# Evaluation of a Driver Assistant Client in the Context of Urban Logistics and Electric Vehicles

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***Abstract*—The use of Electric Vehicles (EVs) is limited. Uncertainty concerning the short range and the lack of solutions matching the users needs are factors that hinder widespread use of the technology in business and logistics contexts. In Smart City Logistik (SCL) project, a Driver Assistant Client (DAC) was developed to help to overcome fears, limited information and uncertainty in the context of urban logistics. To evaluate the users needs and intentions, an iterative and open approach was designed and consequently used. Triangulation helped to get the best possible insights out of each of three phases of development and the findings were used to improve the DAC. The beginning of the project was accompanied by a lot of uncertainty, so qualitative information was gathered to understand how the drivers work routines look like and which attitudes towards new technologies prevailed. A more quantitative approach helped to gather a broad range of opinions on specific usability topics, before the actual users will be asked about their daily experience with the system. This agile and iterative approach helped to identify important aspects while designing the DAC and to compare different solutions, e.g. regarding important functionalities, menu-structure, font, button-size, and other parameters. The implementation of these findings enabled the project partners to develop a broadly accepted user interface and system that will be used in electric vehicles in urban logistics.**

***Keywords*–*Survey; Usability; Electric Vehicles.***

## I. INTRODUCTION

Since the need of delivering goods increased massively in the past decade and will increase further in the next years [1], the use of Electric Vehicles (EVs) for last-mile delivery could help to reduce substantially the air and sound pollution, especially in inner cities. In fact, most researchers agree that even well beyond 2020, the capacity of batteries will not fit future range demands [2]. This restriction affects especially available EVs, that are designed for the transportation of goods. Therefore, many companies have qualms to use this new technology because of range limitations, low density of recharging stations and long charging time [3]. Nevertheless, no matter which technological restrictions appear with EVs compared to traditional vehicles, for most companies it all comes down to the ability to plan the vehicle usage, including the certainty that the planed tour can be done. In fact, many companies interviewed during the Smart City Logistik (SCL) project, have already tours within the range of an EV, or at least are able to adopt tours with little effort. The research project SCL pursues the goal to develop such a system, that provides important information on EV-specific restrictions and helps to overcome fears and to support the usage within urban logistics. As part of the German special federal research program for Information and Communication Technologies for Electric Mobility II (ICT II) [4], the SCL project supports the integration of EVs in fleets through the usage of Information and Communications Technology (ICT).

One of the most important parts in such a holistic system is the assistance of the driver. In a complex socio-technical system where EVs are used within urban logistics, the driver needs to cope with additional information (such as range, battery status, etc.) in order to fulfill his main task of delivering goods. To reduce stress and uncertainty resulting from these important additional parameters, a Driver Assistant Client (DAC) focussing on the needs of drivers was developed, evaluated and implemented as a prototype during the SCL project. Therefore, a concept for technology assessment was developed, combining existing methods from social and computer sciences for the specific project. In an agile managed project, we needed to focus on methods, that provided flexibility and direct user feedback to overcome different phases of non-knowledge, that came along with the novelty of the topic. The results help to achieve the goal, to develop and improve mockup and demonstrator along the users needs. This general concept can be applied to other projects in the field of computer-human interaction, that are confronted with similar conditions and challenges regarding uncertainty and user expectancies.

In Section II existing work regarding the DAC and the prototype evaluation will be outlined briefly, before a more detailed overview on the problem, the purpose of the DAC and its main functionality will be given (Section III). Subsequently, the research design to improve the DAC in an iterative procedure and to assess the users expectancies will be outlined. It consists of three main qualitative and quantitative surveys: In a first step, seven drivers were interviewed to get insights into their daily routines and attitudes towards supporting technology (Section IV) and the findings were used to build the prototype (Section V). Secondly, 43 participants tested two different DAC prototypes and evaluated them with a focus on usability (Section VI). The third part includes the development of the functional demonstrator and is accompanied by a beta-phase with a few drivers of EVs, followed by a qualitative interview. Additionally, a simulator-based test with a higher number of participants from logistic companies is part of the research design (Section VII). Finally, a short outlook and critical reflection of the used approach and the gathered results will conclude this paper (Section VIII).

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## II. State of the Art

Previous work on methods for software design show a broad range of techniques, that can be applied in different development stages. Cognitive walkthroughs, heuristic evaluation, formal usability inspections [5] offer interesting and valuable insights in a development process. More theoretical work focusses on the users needs and expectancies as relevant factors for technology acceptance. Factors that influence the use of a socio-technical system cover the perceived usefulness, the attitude towards using a technology and others [6], [7]. Other work in the field of DACs or EVs point out important factors, that are relevant in the given context [8], but focus too much on the economic decisions of private households and cannot be adapted completely to our project. Unfortunately, knowledge about important factors while using the DAC in a commercial context in EVs, is rare. When it comes to a long-term research project in a field, where user acceptance is rather unknown, a flexible methodology is needed, that provides different forms of knowledge in different project stages. Therefore, methods from social sciences were used. A qualitative research part is used to gather knowledge [9] and quantitative research helps to evaluate existing knowledge and design with a broader range of participants [10].

## III. The Driver Assistance Client

In the context of urban logistics, the driver has to cope with a lot of information, which often comes along with stress and the insecurity about the actual range of an EV. Since the range depends on a lot of parameters (e.g., battery capacity, driving speed, weather conditions, weight, etc.), the consideration of all those influencing parameters would be a complex process while driving. To reduce stress and eliminate insecurity, the DAC was developed. Basically, it works as a navigation system, providing optimized routes for EV, considering different range-affecting parameters of the vehicle while focussing on the planned tour. At the start of a tour, the driver can retrieve the tour on the DAC, which is already optimized and considers all parameters for the EV he is using. During the tour, the driver will be navigated to each point, and informed about possible changes of the tour and all relevant information (e.g., traffic and weather conditions). Hereby the driver is relieved from thoughts about the range of the vehicle, because the tour is always optimized and adapted to changes, so that the driver will be able to perform his tour and drive back carefree to the starting point.

Since the DAC should assist the driver while driving and reduce the added complexity, it needs to be easy-to-use in a vehicle. To find an optimal way to support the driver we elaborated an approach for the realization of the DAC, where in each iteration the acceptance and usability has been evaluated systematically. The findings were used to improve further versions of the DAC.

## IV. The Interview

In theoretical discourses on technology use, EV and driver assistance systems, different factors, that influence the attitude, expectations, and acceptability towards these technologies in general public, are described [6, p. 188] [7, p. 447]. Beside these common factors, there may be specific ones among employees in logistics who use EV, that result from their specific situation (e.g., the employer-employee relationship leads to an involuntary use of the system). In the first place, the professional drivers need to perform their work task without unwanted disruptions by technological peculiarities and EV-specific uncertainties. To overcome the theoretical debate on barriers and drivers of technology acceptance, empirical evidence was gathered in qualitative interviews. Seven drivers from different companies were interviewed, using a semi-structured guide that was developed in advance. The interviewees were asked about their individual common work tasks, their attitude towards new technologies in general and EVs in detail, their expectations towards a DAC and some demographic items as well as their employment biography. A content analysis of the interviews was conducted and the deductive-inductive creation of categories [11] shed light onto possible acceptance factors and requirements regarding a DAC in EV-based urban logistics. In theoretical debates, the general acceptance factors are described as perceived usefulness, perceived ease of use, the attitude towards using a technology [6, p. 188], and some models include the behavioural intention to use the system as well. These factors are influenced by moderators such as subjective norms, experience, the image of a technology, job relevance, output quality or the the voluntariness of use for example [7, p. 447]. We found empiric evidence in the interviews regarding these items. Using the computer-assisted qualitative data analysis software f4analyse [12], we found out, that the drivers tend to prefer a passive system, that gives them useful information on important events during their tour, while not forcing them to act in a single, specified way. Other hints pointed in the direction of up-to-date maps, estimation and inclusion of time and range restrictions, the ease of use of and favoured support while implementing the system. These important factors for technology users were considered, while developing the first versions of the DAC.

## V. Building the Prototype

Taking into account the requirements that were identified in the interviews, as well as previous research, a first horizontal prototype was developed. Horizontal means in this case, that the prototype has no real functionality, and was designed as a draft for the evaluation of the user interface. Figure 1 shows the tour overview and Figure 2 shows the information overview of the prototype. Both figures offer an impression of the main design. The main menu has been arranged on the top to allow switching directly between the main views such as tour information, navigation, map, vehicle status, direct call, messages and common information. To allow the navigation through different information, the submenu is arranged on the left side in each view. Since the DAC should be used on a mobile device with touch screen, big buttons were used, enriched with understandable and clear icons. After login the user directly views the tour overview with all relevant information on stops and clients. While driving, the user will mainly use the navigation view, which represents the route guidance.

During the development of the first prototype, some details of the design were questioned. So, a second prototype was build, which offers the same basic functionality, but has a slightly different User Interface (UI) regarding the views. Figure 3 shows the tour overview for the second prototype. The main menu is also situated on the top of the screen and the submenu also on the left side, whereas the view of the

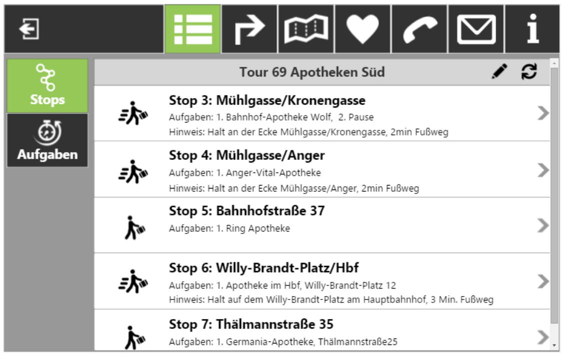


Figure 1. Tour overview of prototype 1


Figure 3. Tour overview of prototype 2

content is divided into two parts, the item list and the content of the selected item. In prototype 1, the list disappears when an item is selected, in prototype 2 the item list remains visual, so the user can always see which item is currently selected.

Another difference compared to prototype 1 is the overview of the main menu shown in Figure 4, which shows up directly after login. This should provide an overview about all available functionalities. Creating two prototypes allowed to evaluate more options and the advantages and disadvantages from slightly different views. The evaluation itself and the results are described in the next section.

## VI. Prototype Evaluation

After developing the first two DAC-prototypes, possible users were asked for feedback in an online survey, targeting possible difficulties that may appear while using EVs in logistics. Before the users performed some basic tasks using the two prototypes, they were asked about different aspects of usability, using a standardized questionnaire focussing on the EN ISO 9241-110 norm [13] , which was slightly adapted to the research context. For questions regarding the functions of the DAC, perceived ease of use, and intuitiveness, the user was asked to rank the specific characteristics of the prototypes on a 7-step-scale and to add qualitative information in free-text fields. Due to limitations in availability of interview partners at the partner companies who took part in the research project (and the resulting inefficiency to carry out the study on-site), an online questionnaire was developed using LimeSurvey [14], and an additional device with the DAC prototypes was brought to the partner companies. In each company, a contact person was instructed and responsible for conducting the evaluation. The access to the questionnaire was restricted by a 6-digit access code, which was handed out to the interviewees by the contact person in an envelope with some further instructions on the evaluation procedure. While the code itself was in a non-personalized envelope, it was possible to track the respondents company and the order in which both prototypes were evaluated. The evaluation order was randomized based on the access code, which also made it possible to match the answers to the proper prototype. With this step, distortions as a result of answer patterns were prevented and this procedure offered a high level of de-personalization. The online questionnaire was accessible for a period of 14 weeks and the users were able to participate independently, at their individual best point in time. When participating, the users opened the envelope, accessed the online questionnaire and answered some basic questions before the first prototype was shown on the second screen. After performing some tasks, the users were asked to answer questions and rate the usability of the prototype, before the same procedure started for the second prototype. The questionnaire concluded with free-text fields for ideas of improvement and some demographic questions.

With this approach, standardized and comparative information, as well as qualitative insights into the perceived usability of the two evaluated prototypes were gathered from 45 users. While 2 answers were excluded from the analysis due to reasonable doubt of sufficiency (e.g., when the evaluation of DAC was carried out in just a few seconds), the remaining 43 cases gave us some interesting insights on the usability

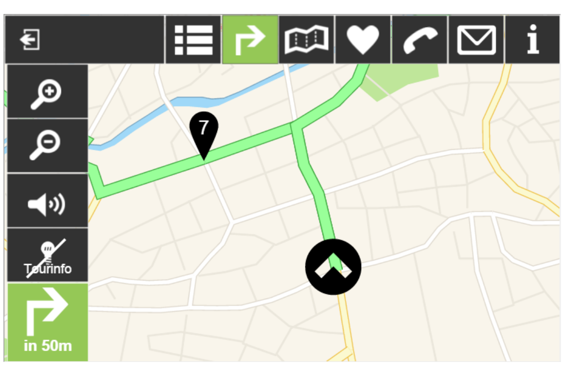


Figure 2. Navigation view of prototype 1

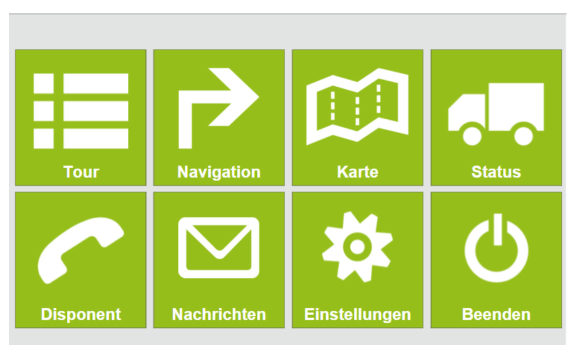


Figure 4. Main menu of prototype 2


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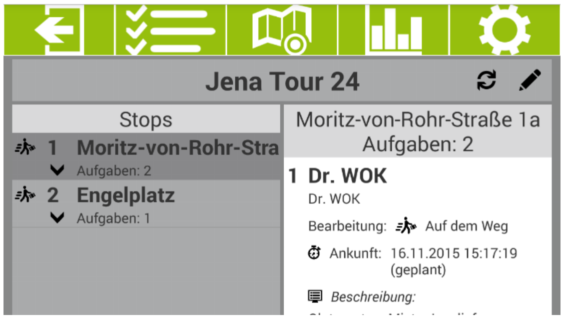


Figure 5. Tour overview of the demonstrator

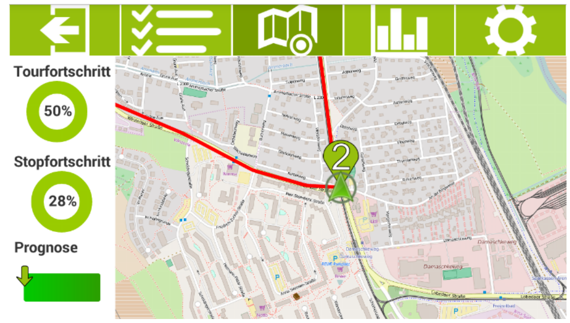


Figure 6. Navigation view of the demonstrator

of the evaluated prototypes. So it turned out that, in general, none of the two prototypes was evaluated better than the other. According to our SPSS analysis, prototype 1 showed better results regarding the usability, while prototype 2 achieved better results in clearness of the design and intuitiveness. Based on these results, a set of adaptations was elaborated. Basically, it combines the positive characteristics of both prototypes. Finally, these adaptations were used to build a functional demonstrator of the DAC, which is described in the next section.

## VII. The Functional Demonstrator and Evaluation

The most important difference regarding the prototypes and the demonstrator is that the latter is fully functional. Compared to the indicated functionality of the prototypes, the demonstrator has been reduced, based on the results of the evaluation. The remaining main functionality covers the tour overview, turn by turn navigation, status overview and settings. Figure 5 shows the tour overview and on the upper border the main menu. The submenu has been removed completely, so that the available space could be used in a better way. Also, the navigation view has been improved by removing unimportant buttons, such as the zoom in and out buttons (see Figure 6). To save space and reduce complexity, the vehicle status and common information (e.g., weather, traffic, etc.) have been merged into the status overview, and the direct call and messages views have been removed.

After two iterations, the DAC has been implemented as a fully functional demonstrator based on the recommendations. To ensure a high quality and a high usefulness, another iteration step will conclude the project. In order to get further information about usability, the driver should use the DAC during his normal working day. To collect more data on possible insufficiencies, two final evaluations will be carried out. The first one will target drivers with experience in driving EVs in an EV-logistic context and will be performed as a qualitative interview. The second one will focus on drivers without specific EV-experience and is planned as a quantitative questionnaire.

For the first evaluation, drivers from the participating companies will use the DAC during their normal working day for a period of two months. Finally, they will be asked about their experiences using the DAC in a semi-structured interview, to bring to light possible deficits regarding usability. The results will be generated through a content analysis, similar to the approach described in Section IV. Due to the fact that only a few drivers at the partner companies can participate while actually using EVs and the DAC, the significance of the results is restricted as a consequence. To overcome this problem, the demonstrator will be evaluated by a higher number of professional drivers in Eltrilo [15], a simulator that was developed during the SCL project and is capable of simulating a real world environment based on map data. Specific scenarios (e.g., transportation from a hub into town with multiple stops) can be simulated and be part of the evaluation. In order to use Eltrilo, the DAC will be installed into the simulator and connected to the live-system via a mobile network connection. In a first step, the participants will get some detailed instructions on what they should do on their tour and use the DAC while performing their tasks in the simulator. During the simulation, some events affecting the tour will be triggered, in order to simulate unpredictable changes of plans. In a second step, the participants will be asked to answer some questions on their experience in the the demonstrator, as well as questions regarding usability. The approach is similar and comparable to the investigation described in Section VI but bases on the improved demonstrator.

This approach guarantees valuable insights from qualitative interview data as well as a usability evaluation by a broad range of possible users. The results can be compared to earlier research and help to improve the system in further development stages.

## VIII. Conclusion and Future Work

The development of a technological solution requires multiple iteration steps, a fact that is crucial for the evaluation and that is considered in the presented research design: opening up for qualitative information in the beginning of the project, where knowledge is limited and uncertainty about important acceptance factors is high, before focussing on the gathered knowledge and comparable evaluation questions with regard to existing norms and standards, is one way to assess technology development and to gain valuable information on user expectancy and experience. Due to the agile project management, the technology evaluation has to be open at any point in time for new information and changes, and needs to combine a variety of existing qualitative and quantitative research methods. This helps to achieve the best possible results, that can be implemented in further technology development.

The first interview showed important aspects in the drivers daily work routines, that had to be considered while developing the DAC. A passive system, that gives hints and relevant, up-to-date information is preferred by the drivers. The prototype evaluation revealed the positive aspects of two slightly different mockups that were implemented in the functional demonstrator. Two iterations resulted in a fully functional prototype of the DAC, which is broadly accepted by possible users. The third iteration step will include two parts, focussing on qualitative information from a small number of real world EV-users as well as a higher number of professional drivers, using a driving simulator. Both evaluations should help to identify final enhancements regarding usability.

Finally, these results will help developers while creating DACs in the context of EVs. As a next step, the evaluation can be carried out by a higher number of participants from different contexts (e.g., private users as well) to find additional use cases for the developed technological system.

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