In-Car Navigation Usage: An End-User Survey on Existing Systems

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***Abstract**: In-car navigation can be recognized as a rather mature application, available to a broad public for almost a decade. Although existing systems are seemingly different in sense of human-computer interaction, their design rationale is strikingly similar. The navigation services primarily seem to address traveling in foreign driving environments. However, the average car driver spends a considerable amount of time driving in well-known areas, not supported particularly well by existing systems. This paper presents an end-user survey on in-car navigation usage. It contributes by exploring and describing the impact of driving context on user behavior.*

***Keywords**: route guidance systems, navigation, context-awareness*

1. Introduction

The last few years have brought a breakthrough for in-car route guidance applications. The adoption rate is still moderate, but most manufacturers provide navigation support systems as an option for premium cars, heading for the mid-price segment. Therefore, the number of vehicles offering integrated navigation system continuously grows. So does the number of system suppliers. Still, the industry is facing a huge challenge in transforming vehicle navigation from luxury gadget into a convenience tool. As an example, the average adoption rate for in-car navigation systems, on the US market, merely stayed under 2 % 2002 (J. D. Power, 2002). One important issue in this process is to increase user value by supporting a wider range of everyday traveling problems.

Even though existing in-car navigation systems are seemingly different in sense of human-computer interaction, their design rationale is strikingly similar. The services are, typically, designed for a foreign driving environment, consequently, offering limited support in familiar areas. Since the average car driver spends a considerable amount of time driving in well-known areas this is a user value problem.

Earlier research indicates the need for a wider range of navigation services tailored for different contexts, assisting users with different needs. Lotan (1997) shows that local knowledge is often reflected in driving behavior. On the basis of a survey Bonsall & Parry (1990) suggest that supporting drivers in familiar areas is, typically, a matter of informing. The assessment is preferably made by the user. In a similar study Lindkvist et al (1995) confirm that users expect little value, in sense of time saving, from a traditional turn-by-turn navigation system when driving in familiar areas. Despite previous work, however, most research contributions are based on either driving simulator studies or surveys/interviews targeting a general audience without experience from in-car navigation services.

This paper presents a survey of end-user behavior based on existing navigation systems. The main objective is to explore and describe the impact of driving context on navigation system usage. A strong correlation between context and user behavior would challenge the accepted design rationale.

The rest of the paper is structured as follows. Section 2 is portraying in-car navigation discussing basic drivers, commercial systems available today and finally some related research. Section 3 is dedicated to the method used when implementing the survey, while section 4 describes the results. Finally, section 5 concludes the paper.

2. In-Car Navigation Systems

2.1 Raison D'être

According to car manufacturers, efficiency, enjoyment and safety are the fundamental drivers behind the implementation of computing and technology in vehicles (Walker et al, 2001). In-car navigation, as we see it today, is typically an OEM (Original Equipment Manufacturer) product, supplied by the car manufacturers, and we have therefore used this categorization when analyzing the basic drivers behind navigation services in cars. Further, we have adopted the end-user perspective only, i.e. leaving out interests from public authorities etc.

Efficiency

When discussing navigation in terms of efficiency it is clearly a matter of optimizing journeys, which is a rather complex task. In the end this is about individual preferences of the specific driver, continuously changing with the purpose of the journey. However, when adopting an end-user perspective it is easy to identify a set of key factors of efficient in-car navigation. First and foremost, the system shall be capable of *saving time* compared to alternative methods. Skilled routing, considering both static map data and dynamic traffic information, is essential to identify fast route alternatives, avoiding congestions. However, a fast journey is not necessarily effective if the targeted arrival time is not met. Therefore, precise time of arrival estimation is an important feature of an efficient navigation service. Other time consuming activities addressed by an efficient navigation service are pre-trip planning and on-demand identification of travel enablers, such as petrol stations.

The second factor is the capability of *reducing mileage*. Basically, this is about offering short routes alternatives to the user, but ability to identify temporary restrictions, such as road works, via dynamic traffic information is also relevant.

A third factor when discussing efficiency is the potential to *save money* for the user. In addition to mileage, it is relevant for a skilled routing to be able to consider toll roads, ferries, charged congestion zones etc, which have a considerable impact on the total travel cost.

Enjoyment

Whether or not a trip has a clear objective traveling can be exciting, interesting and instructive. In-car navigation has a clear potential to improve the subjective quality of the journey, creating a *richer travel experience*. For an open journey this might be about providing entertaining route alternatives, such as scenic routes. For fixed routes a navigation system can, for example, identify relevant intermediate destinations, such as restaurants, shopping centers, tourist attractions etc. Moreover, a navigation system is, to many end-users, entertaining in itself, providing numerous of challenging features.

Safety

Traveling always bring a wide range of safety related questions. On one hand worries about getting lost en-route, on the other hand the risk of getting seriously injured, or killed, in an accident. In-car navigation has a role to play over the entire spectrum of safety issues.

First, in-car navigation services provide *increased confidence*, especially when traveling in foreign environments. Continuous navigation support guarantee that the destination will be found, guidance will be given when action is needed and, maybe most important, the driver will never get lost.

Second, in a stressful traveling environment in-car navigation can be a valuable tool *decreasing frustration*, simply by informing. The main goal is, of course, to notify on traffic problems and redirect route, but even when stuck in a queue traffic information is highly relevant. Information on congestion extension or estimated duration provides options, whether it is about turning around, taking a break, canceling meetings or simply remaining in the queue.

Third, using in-car navigation adds a secondary task on the driver, which always has to be considered during system design. The trade-off between user value and distraction from the primary task, driving, is difficult. However, a navigation system clearly has to *decrease driver workload* compared to traditional methods, such as map reading and notes.

Finally, the extensive map databases used by the navigation services opens up for additional services. From a safety perspective it is very interesting to monitor and *put attention on inappropriate driving behavior*. This might be violation of traffic regulations such as speed limits or other regulations.

2.2 What is offered today?

A typical in-car navigation system of today uses a digital map with numerous attributes, such as turn restrictions, one-way information or address ranges, to enable autonomous in-car route guidance. Destinations can be configured fast and precise thanks to an extensive and structured geographic database. The progress in digital mapping is probably the single most important enabler for route guidance services, as we see them today. However, the obvious price is huge amounts of data to be handled by the systems and enormous annual cost for maintenance and coverage extensions. The navigation community often argues that in-car navigation must not remain a luxury gadget. To generate sufficient business revenues route guidance has to achieve at least the status of convenience application or even necessity (Sena, 1997), opening up a broad mass-market.

The progress in digital mapping has helped bringing new requirements on human-machine interface and display technology. Screen resolution and illumination performance has increased, as size of the display units has decreased. However, the size of the actual screen is often 6-7” or larger. A high position is strongly recommended e.g. by the European Commission (Liikanen, 2000), and often practiced, to minimize the visual cost of using the display when driving.

The route calculation, using considerable computational skills, engages a large set of configurable optimization parameters. The user can, for example, request a route on preference of driving distance or travel time. For convenience driving contexts, as motorways, ferries or toll roads can be excluded in the routing procedure. Additionally, some systems offer a multi-route proposal to give the user a general view of the routing situation, see example in figure 1.

Figure 1. *Example of multi-route functionality (Denso KVT M700).*

Route guidance is about directing the driver along a planned route. Instructions, by voice messages and screen information, are presented turn-by-turn to support every necessary action. Real-time information on distance to action is presented, as well as relevant street names at the intersection. Further, a detailed intersection map, see example in figure 2, is shown to provide overview of the intersection area.

Figure 2. *Example of intersection map (Volvo RTI).*

Most modern systems also support real-time traffic information, further improving performance. With such knowledge the routing can be performed in accordance with the current traffic situation. Moreover, the user can be notified when new problems occur, affecting the ongoing route. In Europe the traffic information services are based on an ISO standard, using a Traffic Message Channel (TMC) in the Radio Data System (RDS), powered by public FM radio.

This brief portrayal of existing systems is based on experience from leading brands as Denso (e.g. in Toyota, Lexus, Saab 95), Alpine (e.g. in Honda, Acura, Mercedes M-class), Delphi (e.g. in Pontiac, Saab 93) and Mitsubishi Electric (e.g. in Mitsubishi, Volvo).

2.3 Related Work

Safety

Using in-car navigation is clearly a secondary task, while driving is the primary assignment. The driver has to master a task-switching situation, still allocating enough attention to the critical driving. This dilemma is what Wickens (1992) referred to as the "resource competition" between the visual demands of the in-vehicle display and the external driving scene.

Several investigations have been made on how map-based navigation systems affect driver behavior. On one hand it is confirmed that the systems decrease workload in comparison with paper map and notes (Burnett & Joyner, 1993; Daimon et al, 1994). On the other hand there are quite a few indications on degraded driving performance when using the systems. Burnett & Joyner (1993) report that use of the system in their study was "associated with large amounts of time with eyes off the road." Another investigation show that task completion times were relatively unaffected by the visual demand of driving (Tsimhoni & Green, 2001), which indicates an unhealthy prioritization between the tasks.

The focus on the secondary task seems to remain at increased visual demand, but the duration of in-vehicle glances decreased, their number increased, and the time between the glances increased.

Driving Behavior and Local Knowledge

The route choice process is as frequent in everyday vehicle traveling as it is complex to describe and understand. When planning a journey in detail a driver is considering numerous of parameters, such as road characteristics, traffic conditions, time of day, personal preferences, purpose of the trip, weather conditions etc. The more information, the better basis for a decision. Without supporting systems this is very much summing up to the driver's level of local knowledge.

Lotan (1997) compared the route choice behavior of familiar and unfamiliar drivers who use the same road network. The investigation, based on a driver simulator without navigation aids, show a larger homogeneity among unfamiliar drivers in terms of switching and diverting behavior. This phenomenon is also confirmed by Lindkvist et al (1995), establishing that the majority of the unfamiliar drivers "are not inclined to divert from the planned route". In contrast, familiar drivers show clear preferences among route alternatives. They tend to stick to their previous route, but at the same time they demonstrate a larger flexibility in their diversion behavior en-route. (Lotan, 1997). Based on a survey Lindkvist et al (1995) confirm this by reporting that

> "two thirds of the drivers on familiar journeys sometimes or often change their normal route during the trip. The most common reason for choosing an alternative route on a familiar journey is to avoid congestion that was anticipated in advance."

The level of familiarity with the road network seems to have clear impact on the route choice behavior, but to what extent are journeys carried out in well known traveling environments? In a survey by Bonsall & Parry (1990) most respondents said that "most of their journeys were along familiar roads to familiar destinations". It is reasonable to believe that this result is representative to all drivers.

Services

The discussion so far shows that driving context, in terms of familiarity with the road network, has impact on driving behavior, but to what extent is that relevant to in-car navigation systems?

One of the first questions to ask is whether the level of system usage is affected by driving context? Both Bonsall (1992) and May et al (1992) have studied *compliance* with guidance, given by the navigation system. The result clearly shows that compliance is strongly influenced by the quality of past guidance. Moreover, Bonsall found a negative correlation between compliance and the level of familiarity. The more local knowledge, the lower compliance with guidance. A reasonable conclusion is that personal preferences on routing become more important in a well-known traffic environment.

A concept system, the Adaptive Route Advisor, implemented at Daimler Chrysler addresses this personalization issue. It is argued that

> "Current route advice systems present a single route to the driver based on static evaluation criteria, with little or no recourse if the driver finds this solution unsatisfactory." (Rogers et al, 1999)

The ambition of the demonstrator is to act as a human travel agent recommending routes on the basis of an adaptive user model and an intelligent dialogue. Pang et al (1995; 1999) is approaching the challenge of personalized routing from an algorithm perspective. The proposed routing method is modeling driver's preferences by a fuzzy expert system.

While routing is a matter of selecting a proper route, guidance is the means of directing the driver, using this route. In traditional guidance methods the necessary driving actions of the entire route are identified and then presented to the driver with a proper timing. The instructions, visual and by voice, are almost exclusively referring to the road network. Many researchers argue that this traditional methodology simply does not reflect human behavior. The use of landmarks in guidance is often stressed as a key issue.

> "Studies within the human factors discipline and elsewhere have shown that the safety, effectiveness and acceptability of these in-vehicle systems could be significantly enhanced, if the interface reflected basic human navigational strategies, and incorporated landmarks within turn-by-turn directions." (Burnett, 2000:2)

In a discussion on route descriptions, used for guidance, Dale et al (2003) is pointing out that "humans often omit steps that the automated systems include". Instead of producing one-sentence-per-step mappings, the human navigator typically gathers together related information into single sentences. Höök & Karlgren (1991) is referring to this phenomenon as "chunking".

Humans have the ability to decide the type and level of guidance needed for a specific driving situation, while the automated systems do not. A well-informed co-driver would possibly give consecutive turn-by-turn directions where the driver has insignificant local knowledge, but definitely not on his or her own backyard. May et al (1992) is arguing that the basic needs are different; familiar drivers are much less likely to seek or follow guidance, and much more likely to prefer real-time information on which to base their own route choice decisions. A survey by Bonsall & Parry (1990) confirms that familiar drivers "would welcome information about scheduled disruptions and current network conditions, but would prefer to assess its implications and decide whether to adjust their route themselves rather than accept advice." The need for a wide set of route guidance services is illustrated also by Wallace & Streff (1993) :

> “in unfamiliar areas drivers have a pressing need for route-guidance information, while during the commuting trip route characteristics (such as congestion levels or travel times) may be sufficient.”

Considering driving context seems to be crucial in deciding what service to deliver. Hypothesizing on this matter Bonsall & Parry (1990) proposes that users might prefer a system which ”learned” their usual route and then, on a given day, either simply confirmed that the usual route was fine or alerted the driver to specific network conditions that might make the usual route sub-optimal.

Finally, the last few years brought completely new platforms for mobile navigation services. With PDA’s and mobile phones route guidance can be provided basically anywhere at any time. These new prerequisites add even more complexity to the question about user needs and value of service in different contexts. Krüger et al (2004) are addressing this topic by presenting a prototype navigation service spanning three different contexts: at home, in-car and on-foot. Also Baus et al (2002) stresses the need for multimodal services, highlighting that “when a change of the means of transportation is detected, the system has to adapt its interface to the new situative constraints.”

2.4. Do we need a wider design perspective?

Though questioned, it is rather easy to argue, as in section 2.1, that in-car navigation systems add significant user value. These tools have a potential to make traveling more efficient, more entertaining and safer. When looking into the systems of today, briefly portrayed in section 2.2, a general impression is that they are strikingly similar, though different solutions for human-computer interaction. Moreover, this accepted design rationale primarily seems to address a rather skilled user, eager to interact with the system while traveling in a *foreign* environment.

The work from Lotan (1997) and others, briefly described in section 2.3, show that the level of local knowledge often are reflected in driving behavior. People simply do not act the same way in well-known areas as they do in foreign traveling environments. Studying system usage those indications are confirmed by a significantly lower level of compliance with guidance instructions in well-known areas (Bonsall, 1992; May et al, 1992).

Many researchers stress the need for a wider range of navigation services tailored for different contexts, assisting different users with different needs. In this paper we are contributing to such a discussion by analyzing in-car navigation system usage. The work is based on an end-user survey conducted November 2003 (Svahn, 2004). Our main objective is to explore and desribe the impact of driving context on navigation system usage. Following questions are addressed:

1. Does driving context have impact on system usage?

2. If so, *how* does driving context impact system usage?
3. Is it possible to identify any fundamental drawbacks in the accepted design rationale, explaining a relation between driving context and system usage?

3. Method

The survey analyzed in this paper was carried out in November 2003. The project was conducted as a cooperative work involving Viktoria Institute (IT-research institute), Volvo Car Corporation (car manufacturer) and Guide Konsult (IT Consultant).

3.1 Target Population and Sample Frame

The survey target population was defined as car drivers frequently using map based, commercial, integrated navigation systems. Reaching a representative selection of this target population is not an easy task since public vehicle databases normally do not contain detailed information about equipment, as navigation systems. Car manufacturers and their sales organizations employ Customer Relationship Management (CRM) tools, which might have been used to get in contact with end-user, but the databases are considered confidential and therefore not exposed in public.

However, in the work with this survey we had the opportunity to make use of a corporate product evaluation programme at Volvo Cars, identified as QUIC (QUality Improvement Customer cars). The purpose of the QUIC programme is to, in a customer-like environment, give immediate feedback on product quality, directly after initiating the production of a car model. The participants dispose the car for rather long periods of time to cover high mileages. The programme follow-up shall, as far as possible, reflect the end-user opinions.

Qualified to participate in a QUIC programme are employees with access to company car, where the contract is ended within three months from the programme start. The final distribution of drivers is made to reflect the targeted end-user for the specific product. Therefore, factors as age, sex, family situation and driving behavior are considered in the distribution process.

The sampling frame was defined as all drivers included in the ongoing QUIC programmes where the car was equipped with Volvo RTI (Road and Traffic Information). As of 2003-11-06 this group had 84 members, whom also received the survey.

3.2 Variables

The survey was defined by 28 different variables, each representing an attribute of interest, see appendix. The questionnaire was designed in Swedish, therefore question descriptions and interpretations are translations. Three different variable types were used; Ratio, Ordinal and Nominal scale.

Ratio variables, having a fixed zero, permit the comparison of differences of values. Age, annual mileage and family status (number of children living within household) were represented by ratio variables. Ordinal scale variables, where data is shown simply in order of magnitude, was used e.g. to represent education level, computer skills or level of usage in different contexts. For an ordinal scale variable there is no standard of measurement of differences. Nominal scales, where data are neither measured nor ordered, were used to represent e.g. primary car usage, habitation or marital status. Correlation coefficients involving nominal scale variables are not considered valid.

3.3 Implementation

The survey was implemented, and distributed, as a Microsoft Excel workbook designed using ActiveX control and Visual Basic for Applications (VBA). The questionnaire was based on radio buttons (for all nominal and ordinal scale variables) and free text fields (for the ratio variables). Further, a VBA script checked each answer to guarantee validity. The questionnaire was distributed by email on the corporate network at Volvo Cars.

3.4 Validity

The survey recipients are, as a group, selected to reflect the targeted end-user of the product, which is the entire car. In-car navigation is an option, meaning that the customer has to make an additional decision, ordering the system. The survey participants, however, have not ordered nor paid for the system. This fact might influence the level of usage, but reasonably by underestimating it.

This investigation is based on employment of one system (Volvo RTI), operated by users on one market (Sweden). Studying other markets and brands might give another result. However, all questions are on a high functional level, where the leading brands are using very similar solutions.

All in all 58 out of 84 recipients provided a valid answer, making a response rate of 69 %. Though a rather high figure, the sampling frame is on the small side. A larger frame would have provided greater statistical confidence.

4. Results

The questionnaire addresses two key topics. First, we are exploring whether driving context has impact on system usage or not. The survey respondents are asked *where*, in sense of traveling environments, they actually use their system. A foreign driving environment, where destination and/or journey are unknown, is put in contrast to a well-known environment where the user has considerable local knowledge.

Second, we study *how* the driving context is impacting the usage. By a set of questions the respondents have to take a position on how they use the system in different environments. Usage is considered as *Active* when a destination is configured. The navigation service will then include routing, turn-by-turn guidance and traffic information notification. When the system is used (switched on) without an active route, and consequently no destination, we consider the usage as *Passive*. This kind of system usage will mainly provide situation awareness and orientation. In the questionnaire we used the phrase *Basic* usage in terms of having the system switched on.

To improve the interpretation of survey data some additional questions were put on the subjective impression of routing, traffic information and driving safety.

Complete survey statistics can be found in the appendix. The table defines every variable in sense of identification number, type, description, coding and interpretation. Further, the result is described by frequency, percentage, mean and standard deviation.

4.1 General Characteristics of Respondents

The typical survey respondent is male (77 %) and married (75 %), with one or more children living at home (70%). The age distribution is rather wide, with an average of 45 year, see figure 3. 62 % have a university degree of more than two years. Further, the respondents are fairly comfortable using computers. 59 % look upon their own skills as considerable, 31 % as moderate.

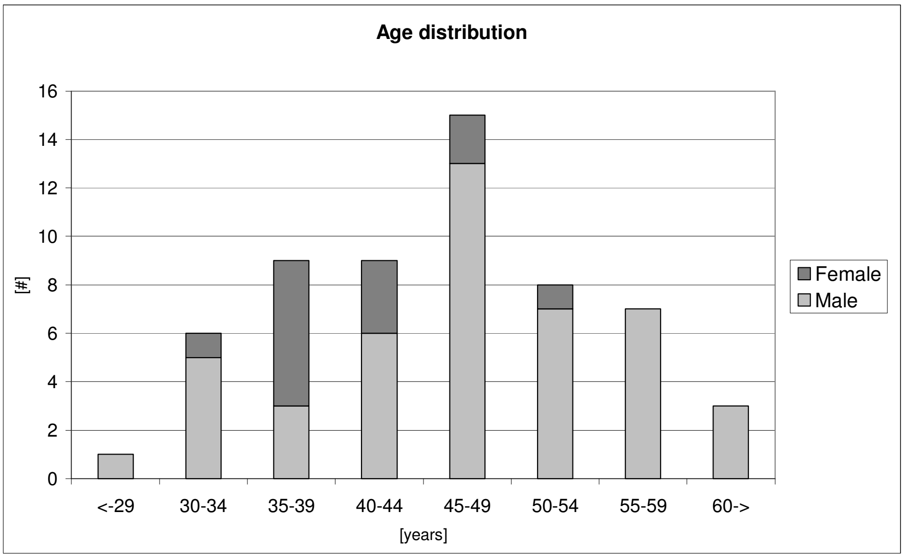

Figure 3. *Age distribution.*

Of the 58 respondents, 60 % live within the city of Gothenburg and 24 % in the metropolitan area, defined as up to 50 km from the city. When rating primary car usage, private trips clearly dominate. The average annual mileage is almost 35.000 km, but some of the drivers exceed 60.000 km/year, see figure 4.

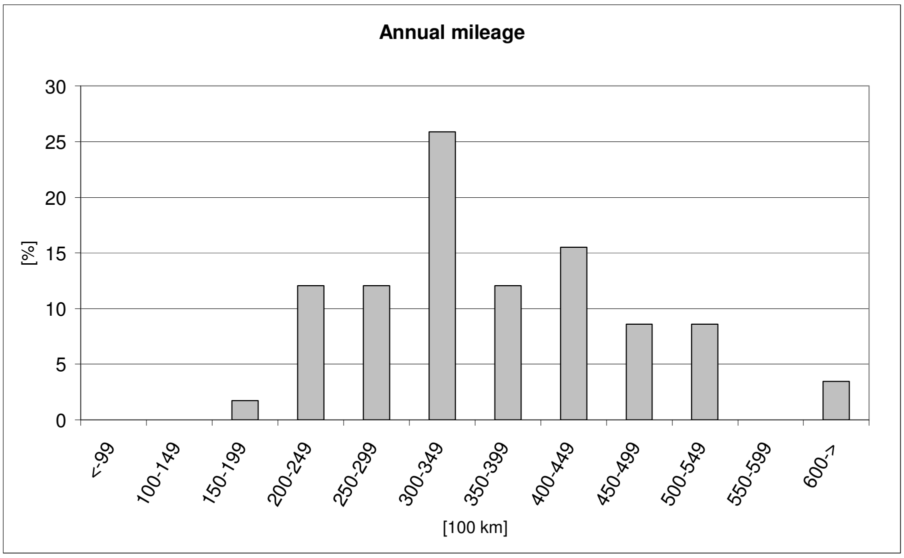

Figure 4. *Annual mileages.*

4.2 Driving Context and System Usage

Figure 5 reflects level of usage in a foreign traveling environment. We can see that the system is frequently used even in this sampling frame of QUIC drivers, where the users have not actually ordered the system themselves. Approximately 90 % of the respondents report basic usage (system switched on) basically always or often. The statistics for active usage (destination configured) is almost identical to basic usage. Obviously, when driving in a foreign environment the system is frequently used, and basically always in an active manner.

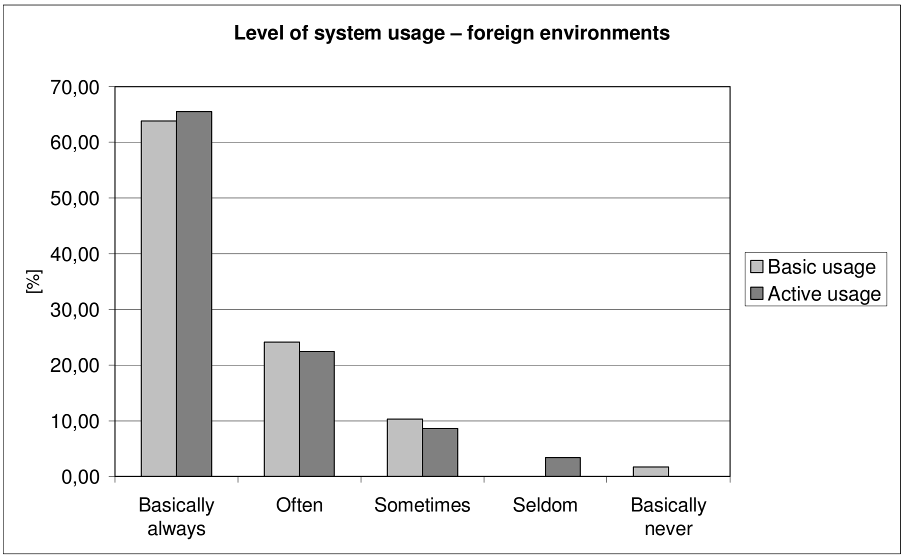

Figure 5. *Level of system usage in foreign driving environments.*

Figure 6 is reflecting the level of usage in well-known traffic environments, where the user has local knowledge. We can see a clear tendency not to use the system actively. Approximately 65 % declare that they seldom or basically never use the navigation system actively when they drive in a well-known area. On the other hand the figure reveals that just about 35 % of the respondents basically always or often have the system switched on in the same traveling context. This is a clear indication of passive usage. Therefore, when driving in a well-known environment the system is moderately used, and then mainly in a passive manner.

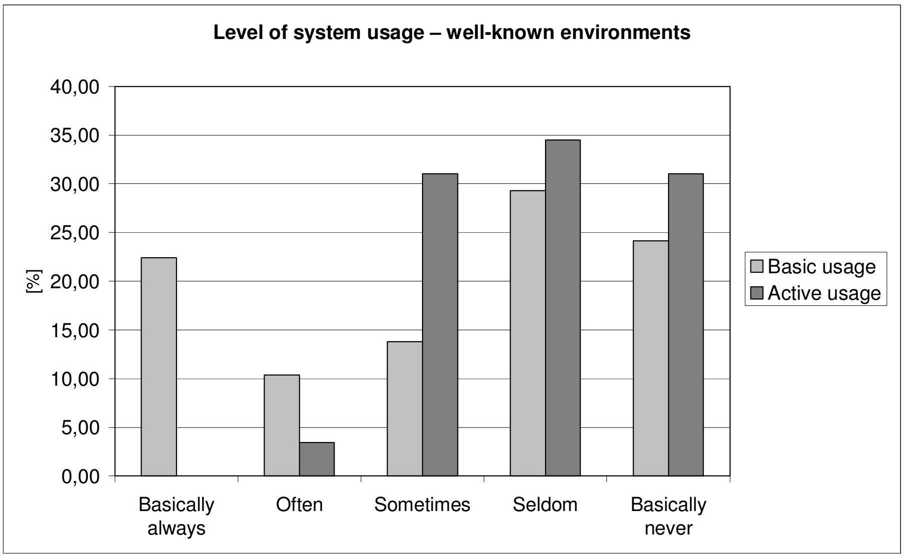

Figure 6. *Level of system usage in well-known driving environments.*

The discussion is summarized in figure 7, illustrating the level of usage in the service/environment domain.

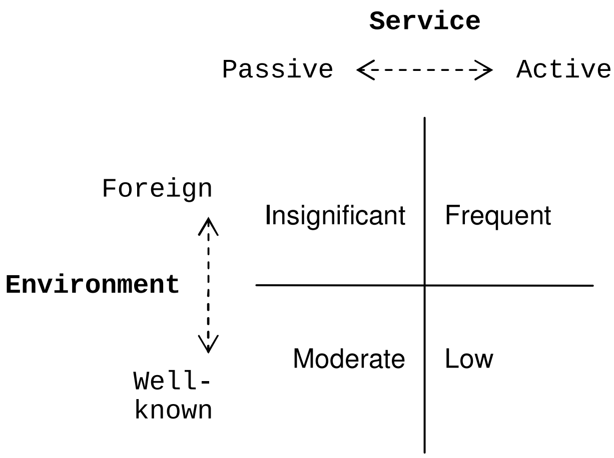

Figure 7. *Level of usage illustrated in the domain of service mode and traffic environment.*

Given those findings, is it possible to identify who is using the system in an active or passive manner? Does the survey data reveal any patterns on this subject?

Table 1 exposes, by correlation coefficients, an interesting relationship between mileage and a set of variables, representing passive usage. Respondents with a high annual mileage:

- Have their system switched on (basic usage) more than average.
- Use their system in a passive manner more than average.
- Value traffic information more than average.
- Value voice guidance less than average, which might indicate a tendency to switch off the sound.
- Value the function orientation and situation awareness more than average.

All in all this is indicating that respondents with a high annual mileage, most likely experienced drivers, regularly use the navigation system as a decision support tool for manual routing, backing their local knowledge.

Another interesting relationship, also illustrated in table 1, is found when studying users with high computer skills. The correlation table suggests that this category

- Use their system actively in well-known environments more than average, meaning they configure the system though having local knowledge.
- Experience less impact than average on traffic attention when interacting with the navigation system.
- Value all functions more than average, but specially the address and POI search capabilities.

It seems, generally speaking, as if users with high computer skills have a somewhat more active behavior, when operating the navigation system, than the average user. They tend to use more functionality, use it more often and without worrying so much about safety considerations.

	Mileage	Computer Skills
Level of basic system usage - foreign environments	**-0,22**	0,16
Level of basic system usage - well-known environments	**-0,32**	0,13
Level of active system usage - well-known environments	-0,13	**0,37**
Level of passive system usage	**-0,41**	0,03
Value of real-time traffic information	**-0,27**	0,31
Preferred source of guidance information	**0,46**	-0,22
Level of reduced traffic attention at system interaction	0,17	**-0,26**
System value in sense of orientation and situation awareness	**-0,29**	0,27
System value in sense of destination search	-0,07	**0,30**

Table 1. *Correlation coefficients.*

4.3 Routing

It is reasonable to believe that routing quality has impact on system assessment, and thereby behavior. A user always being disappointed with the proposed route will probably avoid configuring the system when he or she has acceptable local knowledge. Therefore, one of the survey questions addresses subjective routing quality. The respondents were asked about the correspondence between the proposed system route and the route of their personal preference, all given a well-known environment.

Approximately 65 % of the respondents are satisfied enough to rate the correspondence as significant or reasonable. This measure is clearly very subjective, but the result still indicates that the users are fairly satisfied with the routing quality offered by the navigation system.

4.4 Traffic Information

Real-time traffic information is often considered a key in the struggle to increase user value of in-car navigation. To understand the opinion of the users, and potential impact on behavior, this survey contained two questions on this issue. First, the respondents where asked about how they value traffic information generally. The question was not followed by a discussion on definitions etc.

Studying variable 18, see appendix, we can tell that a vast majority of the navigation system users consider real-time traffic information a valuable service. However, there is a group of approximately 15 % with the opinion that traffic information is of rather low value or insignificant value.

Second, as a subjective quality measure, the respondents also were asked to rate the level of correspondence between the received traffic information and its real-world equivalence. This is an indication on whether the users look upon the received traffic information as accurate or not.

Figure 8 is a rather ambiguous illustration of the user opinion in this matter. Only a fraction considers the level of correspondence as significant, which is the highest rating. On the other hand as much as 50 % choose reasonable correspondence, which is the second highest rating. The rather irregular distribution might be an indication on different interpretation of the question. Nevertheless, the high rating makes it reasonable to believe that the users look upon the received traffic information of today's services as fairly accurate. It is important to point out that this conclusion refers to accuracy of received messages. It does not reflect whether the proper amount of information is received. Neither does it deal with the question about information value.

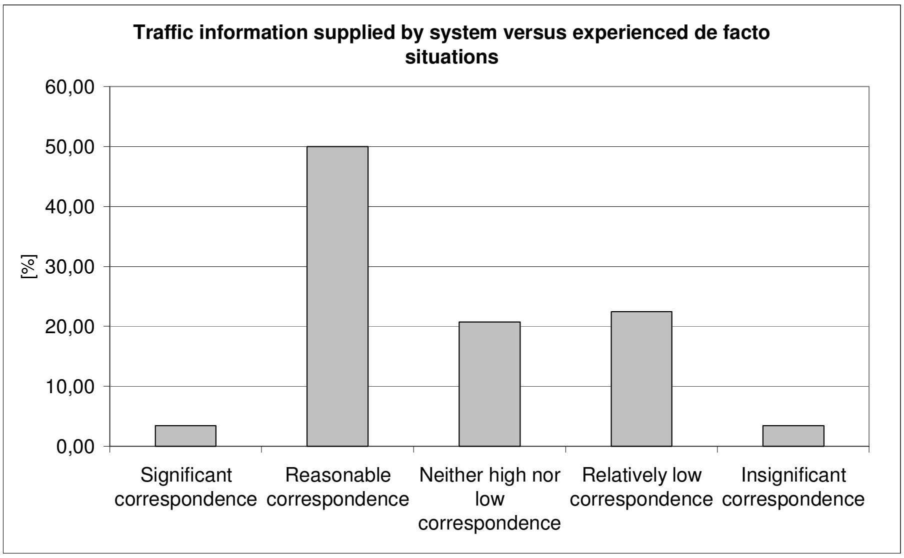

Figure 8. *Correspondence between traffic information and its real-world equivalence.*

4.5 Safety Considerations

The navigation display is a controversial component of the system. Many investigations confirm that secondary tasks, as navigation usage or telephone conversations, have negative impact on the driving performance. The visual distraction is clearly one of the main factors. It is reasonable to expect that users pay attention to safety aspects and therefore intentionally change their behavior.

One interesting subject on this topic is whether the users experience any reduced attention on the surrounding traffic when they are using the navigation system. The respondents were asked to rate the level of reduced attention at ordinary usage and at system interaction. Here ordinary usage is defined as simply following system guidance, while system interaction means active operations such as configuring a destination. Figure 9 confirms that the users recognize that employing the system does affect their attention, but only to a quite limited extent. However, the figure also shows that system interaction has a far greater impact. As much as 65 % consider the attention clearly or significantly reduced when interacting with the system during driving. Hence, this indicates that the users acknowledge that using the system has an impact on their attention of surrounding traffic, though limited. However, interacting with the navigation system has a far greater impact, clearly reducing the attention.

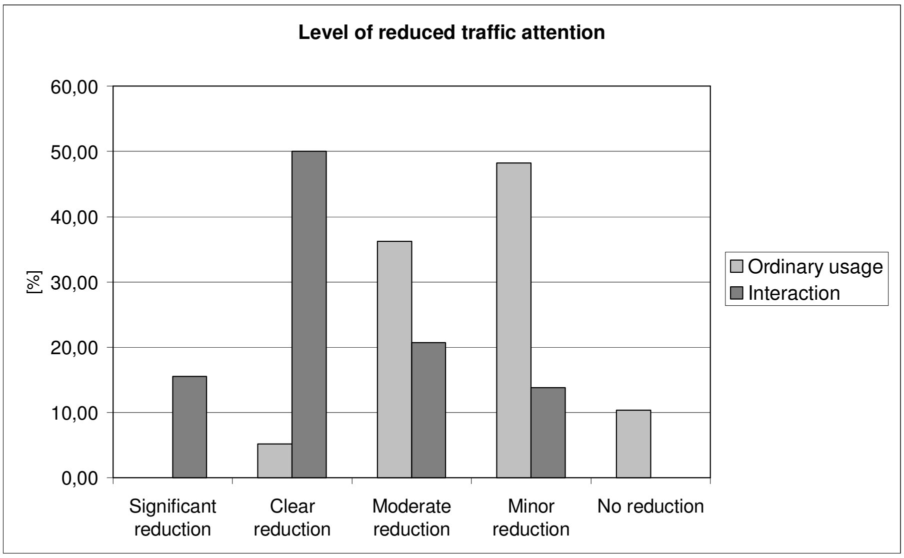

Figure 9. *Level of reduced attention on surrounding traffic when using the navigation system.*

The survey confirms that users employing the system frequently tend to experience less impact on the attention on the traffic situation, both at normal usage and at interaction.

5. Discussion

The analyzed end-user survey is dedicated to in-car navigation usage – as practiced. Many lessons are learned, but some issues call for special attention. First, the survey provides a clear answer to the question whether driving context has impact on system usage. When driving in a foreign traffic environment the participants frequently use the navigation system. However, the study also shows that it is only moderately used when driving in a well-known environment. Therefore, driving context, in sense of *where* the journey is carried out, has a clear impact on the level of usage.

Second, the survey illustrates *how* user behavior is related to driving context. In a foreign traffic environment the users basically always employ the system in an active manner. By the expression *active* we refer to a use case where a destination is set, route calculated and guidance provided. However, when employing the system in a well-known environment users seem to prefer a passive usage, without configuring a route, and thereby focusing on orientation and situation awareness.

The study also exposes individual differences in system employment. For example, the survey indicates that drivers with a high annual mileage regularly use the navigation system as a decision support tool for manual routing, backing their local knowledge. Further, we can see a tendency that users with high computer skills have a somewhat more active behavior, when operating the navigation system, than the average user. They use more functionality, use it more often and without worrying so much about safety considerations.

Finally, is it possible to explain the findings by drawbacks of the accepted design rationale? We have identified a clear difference in system usage; a majority of the respondents seldom use the system at all in well-know environments, while those doing so prefer a passive service. The questionnaire does not provide unambiguous information on the reason to this behavior, but it is reasonable to believe that the users simply lack relevant support in this driving context.

Today's systems are aware of position, vehicle motion, destination and numerous of other parameters. However, they are completely unaware of fundamental issues as the driver's local knowledge, experience of driving in a specific area or simply personal preferences of driving or system interaction. Therefore, extended context-awareness seems to be a key to a broader design rationale, considering a wider range of driving contexts.

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Appendix – Survey Data

This appendix summarizes all variables of the survey. Each variable is identified by a tag (var #). Further, each variable is defined by type, description, coding and interpretation of the coding. Finally, the survey statistics is provided in sense of frequency, percentage, mean and standard deviation for each variable.

Var #	Type	Description	Interpretation	Coding	Statistics #	Statistics %	Statistics μ	Statistics σ
1	Rat.	Age	Respondent age [years]	-	-	-	45,3	8,8
2	Nom.	Gender	Male	1	45	77,59	-	-
			Female	2	13	22,41		
3	Nom.	Marital status	Married	1	44	75,86	-	-
			Cohabiting	2	5	8,62		
			Single	3	9	15,52		
4	Rat.	Family status	Number of children living at home	-	-	-	1,50	1,27
5	Rat.	Mileage	Annual milage [100 km]	-	-	-	343	103
6	Ord.	Education level	PhD or equivalent	1	0	0,00	2,66	0,93
			University degree, more than two years	2	37	63,79		
			University degree, less than two years	3	5	8,62		
			High school	4	15	25,86		
			Compulsory school, 9 years	5	1	1,72		
			Compulsory school, less than 9 years	6	0	0,00		
7	Ord.	Computer Skills	Expert	1	3	5,17	2,36	0,67
			Considerable skills	2	34	58,62		
			Moderate skills	3	18	31,03		
			Some skills	4	3	5,17		
			Insignificant skills	5	0	0,00		
8	Nom.	Habitation	Large city (> 250.000 inhabitants)	1	35	60,34	-	-
			Metropolitan area	2	14	24,14		
			Average city (~100.000 inhabitants)	3	1	1,72		
			Small town (~20.000 inhabitants)	4	1	1,72		
			Countryside	5	7	12,07		

Var #	Type	Description	Interpretation	Coding	Statistics			
					#	%	µ	σ
9	Nom.	Primary Car Usage	*Work-related long distance trips* and *Work-related short distance trips* are the two most important types of usage	1	0	0,0	-	-
			Work-related long distance trips and *Travelling to and from work* are the two most important types of usage	2	2	3,45		
			Work-related long distance trips and *Private long distance trips* are the two most important types of usage	3	7	12,07		
			Work-related long distance trips and *Private short distance trips* are the two most important types of usage	4	1	1,72		
			Work-related short distance trips and *Travelling to and from work* are the two most important types of usage	5	1	1,72		
			Work-related short distance trips and *Private long distance trips* are the two most important types of usage	6	3	5,17		
			Work-related short distance trips and *Private short distance trips* are the two most important types of usage	7	1	1,72		
			Travelling to and from work and *Private long distance trips* are the two most important types of usage	8	13	22,41		
			Travelling to and from work and *Private short distance trips* are the two most important types of usage	9	8	13,79		
			Private long distance trips and *Private short distance trips* are the two most important types of usage	10	22	37,93		

Var #	Type	Description	Interpretation	Coding	Statistics			
					#	%	µ	σ
10	Nom.	Employment Status	Self-employed	1	0	0,00	-	-
			Employed manager	2	22	37,93		
			Employed	3	36	62,07		
			Retired	4	0	0,00		
			Others	5	0	0,00		
11	Ord.	Income	Over 550.000 SEK/Year	1	11	18,97	2,66	1,42
			450.000 <-> 549.999 SEK/Year	2	20	34,48		
			350.000 <-> 449.999 SEK/Year	3	17	29,31		
			250.000 <-> 349.999 SEK/Year	4	4	6,90		
			Less than 249.900 SEK/Year	5	0	0,00		
			No answer	6	6	10,34		
12	Ord.	Level of basic system usage - foreign environments	Basically always	1	37	63,79	1,52	0,82
			Often	2	14	24,14		
			Sometimes	3	6	10,34		
			Seldom	4	0	0,00		
			Basically never	5	1	1,72		
13	Ord.	Level of basic system usage - well-known environments	Basically always	1	13	22,41	3,22	1,50
			Often	2	6	10,34		
			Sometimes	3	8	13,79		
			Seldom	4	17	29,31		
			Basically never	5	14	24,14		
14	Ord.	Level of active system usage - foreign environments	Basically always	1	38	65,52	1,50	0,80
			Often	2	13	22,41		
			Sometimes	3	5	8,62		
			Seldom	4	2	3,45		
			Basically never	5	0	0,00		
15	Ord.	Level of active system usage - well-known environments	Basically always	1	0	0,00	3,93	0,88
			Often	2	2	3,45		
			Sometimes	3	18	31,03		
			Seldom	4	20	34,48		
			Basically never	5	18	31,03		

Var #	Type	Description	Interpretation	Coding	Statistics #	%	μ	σ
16	Ord.	Level of passive system usage	Basically always	1	12	20,69	3,02	1,38
			Often	2	9	15,52		
			Sometimes	3	12	20,69		
			Seldom	4	16	27,59		
			Basically never	5	9	15,52		
17	Ord.	System routing versus individual preference	Significant correspondence	1	4	6,90	2,41	0,84
			Reasonable correspondence	2	34	58,62		
			Neither high nor low correspondence	3	13	22,41		
			Relatively low correspondence	4	6	10,34		
			Insignificant correspondence	5	1	1,72		
18	Ord.	Value of real-time traffic information	Of great value	1	25	43,10	2,07	1,15
			Valuable	2	14	24,14		
			Reasonable value	3	10	17,24		
			Rather low value	4	8	13,79		
			Insignificant value	5	1	1,72		
19	Ord.	Traffic information versus experienced de facto situations	Significant correspondence	1	2	3,45	2,72	0,97
			Reasonable correspondence	2	29	50,00		
			Neither high nor low correspondence	3	12	20,69		
			Relatively low correspondence	4	13	22,41		
			Insignificant correspondence	5	2	3,45		
20	Ord.	Preferred source of guidance information	Voice messages only	1	0	0,00	3,59	0,75
			Mainly voice messages	2	2	3,45		
			Voice and display is of equal importance	3	27	46,55		
			Mainly display information	4	22	37,93		
			Display information only	5	7	12,07		
21	Ord.	Level of reduced traffic attention at ordinary system usage	Significant reduction	1	0	0,00	3,64	0,74
			Clear reduction	2	3	5,17		
			Moderate reduction	3	21	36,21		
			Minor reduction	4	28	48,28		
			No reduction	5	6	10,34		
22	Ord.	Level of reduced traffic attention at system interaction	Significant reduction	1	9	15,52	2,33	0,91
			Clear reduction	2	29	50,00		
			Moderate reduction	3	12	20,69		
			Minor reduction	4	8	13,79		
			No reduction	5	0	0,00		

Var #	Type	Description	Interpretation	Coding	Statistics			
					#	%	µ	σ
23	Ord.	System value in sense of orientation and situation awareness	Of great value	1	19	32,76	1,90	0,79
			Valuable	2	28	48,28		
			Reasonable value	3	9	15,52		
			Rather low value	4	2	3,45		
			Insignificant value	5	0	0,00		
24	Ord.	System value in sense of route planning	Of great value	1	26	44,83	1,91	1,03
			Valuable	2	18	31,03		
			Reasonable value	3	7	12,07		
			Rather low value	4	7	12,07		
			Insignificant value	5	0	0,00		
25	Ord.	System value in sense of guidance	Of great value	1	39	67,24	1,34	0,51
			Valuable	2	18	31,03		
			Reasonable value	3	1	1,72		
			Rather low value	4	0	0,00		
			Insignificant value	5	0	0,00		
26	Ord.	System value in sense of destination search	Of great value	1	39	67,24	1,38	0,62
			Valuable	2	17	29,31		
			Reasonable value	3	1	1,72		
			Rather low value	4	1	1,72		
			Insignificant value	5	0	0,00		
27	Ord.	System value in sense of traffic information	Of great value	1	23	39,66	1,97	0,97
			Valuable	2	18	31,03		
			Reasonable value	3	14	24,14		
			Rather low value	4	2	3,45		
			Insignificant value	5	1	1,72		

Var #	Type	Description	Interpretation	Coding	Statistics #	%	µ	σ
28	Nom.	Functional prioritization	*Orientation and situation awareness* and *Routing support* are the two most important reasons for navigation system usage	1	2	3,45		
			Orientation and situation awareness and *Route guidance* are the two most important reasons for navigation system usage	2	4	6,90		
			Orientation and situation awareness and *Address and POI search capability* are the two most important reasons for navigation system usage	3	4	6,90		
			Orientation and situation awareness and *Real-time traffic information* are the two most important reasons for navigation system usage	4	1	1,72		
			Routing support and *Route guidance* are the two most important reasons for navigation system usage	5	6	10,34		
			Routing support and *Address and POI search capability* are the two most important reasons for navigation system usage	6	3	5,17		
			Routing support and *Real-time traffic information* are the two most important reasons for navigation system usage	7	0	0,00		
			Route guidance and *Address and POI search capability* are the two most important reasons for navigation system usage	8	25	43,10		
			Route guidance and *Real-time traffic information* are the two most important reasons for navigation system usage	9	10	17,24		
			Address and POI search capability and *Real-time traffic information* are the two most important reasons for navigation system usage	10	3	5,17		