Users' perception and reported effects of long-term access to in-vehicle traffic information services mediated through nomadic devices: Results

Citation for the original published paper (version of record):
Skoglund, T., Wallgren, P., Karlsson, M. et al (2015). Users' perception and reported effects of long-term access to in-vehicle traffic information
services mediated through nomadic devices: Results from a large-scale inter-european field operational test. Transport and Telecommunication, 16(3): 197-206.
http://dx.doi.org/10.1515/ttj-2015-0018

Transport and Telecommunication, 2015, Volume 16, no 3, 197-206
Transport and Telecommunication Institute, Lomonosova 1, Riga, LV-1019, Latvia
DOI 10.1515/ttj-2015-0018

USERS' PERCEPTION AND REPORTED EFFECTS OF LONG-TERM ACCESS TO IN-VEHICLE TRAFFIC INFORMATION SERVICES MEDIATED THROUGH NOMADIC DEVICES

RESULTS FROM A LARGE-SCALE INTER-EUROPEAN FIELD OPERATIONAL TEST

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ICT-mediated traffic information has been argued to contribute to a more sustainable transport system through affecting drivers. Nevertheless, long-term effects of travellers having access to nomadic in-vehicle systems for traveller information are not well known. This study presents the results from a multi-national large-scale field operational test (FOT). The results show that the users in general were positive to the tested systems and that there were several effects on their driving behaviour but in many cases the effects were limited. Moreover the effects varied between system types. Positive effects were related to comfort, as well as individual and system efficiency. One could also notice that perceived effects were not as high as the participants had expected, leading to some disappointment. Most of the times this was due to the tested systems functioning in a less than optimal way.

Keywords: field operational test, traffic information, nomadic device

1 Introduction

Having access to ICT-mediated systems for traffic information has been argued to contribute to a more sustainable transport system. The European Commission stated already in 2001 that "vehicles throughout the Union need to be equipped with ['technologies that can determine optimum speed at any moment with reference to traffic conditions, road features and external conditions'] as soon as possible, and information systems made accessible to everyone" (CEC, 2001, p. 70). The underlying notion is that people when getting information about the current traffic situation along the intended route, will choose alternative routes and hereby lessen the pressure on the congestion affected roads, choose an alternative mode of transport (such as bicycle or public transport), or even choose not to make the trip.

Even though traffic information systems have been in service for a long time, recent development have brought this type of services, previously only available on variable signs by the road or broadcast through radio, to nomadic devices where the information can be more tailored to the individual. The effects of in-vehicle information services have been previously been studied in simulators and field trials. Studies have however typically focused on safety related systems such as Adaptive Cruise Control and Intelligent Speed Adaptation (Saad et al, 2004). Furthermore, little is known about the long-term effects that in-vehicle traffic information service has on car drivers in real-life traffic, since the few studies on these types of systems have mainly focussed short term effects (Abdel-Aty et al., 1997). In addition, there is a scarcity of studies on mature products as most research has been done on pre-market solutions.

A pre-requisite for this type of systems to have any impact at all is that the users adopt the technology, i.e. that they use it and make use of the information presented to adapt their driving behaviour. One factor that influences users' adoption is perceived benefit why it is important not only to investigate effects as such but also participants' expectations before as well as experiences of using the system. In sum, a better understanding is needed of car drivers' perceptions of in-vehicle information services accessible through nomadic devices, how these perceptions evolve with use and over time, and what effects these systems have on driver and travel behaviour.

2 Method

Five hundred ten drivers from four test sites in three European countries: Finland, Greece, and Sweden, participated in testing mature nomadic in-vehicle systems offering traffic information. The Field Operational Tests (FOTs) were carried out in real traffic in the vehicles of the participants for private as well as work related trips. Participants were recruited through advertising in local media and informed to use the system and service as if they had acquired the system themselves.

Each of the four test sites tested a different traffic information system. The devices differed in physical design as well as in the way the system presented traffic information but all systems informed the participant of disruptions in the transport system, such as e.g. information and warnings about congestion and other temporary disturbances. Two of the test sites, here referred to as Sweden 2 and Greece, tested physical "off the shelf" products while the other two test sites, Sweden 4 and Finland, tested software based solutions that were installed on the participants' smart phones. In the overview (presented in **Table 1**) can be noted that the number of inhabitants differed in the test sites where the systems were distributed, the Greek test site was considerably larger than for example the Finnish test site. (More extensive information on systems and test execution is found in Solar et al., 2011).

Table 1: Short description of systems and distribution sites

Test site	System	Information source	Main distribution point(s)	Approximate no. of inhabitants in test site
Finland	Logica LATIS sw for Symbian phones	Mediamobile Nordic	Oulu / Tampere	190 000/ 351 000
Greece	Sygic Nav sw for Samsung Omnia II (WinMob 6.1)	Traffic Management Center of Athens	Athens	3 700 000
Sweden 4	Trelocity sw for Android phones	Trelocity: Crowd-sourcing/Stockholm Taxi	Online, Sweden	n/a
Sweden 2	Garmin Nüvi 205 WT	Swedish Transport Administration	Gothenburg	950 000

The FOTs lasted over nine months starting in December 2010 with a baseline period of three months. Paper or online questionnaires, distributed to the participants in their native languages, were answered before, during and after the test period. Background data was collected regarding age; gender; car ownership; driving behaviour; driving experience; and traffic information system familiarity. Expectations on the effects of the system that the participants were going to test were collected before actual use but after being introduced to the system.

The study included eighteen effect indicators. Some of these effects can be associated to comfort, i.e. "a satisfying or enjoyable experience" (Merriam-Webster, 2013) and others can be related to efficiency, here defined as the extent to which time or effort is well used for the intended task or purpose. Trust in the information provided by the system, perceived benefit of having access to the system, frequency of use, and opinion of the device tested have been measured in order to interpret the results.

The responses were analyzed using SPSS Statistics 20 for Macintosh. The data was primarily ordinal to its nature and non-parametric tests were therefore used for significance testing (α=0.05). Correlations with magnitudes <0.2 have been deemed small (cf. Cohen, 1969) and thus ignored. There were also a number of open-ended questions in the questionnaires, these have been analysed and grouped using the KJ method (e.g. Scupin, 1997).

3 Results

This section will first introduce some background data. The frequency and type of use are then presented in order to provide an overview to how the respective systems were used. This is followed by an account of reported effects of using the different devices and services offered. Lastly results regarding opinion, trust, and perceived benefit of the tested services are presented.

3.1 Participants

The birth years of the participants spanned from 1933 to 1997. A majority of the participants were male and only 17.3% were female. The most commonly reported distance driven was for all test sites 10 001-20 000 km/year except the test site Sweden 4 where the most common distance/year was longer, 20 000-30 000 km.

More than four out of ten participants had never used a traffic information service before the FOT and a majority of the participants did not have access to traffic information service (i.e. "real-time information about the status of the traffic system, including road works, queues, accidents, etc.") before the beginning of the test period. **Table 2** describes some of the background data collected about the participants from the different test sites.

Table 2: Participant background data

Test site	n	Year of birth (median)	Drivers licence since (median)	Female/ Male (%)	Distance driven/yr (Mm) (median)	Never used traffic info before (%)	Did not have access function before test (%)
Finland	110	1971	1989	15.5/84.5	10-20	42.7	78.2
Greece	88	1974	1995	33.0/67.0	10-20	78.4	89.8
Sweden 4	218	1975	1995	2.3/97.7	20-30	12.9	31.2
Sweden 2	94	1964	1983	39.4/60.6	10-20	72.3	76.6
Total	510	1972	1991	17.3/82.7	10-20	42.5	62.4

3.2 Frequency of use

The frequency of use is likely to influence the effects of having access to a traffic information service, as well as being an indicator of the overall usefulness of the product. The participants therefor reported their use of the traffic information service in relation to the number of car journeys by answering a 5-point Likert scale ranging from "Never" via "Less than 25% of the total number of car journeys"; "Between 25 and 75% of the total number of car journeys"; and "More than 75% of the total number of car journeys" to "Always".

The most common answer to the question "To what extent have you used the traffic information service in relation to your number of car journeys" was "Less than 25% of the total number of car journeys". No statistically significant changes in frequency of use could be found over time, nor were there any differences in use of the system related to gender, age, or frequency of car use.

The use differed however between the different systems tested. *Figure 1* shows for example that the participants at the Greek test site reported to use the system to a larger extent than in other test sites.

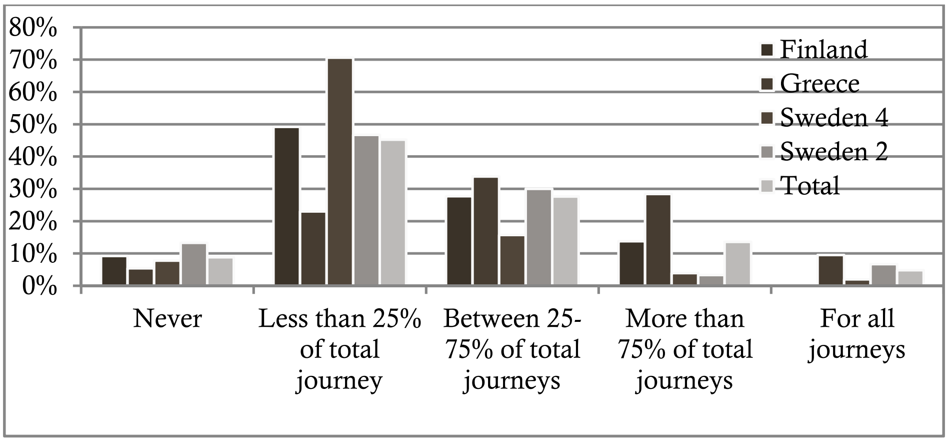

Figure 1. Frequency of use per test site (per cent of valid answers, n_{Fi}=65, n_{Gr}=74, n_{Se4}=51, n_{Se2}=60, n_{tot}=250)

3.3 Use situations

The context in which a traffic information service is used is also likely to influence the effects of having access to that service. The participants were therefore after the test period asked "If you have used the system for some car journeys only are these a particular type of journeys?"

Although more than fourty-four per cent of the participants reported not to have used the service for a particular type of journey, there was some alternatives that stood out. One in four reported having used it when the route/destination has been unfamiliar (see **Table 3**), and a similar percentage reported having used the service when congestion had been expected.

Table 3: Type of journeys when system was used (n=216)

Not for a particular type of journeys	44.4%
When the route/destination has been unfamiliar	25.0%
When congestion has been expected	22.7%
For longer journeys	16.7%
When there has been a time pressure	9.7%
For journeys on highways/motorways	5.1%
For journeys on rural roads	3.2%
When the journey has involved many changes between different modes of transport	2.3%
Other	3.2%

3.4 Reported effects

The participants were after the test period asked to answer the question "Do you think that any of the following have changed due to your access to the Traffic information service?" Fourteen statements were in this way rated on a 5-point Likert scale ranging from "Have radically decreased" via "Have decreased slightly"; "No change"; and "Have increased slightly" to "Have radically increased".

While the overall most dominant answer after the test period was "No change", a number of positive changes were reported. The effects that were found were however predominantly indicated to be slight and not radical changes. If measurements are treated as interval measurements with latent variables efficiency and comfort (cf. Boone and Boone, 2012) the results from the five-point Likert scale show significant changes as presented in **Table 4**.

Table 4: Statistically significant (cut-off level $p_{Wilcoxon}$=0.05, n=240) changes as consequence of long-term access to nomadic in-vehicle solutions for traffic information if measurements are treated as interval measurements with latent variables efficiency and comfort. [1] Indicates effects related to individual travel efficiency, [2] indicates effects related to transport system efficiency, [3] indicates effects related to comfort.

Effect	$p_{Wilcoxon}$	**Direction of change**
Delays when travelling[1,2,3]	<0.0005	Decrease
The time it takes to reach destinations[1,2,3]	<0.0005	Decrease
Fuel consumption[2]	<0.0005	Decrease
Compliance with speed regulations[1,2]	<0.0005	Increase
The distance covered to reach destinations[1,2]		No sign. change
Number of journeys made by car[2]		No sign. change
Use of highways/motorways[2]		No sign. change
Use of rural roads[2]	<0.0005	Increase
Possibilities to choose the optimal route according to preferences (e.g. shortest, quickest)[3]	<0.0005	Increase
Comfort when travelling[3]	<0.0005	Increase
Safety when driving[3]	<0.0005	Increase
Stress associated with travelling[3]	<0.0005	Decrease
Getting stuck in traffic jams[1,2,3]	<0.0005	Decrease
Feeling of uncertainty when travelling[3]	<0.0005	Decrease

The statements to which the largest portion of respondents reported a change were an increase in the "Possibilities to choose the optimal route according to preferences (e.g. shortest quickest)", a decrease in "You getting stuck in traffic jams", and an increase in "Comfort when travelling" (see Figure 2).

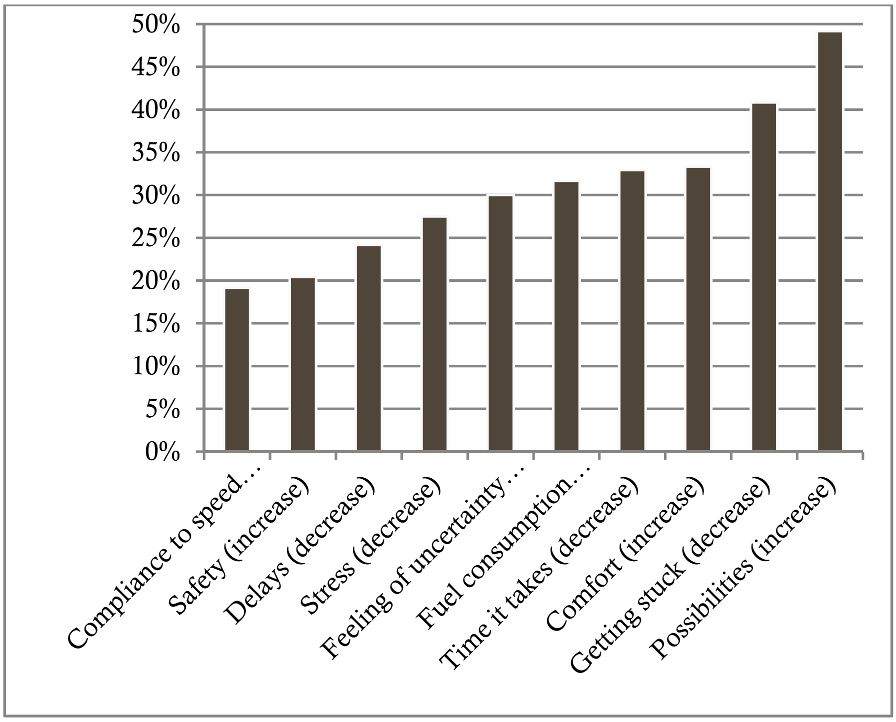

Figure 2. Percentage of respondents reporting a slight or radical change (n=240)

The assessments were however not homogenous. A majority of the statements had responses indicating both "increase" and "decrease". Effects did also vary between the test sites. Participants from the Greek test site reported for example more often a change, for effects deemed central to the service, than did participants from other test sites.

3.5 Expected effects compared to reported effects

The expectations that a user has on a service might influence how or if an effect will be experienced. Disappointment about not experiencing an expected effect might influence use and thus future effects. The responses to the question "Do you think that any of the following will change as a result of your access to the traffic information service?", asked before use but after introduction to the service, was therefore compared to the responses to the question "Do you think that any of the following have changed with your access to the Traffic information service?" asked after the test period for the same fifteen statements (n_{before}=479; n_{during}=298; n_{after}=240). **Table 5** shows the nine of those fifteen statements where the responses had changed significantly ($\alpha_{Wilcoxon}$=0.05, n=233).

Table 5: Statistically significant (cut-off level $p_{Wilcoxon}$=0.05) differences between the expected effects before and stated effects after the test (n=233)

Effect	$p_{Wilcoxon}$	Direction of change
The time it takes to reach destinations	<0.0005	Smaller decrease than expected
Fuel consumption	<0.0005	Smaller decrease than expected
Compliance with speed regulations	0.020	Smaller increase than expected
The distance covered to reach destinations	0.001	Smaller decrease than expected
Use of rural roads	0.037	Smaller increase than expected
Possibilities to choose the optimal route according to preferences (e.g. shortest, quickest)	<0.0005	Smaller increase than expected
Comfort when travelling	<0.0005	Smaller increase than expected
Safety when driving	<0.0005	Smaller increase than expected
Stress associated with travelling	<0.0005	Smaller decrease than expected

The results show that the participants were disappointed with the tested devices and applications not delivering the positive effects that they had anticipated.

3.6 Opinions

The attitude that a user has towards a system for traffic information service is likely to influence the use and effects of having access to that service. The participants were before, during, and after the test period therefore asked to rate their opinion of the traffic information service tested on a five-point Likert scale ranging from "Very negative" to "Very positive".

The ratings of the traffic information services were (see *Figure 3*) in general positive. In fact 73.1% of the participants rated their reactions as Positive or Very positive after having been introduced to the device, but not started using it. The reaction by the participants turned less positive after the test ($p_{Freidman}$<0.0005, n=211), but was nevertheless mostly positive.

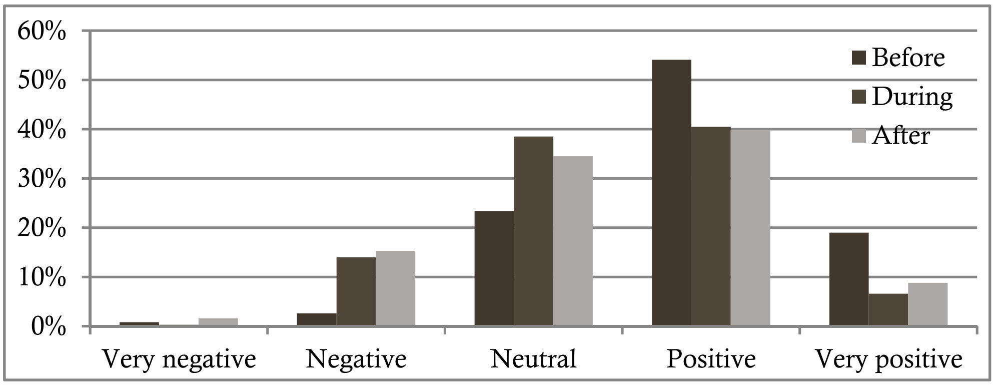

Figure 3. Reaction to the traffic information service (n_{Before}=495; n_{During}=301; n_{After}=249)

The reaction to the system after use did, as seen in *Figure 4*, however vary between the test sites. The systems tested in Greece and Sweden 2 were generally assessed more positively than the systems in Finland and Sweden 4.

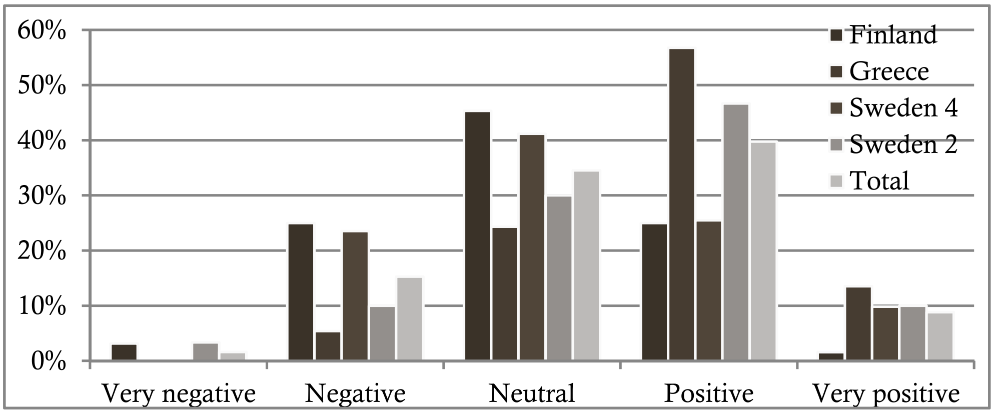

Figure 4. Reaction to the traffic information service after use (n_{Fi}=64; n_{Gr}=74; n_{Se4}=51; n_{Se2}=60; N=249)

3.7 Perceived benefit

Perceived benefit of a traffic information service is likely to affect the use and effect of having access to such a service. The participants were therefore asked before, during and after the test period to rate the benefit of having access to the traffic information service on a five-point Likert scale ranging from "No benefit" to "Very large benefit".

The participants' expectances for the tested devices/applications included being able to get a good prediction of travelling time and a picture of the traffic situation that enables you to avoid the worst traffic. Traffic information services in nomadic devices could also contribute to less stress, more fluent traffic and, as a consequence, lower emissions.

> *"Since I drive a lot during rush hours and always feel stressed about picking up the kids at kindergarten I hope that this function will help me a lot. I have TMC today and think that the functionality in Sweden is completely worthless…" (Sweden 2 Before trial)*

More than thirty per cent of the respondents assessed the benefit of having access to the traffic information service as Large or Very large benefit (see Figure 5). The results show that to some extent these expectances were met, but certainly not in all cases and to the full extent. The decrease in perceived benefit over time was statistically significant ($p_{Freidman}<0.0005$, n=209).

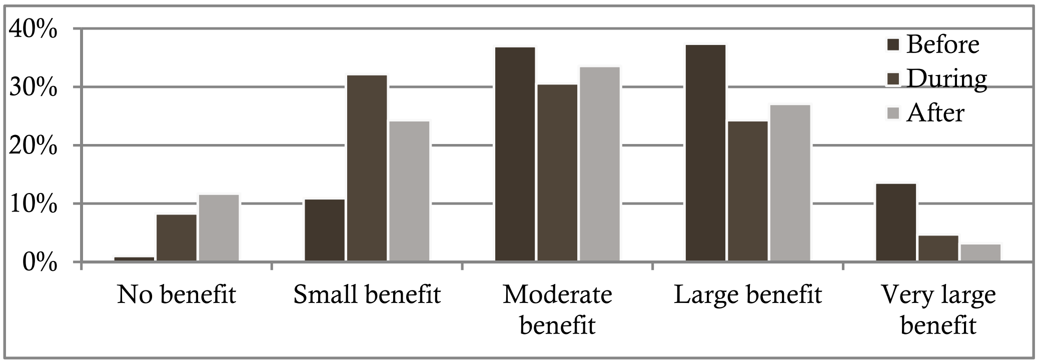

Figure 5. Perceived benefit (n_{Before}=494, n_{During}=301, n_{After}=247)

The perceived benefit varied moreover between the test sites. The participants in Finland reported for example less often than in other test sites the benefit to be Large or Very large. The participants in Greece reported on the other hand more often the benefit as Large (see *Figure 6*).

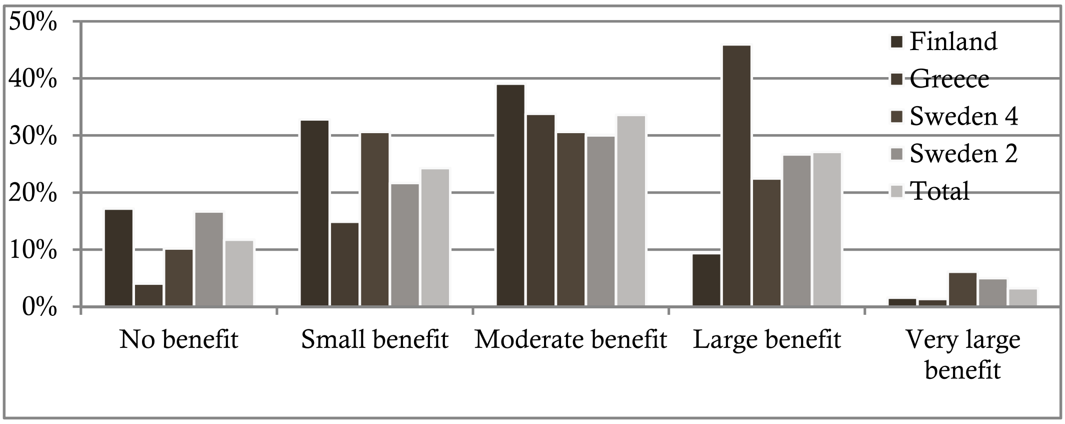

Figure 6. Perceived benefit.(n_{Fi}=64; n_{Gr}=74; n_{Se4}=49; n_{Se2}=60; N=247)

No statistically significant correlation $|\rho|>0.2$ could be found between birth year and ratings of perceived benefit before or after the test period. Neither was any statistically significant difference found between men and women.

3.8 Correlation between reported effects and use, benefits and trust

Table 6 shows that people who found the device to have positive effects, used the system more often, perceived the device as more beneficiary and trusted the system to a higher degree The 18 different effect measures were also tested against gender and age, but no statistically significant correlations were found.

Table 6: Statistically significant Spearman correlations |ρ|>0.2 between reported effects and the reported use, perceived benefits, and trust in the system (n=240)

Reported Effects	Reported use	Perceived benefit	Trust in system
Possibilities to choose optimal route according to preferences according to preferences (e.g. shortest, quickest)	0.494	0.321	0.398
Comfort when travelling	0.443	0.318	0.375
Getting stuck in traffic jams	-0.419	0.294	-0.362
Safety when driving	0.418	-	-
Stress associated with travelling	-0.409	0.314	-0.292
The time it takes to reach destinations	-0.403	0.364	-0.275
Fuel consumption	-0.396	0.348	-
Feeling of uncertainty when travelling	-0.391	0.252	-0.243
Delays when travelling	-0.311	0.301	-0.234
The distance covered to reach destinations	-	0.263	-

3.9 A qualitative analyses of the quantitative results

The free text answers gives us some clues to why the rating of devices/applications as well as the perceived benefits of using such a service went down during the trial. It seems to be related almost exclusively to the quality of the tested devices and services. In this, our findings correspond with that of Lappin (2000) who stated that drivers consult ATIS to reduce the uncertainty of the trip. For it to be successful it must provide value to the driver every day. In order to do so, the service has to be reliable, accurate and easy to use. One can argue that this is even more true for a nomadic device that has to be turned on before every trip to be of use.

A pre-requisite for a traffic information service is that **it actually provides traffic information** for the route that you are taking. The different devices and applications tested received their information from different sources, both traditional (like the national or regional road administrations) and through crowd sourcing.

> *"On many occasions, information on congestion was missing so we ended up in traffic anyway." (Sweden 2 during)*
>
> *"It didn't provide the user with any important information. It concerned only very few streets, that was not part of my journey routes" (Greece post)*
>
> *"Make it work in rural areas" (Sweden 4 post)*

Regardless of the source of the data, it was apparent that traffic information was lacking for the roads that many of the participants travelled, since it mostly covered large roads and/or city centers.

Some participants also experienced information that was not **correct**. There is little doubt that that if you experience the information as incorrect your **trust** in the ICT mediated service goes down.

> *"The info given is of low quality. When red congestion is indicated it has been smooth traffic and vice versa." (Sweden 4 post)*
>
> *"One thing that has come up the latest time is a road work near the home that is not causing any effect on traffic flow. The device anyway informs of a six minutes delay. Cues in rush hour that delays you way more than six minutes never shows up, so the impression on the whole is just so so." (Sweden 2 during)*

Moreover, if you do not **trust** the data, the benefit of having access to the data goes down. The (Spearman) correlation between trust in the information and perceived benefit was strong 0.637 ($p<0.0005$, $n=247$) after the test.

> *"It would have been great if only you could trust the info". (Sweden 4 post)*

The finding that trust is crucial corresponds with Levinson et al. (1999) as well as Abdel-Aty et al. (1997) who independently claimed that people choose the route with highest certainty rather than take a chance with a route that might be faster.

In order to react to traffic information and choose another road, traffic information must be very **quick to update**. A queue can form quickly in rush hours and then disappear just as quickly.

> *“The information about queues or slippery road surface is a bit late, often you are already standing in the queue when you get it. But if it had warned earlier it had been worth gold” (Sweden 2 during)*

Some of the participants pointed out that there exist **alternative sources** for traffic info that are faster, more precise and sometimes already paid for (radio) or virtually free (Waze).

Participants in all of the test sites experienced in some cases that the devices/applications were **not as stable as they expected**.

> *“The Android app works when it wants to. 8/10 it unfortunately doesn’t work” (Sweden 4 post trial)*

There were also problems with the **user interface** of the devices, such as icons being too small, screen savers shutting down the screen on mobile devices when no input had been given for some time, and applications lacking a fast and precise way to input destinations.

> *“It did not serve me well. I could not see clearly the traffic sign indicated via small vehicle icons. If was difficult for me to use it” (Greece post)*
>
> *“There is only one thing that is missing and that is that an address has to be possible to type in. Then the service will be great. As it is now, “click on the map to set your destination”, it is completely unusable” (Sweden 4 post)*

A general problem for all the devices and applications tested was that although traffic information was presented, the user did not get any **advice for action**. The participants asked for a system that not only told them that congestion was to expected, but also advised on alternative routes. Already in 1993, Khattak et al. showed the importance of ATIS to provide the user with routing suggestions, but this is still to be implemented in any but the most advanced traffic information systems.

> *“It there was a problem within the scheduled route (e.g. a protest) this should be able to help the driver avoid it. Useful and well communicated information regarding alternative routes would be of value” (Greece post)*

Another fairly common comment was that the traffic information was of little use since the participant did not have **any alternative** routes to choose between, but had to take the same route with or without traffic information.

> *“The routes I usually travel seldom have an alternative, even if there is a queue” (Sweden 2 post)*

This was of cause a bigger concern in smaller cities and rural areas, than in a large city as e.g. Athens were the alternatives are plural. This can be seen in the data as people in Athens ranking the benefits of havin access to Traffic information being much higher than in the other test sites.

4 Conclusion

In general the participants found traffic information available through nomadic devices to be useful, and they also reported the use of the devices and application to have an effect on their driving. They experienced a decrease in getting stuck in traffic and an overall increased comfort when driving. Nevertheless the effects were smaller than the participants had expected. The reasons for this could be divided into three areas: The quality of the data, the options for action (i.e. infrastructure), and the usability of the tested devices and applications.

The four devices and applications tested in these trials were all mature ‘off the shelf’ products, or very close to market introduction. It is therefore somewhat surprising as well as disappointing that there were so many problems with the products in terms of the quality of the information provided, as well as the usability. These are crucial for the user's experience and evaluation and hence to the market of these products.

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