Development of a Smartphone App for Efficient Driving of Electric Cars

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1 Introduction

1.1 Relevance and motivation

In times of scarce and highly priced oil, mobility must continue to be affordable. Electric mobility (e-mobility) is a central field of action. Today, Germany can be a worldwide, highly esteemed pioneer for a climate friendly and sustainable energy and traffic policy. The government has ambitious goals. That is why a lot of projects dealing with e-mobility have been initiated. For example, the project "BeMobility" supported by the Federal Ministry of Transport, Building and Urban Development, wants to integrate e-mobility on the public transport system.[1] Within the project, the integration of electric cars (e-cars) into existing Carsharing fleets of Flinkster, a Carsharing provider of the Deutsche Bahn, plays an important role. E-Carsharing reaches a large number of potential users with the objective to reach a high degree of public awareness and acceptance. Although there are a number of projects dealing with e-mobility, the acceptance is limited.[2] The high level of uncertainty with e-cars is due to the limited range and the high acquisition costs.

To influence the efficiency of driving and maximize the range, the driver has a crucial role as optimizer with regard to the driving behavior. The manner in which the car is driven and other factors, like the use of air conditioning systems, affect consumption of electricity and consequently the limited range and the wear of the battery etc..

To support the lifetime of an e-car as long as possible, the driver should receive additional information and specific signals for efficient driveability. To this end, the e-car yields data which gives information on driveability. This data has to be collected to achieve the desired driveability. The data passes directly through an interface to the driver and leads to a desired behaviour.

[1] cf. DB FuhrparkService (2013).
[2] cf. Götz, K. et al (2011), p.47.

The increasing use of smartphones supporting this man-machine interface. Resulting data from the vehicle can for example be transferred via Bluetooth, to the smartphone. Therefore, a specific mobile application (app) is needed that transfers the acquired data to the driver. For example the braking behavior could be provided to the driver, because energy recuperation during braking is important for e-cars. The aim is to improve the awareness for energy and operating efficient driving and to provide the driver with an anticipatory driving style. This data can also be used to compare an e-car with a conventional car based on driven routes, which give information about costs and carbon dioxide (CO_2) emissions. The driver can get a good feeling for doing something for the environment and sustainability.

1.2 Objective and structure of the Master Thesis

The objective of this thesis is to analyze factors for efficient driving of e-cars. These factors will be used for developing a smartphone app, which will be described in detail during this thesis. Not only should the driving behavior be a factor, but also the environmental awareness should be further strengthened and therefore e-cars should be compared to conventional vehicles.

The following chapter describes the theoretical background of app development and factors for efficient driving of e-cars. In chapter 3, the target group and competitors are identified and an evaluation method for efficient driving is worked out which will be integrated into the app. Furthermore, critical success factors of app development are considered before the developing process itself is demonstrated in chapter 4 and 5. Finally, findings are discussed and the thesis is finalized with limitations and an outlook for further research.

Accordingly, by getting a brief explanation, mistakes should be avoid during use. This page is a static page where no controller is needed. Therefore there is no need for a separate model and this page is integrated into the model Driving Results.

6 Final consideration

6.1 Summary of the achieved findings /conclusion

The objective of this thesis is to develop a smartphone app that analyzes the driving behavior and strengthens the environmental awareness when driving e-cars. The app should provide a man-machine interface between the driver and the e-car because the driver has a great influence on an e-cars range, lifetime etc. with the individual driving behavior.

Therefore, four functions are derived for the app which have to be implemented within the development process. Pre-identified success factors and barriers are defined which have to be considered during development. The success factors and barriers affect an interdisciplinary view on the dimensions technology, economic and e-mobility to develop an app which is successful in the market for as long as possible.

The first function of the app is a real-time analysis of the driving behavior. Therefore, factors for efficient driving of e-cars have to be identified, which should be integrated into the app to evaluate same.

To determine these factors, the target group has been identified and thematically similar apps have been examined. With the help of a market overview it becomes clear, that factors for accelerating, the way of driving and braking have to be found to evaluate the driving behavior.

Based on this information an experiment has been conducted with the e-car "Stromos" and two different drivers. The same route was driven by an offensive driver and a defensive driver to generate two different data sets in order to determine factors for a good and poor driving behavior. Based on the two data sets the following connections were found, which have been validated with more data sets:

1) Acceleration: connection between the use of the gas pedal and the energy consumption.

2) Way of driving: average energy consumption based on the driven route (rural, urban or highway).

3) Braking: The use of the brake pedal which leads to no recuperation.

After identifying these factors, limited values for good, medium and poor driving behavior were determined. While driving, the relevant data for evaluating should be sent from the e-car to the smartphone. Within the function "real-time analysis" the app evaluated the delivered data and signals the driver via traffic lights if his driving behavior can be classifies as good, medium or poor.

Based on the real-time analysis, the next function is an overview page where the driver has an individual logbook. Therefore, data for energy consumption, driven km etc. are displayed for all real-time analyses for a particular driver. These two functions help the driver to adapt his driving behavior towards a more efficient driving of e-cars.

A further aim is to improve environmental friendly awareness. From the user´s perspective, e-cars are measured by conventional cars in every respect. Accordingly, factors like range, acquisition costs etc. will be compared to a conventional car. E-cars have clear benefits in consideration of CO_2 emissions. Therefore, the next function implemented into the app was a comparison of CO_2 emissions. The comparison is based on an e-car, an e-car in consideration of the German electricity production and a conventional car of same vehicle model of the driven routes during the real-time analysis.

Despite efficiency and environmental friendliness, e-cars have to meet other demands of to the product car. Therefore, the last function which was implemented into the app is a cost comparison. The cost comparison will be made between an e-car and a conventional car of the same vehicle model based on the current fuel and electricity prices for the routes driven during the real-time analysis.

6.2 Discussion

The potential of the app should be considered in respect to the development. In general it should be noted that the learning of a new development environment and the associated training period shortens the pure development time of the app. Accordingly, the app can be seen as a prototype. This prototype should now be discussed with the six characteristics of a quality software product (ISO/IEC 9126), shown in figure 44.

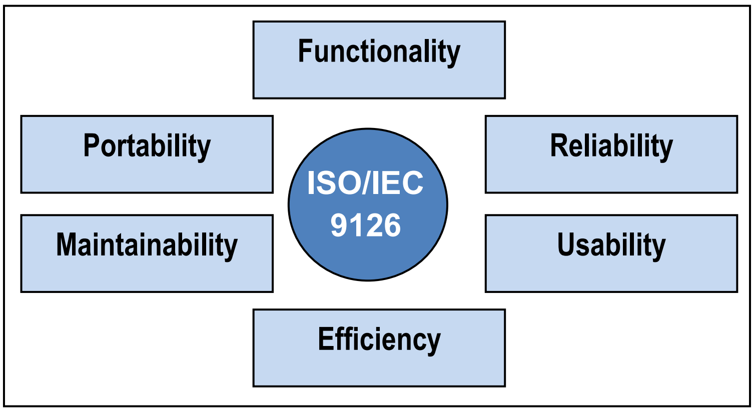

Fig.44. ISO/IEC 9126 Software engineering - Product quality
Source: ISO (1991)

Functionality shows whether all required functions are avaiable in the app. Functionality is the essential purpose of any product or service.[129] The app provides the four functions (real-time analysis, logbook, cost and CO_2 comparison) completely in detail. Therefore, the app responds to customer needs and fulfills the criterion functionality which is necessary for all other criterions. Each of the

[129] cf. ISO (1991).

following characteristics can only be measured when the functionality of the app is present.

Usability indicates whether the app is easy to use.[130] During the development process there has been a special focus on usability. The navigation is intuitive and well structured. Important information can be recognized at first glance. The user is guided through the app with the help of successive messages integrated via pop-up windows. In addition, error messages are integrated but these are not origin-related measures, only general error-messages. Previously, error-messages had to be revised, to show the user the respective error. All in all, the user has to put little effort into learning how the app works.

Maintainability checks if and how easily the app can be modified.[131] During the software specification phase it was defined that the app should be developed for various platforms. Therefore Rhodes was chosen because it offers one source code base for various platforms. The one source code base leads to the fact that maintainability does not involves a lot of time and expense. For example, if there is the wish change the layout of the app for all platforms, the layout has to be adapted within one file. The layout file implies the particular design for every platform. In addition, to simplify the maintenance work, the source code is added with inline comments. Furthermore, the models and variables are mainly termed intuitve. Especially the idiomatic of Rhodes supports the readability.

Portability affects the possibility to transfer the app to another environment.[132] With the aim to develop a cross-platform app, it is possible to use the app on all major platforms in principle. The installation varies with the platform. To use the app on Android, the app can be installed on the smartphone without great effort. Compared to Android, to use the app on an iPhone, it has to be offered in the App Store first and needs to be downloaded from there. Currently, the app is implemented for all Android smartphones. To offer the app on various platforms, the standard design from Rhodes has to be adopted. As mentioned above, the

[130] cf. ISO (1991).
[131] cf. ISO (1991).
[132] cf. ISO (1991).

standard design is defined in the layout file where it has to be changed. All in all with a manageable effort, a good portability is available.

Following the idea that a system is never 100% error-free, the reliability looks at the maturity of the app, fault tolarence and recoverability.[133] The app is situated at an initial point of the maturity.The user should not have the option to type in unrealistic entries. Within the app, the user has the possilitiy to make an entry at one point only. This is when he enters the electricity price for the cost comparison. There is no testing of a valid entry. It is possible, that previously this entry has to checked first to see if it leads to faults. Various practical tests will show if and where the weaknesses are within the app, because at the this time the reliability is difficult to evaluate.

Efficiency depends on how the quickly the system responds and how the system makes use of resources.[134] The app has an adequate response and processing time. The code, however, has weaknesses with regard to the efficieny. The prototyp provides all required functions but partly the aim is reached indirectly. For example, within the function "real-rime analysis" with the help of JavaScript at some points at the source code the view could be improved. The use of JavaScript within a Rhodes app is little documented by RhoMobile. Accordingly, the same result was achieved with Ruby source code. Therefore, arises for this function improvement potential.

To summarize, the app does not have the status of a quality software product up to now. With further development work and an improvement of reliability and efficiency the app can evolve to a high quality software. The RhoMobile Suite is a new product which leads to the fact that more and more documentations can be used for the app and the software will be improved over time. All of these general conditions should lead to an improvment and help to simplify to reach the status of a quality software product.

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[133] cf. ISO (1991).
[134] cf. ISO (1991).

6.3 Limitations and further research

Based on the discussion of the potential of the app and the previous development work, the confirmed limitations indicate the need for further research.

The necessary further development includes the integration of Rhodes GPS API and Bluetooth API. With the help of GPS, the driven km can be charged. Therefore, the difference between GPS coordinates has to be calculated and again the coordinates can be used for displaying the driven routes into Google Maps, for example. To a certain extent Google Maps has been integrated already but could not be integrated completely.

The Bluetooth API should connect the smartphone and the OBD2 adapter in an e-car. The programming code for integrating Bluetooth is given on the Rhomobile web site which has to be adapted for this app. For the connection between the iPhone and an OBD2 adapter via Bluetooth, the prevailing restrictions have to be taken into account.

Furthermore, with the integration of suggestions for improvement of the individual driving behavior an additional value of smartphones can be strengthened. The driver has the information before and after driving permanently available which help to learn about individual driving results. Furthermore, the driver can compare different routes and realize progress to more efficiently driving.

The integration of various e-cars is needed to allow the user to use the app for the most e-cars available on the market.

In addition, there are other functions which would be nice to have. An inclusion of auxiliary consumer use which is another great driver for energy consumption and completes the app in this direction. The app user needs to be aware that the use of for example air conditioning reduces the range of the e-car.

Another idea for an extension is a total cost of ownership consideration for the cost comparison between e-car and conventional car. This comparison is difficult to measure and needs accurate information on which the comparison takes place.

Besides the developing work, there is a need for further research. The app is implemented with all functions. The two phases of the development process - software validation and software evolution - have not yet fully passed through. For an evolution, practical tests within an e-car, one has to find out how the app behaves in reality.

Furthermore, the evaluation system for the driving behavior has to be validated with increased data sets. With a growing number of data, the limited values can be adapted exactly.

Currently during development, success factors and barriers of the technological and e-mobility dimension are considered. The economic dimension is taken into consideration with the size of the target group only. Accordingly, a business model has to be worked out. It is necessary when the app is distributed via app stores.