others

4. Discussion

This paper was designed to evaluate the impacts of cooperative safety-related traffic information systems on driver behaviour and user acceptance of the system assessed in the NordicWay corridor project.

The results show that in many cases, information provided by the test system was the first source of information about a hazard, especially regarding obstacles on the road. The information was felt to be in line with that provided by other sources if there were any. Sometimes, the tested service pinpointed the hazard location more accurately than did other sources, or possibly gave more precise/correct information on the hazard type.

The questionnaire results indicate that all the warning types affected the speed choice of at least 30% of users. Another common response was a change in the driver's focus of attention in traffic. An alternate route was considered for an obstacle on the road, accidents and roadworks. Distance to the vehicle ahead was affected most by a poor visibility warning. Overtaking behaviour was affected most by warnings of road obstacles and accidents. An impact on driving comfort was reported by only a few users (at most 11%). Warnings of poor visibility had no impact on driving behaviour for 33% of users, roadworks warnings for 15% and accident warnings for 11%.

The logged data analysis showed that e.g. for the accident warning, there was a statistically significant drop of 1.9 km/h in average speed between spots 250 and 200 metres before the incident location. Comparing the speed pattern with baseline data indicated that this speed reduction was indeed stronger for warned drivers than their baseline. The questionnaire results support this outcome. In addition, the questionnaire results indicate that most drivers kept a slightly or clearly greater-than-usual distance to the vehicle ahead because of the received warning. Some users also reported that they avoided overtaking, overtook more seldom, or were more careful when overtaking. Many drivers also considered the warning to have shifted their focus of attention, allocating it more to the traffic ahead or traffic conditions. Based on the questionnaire results, most of the drivers had not noticed making any driving errors due to using the app. The most typical errors reported were accidentally dropping the driving speed (16%) and a delay in noticing another road user or obstacle (7%).

Most users found the test app useful. The most common reasons given were that it provides a means to warn other drivers of hazards on the road, and improves traffic safety and fluency. Dissatisfaction pertained mostly to limited functionalities of the prototype app or to the small penetration of users in traffic (and therefore events). The highest priority was given to warnings of accidents and obstacles on the road. Poor visibility was rated as the lowest priority.

Almost all users who had longer experience with the system would have been willing to continue using the app. Only 2% of experienced users and 8% of other users would not have been willing to use it, and correspondingly 4% and 7% stated ‘I cannot say’.

The results of the impact assessment study in NordicWay were in line with the previous results from the DRIVE C2X study and C-ITS Platform.

The limitations of this study include the use of subjective data as person’s ability to assess the driver behaviour impacts is not fully reliable. Even though field data (GPS data on driver behaviour) was collected in rather long (one year) and extensive (over 1000 participants) experiment, the number of events when the test users got the warnings of these rather rare incidents was low. Therefore, the results of the objective data analysis were mostly indicative rather than statistically significant. When using the results in other regions, one must bear in mind that the traffic volumes in Finland are low and the challenges are typically related to weather and other incidents, not to the over-demand. In addition, the network covered by the corridor was of the highest quality network. On more incident prone roads, the benefits might be more evident.

To summarise the outcome of the evaluation, the service of receiving warnings and being able to warn about hazardous situations on the road was well-accepted by the road users. They saw it providing information that other services did not provide, more detailed information or more targeted information despite limited functionalities of the prototype app. The drivers also assessed that the information of hazardous locations ahead affected their driving behaviour. The changes in speed could be seen also in the GPS data analysis. As a main conclusion, the results of this evaluation study indicate that a cooperative safety-related traffic information system in mobile phones has positive impacts on driver behaviour. The results also show that road users would be willing to use this kind of system.

The results of the NordicWay Coop pilot will be used as a basis for decision making on public sector actions for the deployment of C-ITS in Finland. The decisions will cover the choice of technologies, roadside and digital infrastructures, road network coverage, and C-ITS services to be promoted.

Acknowledgements

VTT would like to thank the Finnish Transport Agency, Finnish Transport Safety Agency and HERE for this interesting project and their cooperation during this time.

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