Development of a Mobile Application for Android to Support Energy-Efficient Driving of Electric Vehicles

Masterarbeit

zur Erlangung des akademischen Grades „Master of Science (M.Sc.)“
im Studiengang Wirtschaftsingenieur der Fakultät für Elektrotechnik und Informatik,
Fakultät für Maschinenbau und der Wirtschaftswissenschaftlichen Fakultät
der Leibniz Universität Hannover

vorgelegt von

Name: Dreyer Vorname: Sonja

[redacted] [redacted] [redacted] [redacted]

Prüfer: Prof. Dr. Michael H. Breitner

Betreuer: M. Sc. Sören Christian Meyer

Ort, den*: Hannover, den 28. September 2015

*(Datum der Beendigung der Arbeit)

Table of Contents

1 Introduction

The issue of electric vehicles is more topical than ever before. Big automotive manufacturers are investing a lot of money for the research and development of them. As a consequence the number of registered electric vehicles has been increasing continuously for the last years as it can be seen in figure 1. Nevertheless, the amount of electric vehicles is low compared to the overall registered cars.

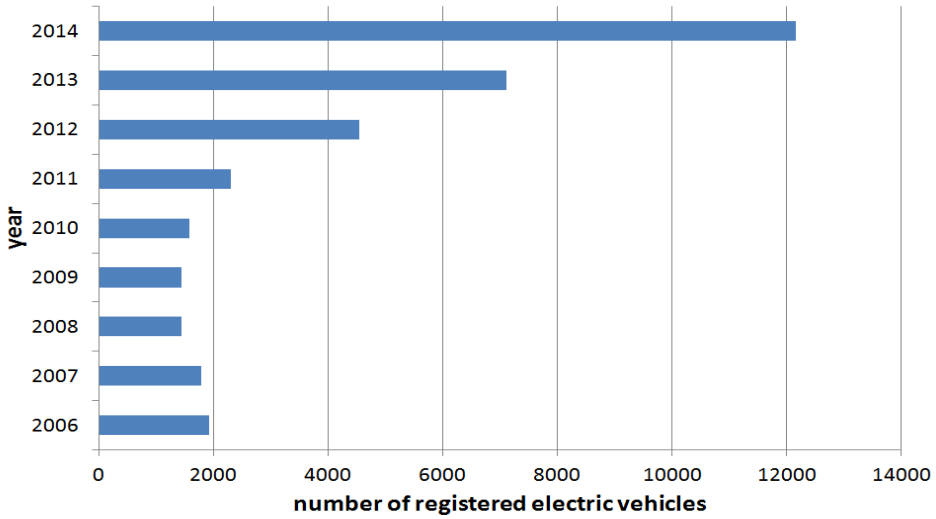

Figure 1: Number of registered electric vehicles in different years in Germany

Source: Own representation based on Statista GmbH 2015.

In this, there are different challenges which have to be mastered regarding electric vehicles. One of the major problems of electric vehicles is the range. Due to the use of a battery system the maximum range is very limited considering the current state of technology. Thus, driving energy-efficiently is essential. That is the reason why tools which are optimising the current driving behaviour are very useful.

1.1 Problem and Relevance of the Thesis

Considering the fact that the use of electric vehicles is becoming more and more popular, the question of how to drive energy-efficiently to maximise the range is increasingly important. Hence, investigating this issue more intensively helps to optimise the range of electric vehicles which is why different possible factors are analysed within this thesis to determine the respective degree of influence. However, as the mere analysis is not useful for the driver of an electric vehicle, this can only be a first step. In a second step all this information is utilised to design a mobile application which allows to evaluate the current driving behaviour and to display this on the screen of the mobile device in real time. Due to this, the driver is able to adapt the driving behaviour continuously and drive more energy-efficiently. So, by means of this mobile application it is possible to support energy-efficient driving of electric vehicles.

1.2 Motivation and Objective

The design of a mobile application to support energy-efficient driving of electric vehicles provides the opportunity to optimise the driving behaviour of the driver and consequently the range. As the range is one important factor when talking about electric vehicles, the design of a mobile application to support this is a useful opportunity. What distinguishes the mobile application in this thesis from others is that it is particularly designed for the Volkswagen (VW) e-up!. Because there is not a mobile application like this yet, it is possible to close a gap due to this thesis.

The aim is to elaborate a concept which serves as a basis for programming a mobile application to support energy-efficient driving. This means that this thesis satisfies the requirement of developing a concept for a mobile application. Therefore, every important influencing factor is considered as far as possible. This is feasible due to a comprehensive analysis of different influencing factors. The elaboration of these factors in combination with measured data is the basis for the following design of the mobile application. Like indicated before, the special feature is that the design is not only elaborated on theoretical considerations and calculations but also on base of measured data, partially especially made for this project. As

there is a concept compiled for a mobile application to support energy-efficient driving and not a mobile application as such, this thesis can be the starting point for further refinements which are explained in more detail in chapter 9.

1.3 Structure of the Thesis

A theoretical background is given in the chapter after the introduction. It is useful to know the most important processes inside an electric vehicle to be able to understand how different factors are influencing the maximum range and thereby the way of energy-efficient driving. In chapter 3 the context of this thesis is explained. This is relevant because the present thesis can be seen as part of a larger project. The market analysis in chapter 4 introduces comparable mobile applications as well as the "Think Blue. Trainer" which is a mobile application developed by the VW AG. In chapter 5 factors that influence the maximum range of an electric vehicle are elaborated in detail. Within this chapter, there is differentiated between factors which are changing during the journey and those who are depending on the respective vehicle. The sixth chapter contains the statistical analysis of selected influencing factors which is done through data raised during test drives. In the following chapter a mobile application to support energy-efficient driving is designed. This is done mainly based on the results of chapter 5 and 6. Finally, the thesis ends with a critical appraisal and the description of limitations. Moreover a conclusion and an outlook are given.

In general, the methodology of this thesis follows the concept of Hevner et al. and his seven guidelines for "design science in information systems research"[1]. The first guideline demands that something innovative has to be produced. In this thesis that is done by the development of the mobile application, which is generally explained in chapter 2.4 and designed in chapter 7. According to the second guideline, the topic has to be relevant. The relevance is explained in chapter 1.1 and hence is given. The requirement in guideline three is a well-founded evaluation of the elaborated aspects. The different influencing factors which are explained in chapter 5 are evaluated in chapter 6 with base on data collected in test drives. Thus, the evaluation can be seen as well-executed. This guideline is followed by the demand of solving a problem in a better way than before. Within this thesis, this is done by developing the mobile application and so supporting the driver of an electric vehicle to drive more

[1] See here and in the following Hevner et al. 2004, p. 8 ff.

energy-efficiently. The fifth guideline deals with the elaborated artefact. It has to be ensured that it is coherent and consistent and besides it has to be determined how well it works. This is mainly done in chapter 8 in the course of the critical appraisal and the limitations. The penultimate guideline demands a contracted problem space to be able to reach the objective of the research. In this case, the problem deals with energy-efficient driving and its influencing factors and there is a clear definition in the first chapter of what has to be covered by this thesis. The last guideline formulated refers to the results. They have to be presented and communicated clearly what is done in chapter 9 within the conclusion and the outlook.

Consequently, all guidelines established by Hevner et al. are fulfilled within this thesis. As an illustration, the whole structure of this master thesis can be seen in figure 2 on the next page.

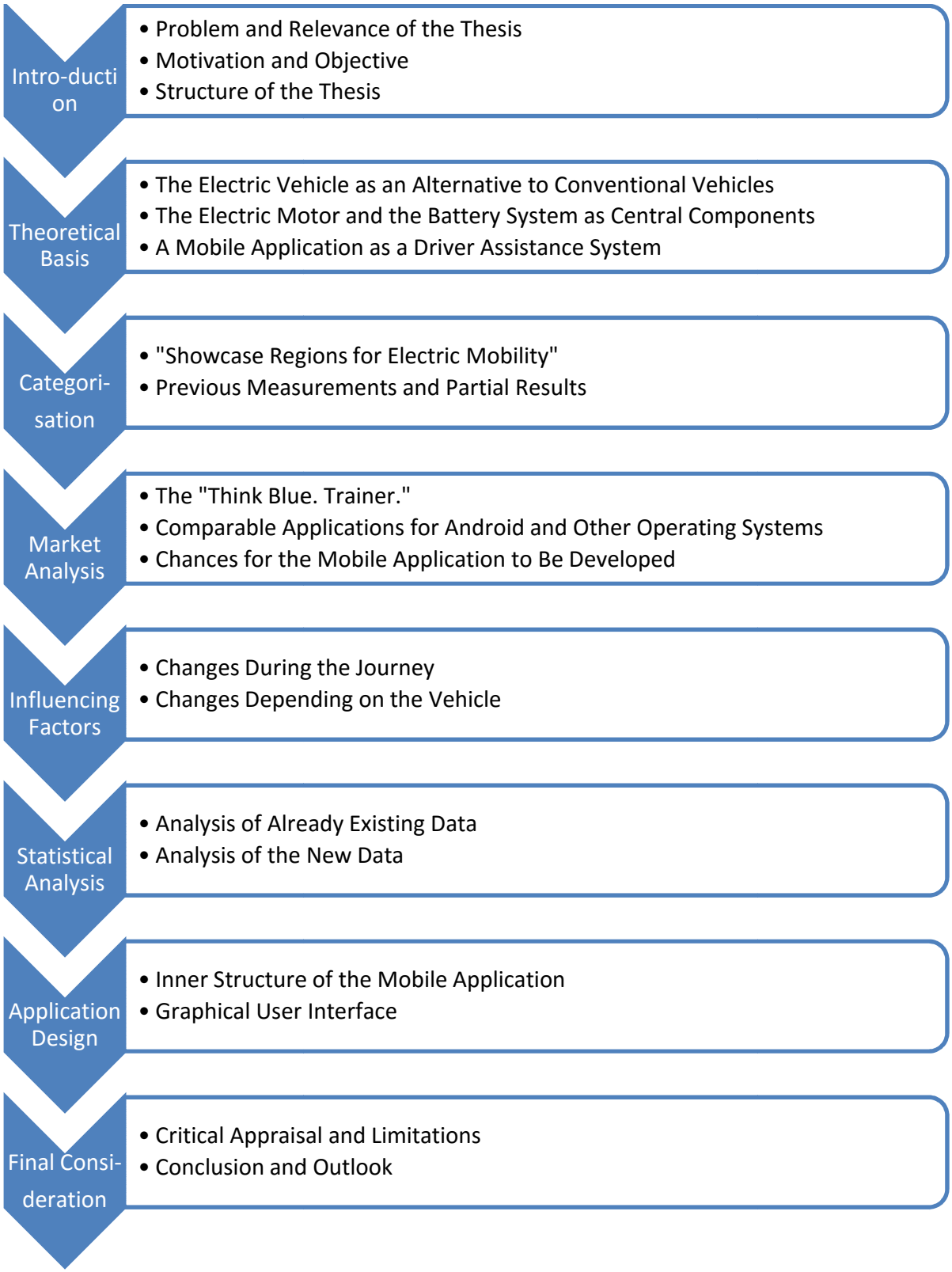

Figure 2: Structure of the thesis

Source: Own representation.

9 Conclusion and Outlook

Because of the fact that electric vehicles become more and more popular, it is of importance to consider the topic of the limited range. Due to the current state of the art the range of electric vehicles is relatively small in comparison to vehicles with a combustion engine. Additionally, there is the problem that recharging the battery can take a lot of time. Because of this, especially in case of electric vehicles, energy-efficient driving is very important.

This thesis is picking up on this point and elaborates a possibility to support energy-efficient driving of electric vehicles. That is the reason why the objective of this thesis is to design a mobile application which is supporting such a driving behaviour. To be able to do so, firstly a market analysis is made. The main result is that there is not yet a mobile application like the one designed within this thesis. As there are several helpful aspects elaborated like the data storage to reflect the previous driving behaviour, it is possible to work out chances for the mobile application to develop.

Thereupon a concept for the mobile application is generated. This concept is influenced by a theoretical and a practical part. The theoretical part is the analysis of different influencing factors which affect the optimum driving behaviour. On the one hand factors which are changing dynamically are analysed in detail. With respect to this, one of the most relevant factors regarding electric vehicles appears to be the opportunity of recuperation. Depending on the driving behaviour the driver is able to recover a certain amount of energy. On the other hand influencing factors which are not dynamic but depend on the used electric vehicle are scrutinised. One of these influencing factors is the age of the battery which can be a decisive point regarding the range.

The precise observation of these influencing factors is one important corner stone for the mobile application. The other corner stone is the analysis of measured data. These measured data are collected during test drives with a VW e-up!. Thus, many different influencing factors which also may interact are considered at least indirectly due to the measurements. Because of the fact that the data are measured it is inevitable to filter these data. Moreover, it is possible to analyse and evaluate the data based on different calculations. One example for such a calculation is the determination of the degree of efficiency of the recuperation depending on different influencing factors. As calculated, a value of 58 % is realistic for this degree of efficiency. Another essential point regards the range of 160 km, reached when driving in conformity with the NEDC. It is elaborated that the net energy consumption must

not exceed a value of 11.6875 kWh/100 km to be able to cover this range. As analysed, this net energy consumption can reached realistically when not accelerating too strong. In connection with this, another result of the analysis of the measured data is that a maximum acceleration intensity of 20 % is sufficient to remain part of the flow of traffic.

Based on these different elaborations it is possible to design the concept of the mobile application. As there are two important parts of the concept, this is divided into the inner structure of the mobile application and the graphical user interface. The inner structure shows the general design of how incoming data are processed. In this, one aspect regards the current speed. As there is a speed limit of 130 km/h implemented in the VW e-up! it is helpful to control the current speed. Another point concerns the current acceleration. Because of the fact that an acceleration intensity of 20 % is sufficient, the current acceleration has to be checked. Furthermore, it is essential to analyse the current braking force. It is recommended in this thesis to use the highest recuperation level B. Thus, the current negative acceleration is compared to the negative acceleration of -1.05 m/s^2. This value occurs in case of using the engine brake and also the recuperation level B. As the application is based on measured data buffers are implemented.

On the contrary, the graphical user interface treats the external appearance of the mobile application. Using mock-ups it is possible to give an idea of how the mobile application could look like. So, the previous analyses result in a comprehensive concept for a mobile application with the objective to support the user to drive an electric vehicle in an energy-efficient way. But as it is not possible to consider every single influencing factor and each partial result of the analysis of the measured data, the presentation of the concept is followed by a critical appraisal and limitations.

Although there are some limitations, recommendations for action are elaborated within this thesis. The probably most important point refers to the acceleration, the positive one as well as the negative one. In case of increasing the speed it is recommendable to accelerate moderately. Furthermore, it is important only to accelerate if it is necessary because a positive acceleration means the use of extra energy. The other possibility is to reduce the speed. Therefore, it is recommendable to select the highest recuperation level, B, of the VW e-up! to recuperate as much energy as possible. In addition to careful acceleration behaviour, it is sensible to use additional energy consumers as sparingly as possible to maximise the range.

With basis on the limitations made in chapter 8, it is possible to develop ideas of how to expand the mobile application and in general of further research. As there is only designed a concept of how a mobile application could look like, it is possible to expand this concept. On the one hand this could be done by a more detailed market analysis. By elaborating carefully

which aspects are not part of such a mobile application yet it would be possible to reach more users which are interested in electric vehicles. Furthermore, maybe there are more influencing factors which can occur depending on the particular driving situation. As in this thesis only influencing factors which occur in nearly every case are considered, there might be additional ones which only occur because of specific reasons. To underpin this it could be useful to make more test drives. This is also a useful way to improve the reliability of the data further.

In case of expanding the mobile application, the colour scale to evaluate the current driving behaviour could be expanded. This means that apart from the two extremes green and red which are standing for driving very energy-efficiently and not driving energy-efficiently at all, there could be different shades between these two extremes to give a more detailed feedback. Nevertheless, the user should not be confused by too much information. Furthermore, the mobile application could be expanded regarding the type of electric vehicle. In this thesis there only the driving behaviour when driving with the VW e-up! is analysed. Including more types of electric vehicles would increase the potential number of users. The same effect can be reached by offering the mobile application not only for Android but also for other operating systems.

In summary, this thesis is a good starting point for further research and is a comprehensive basis for thinking about energy-efficient driving of electric vehicles. This thesis and the within elaborated concept of a mobile application to support energy-efficient driving of electric vehicles can be seen as an important contribution in the field of analysing the optimum driving behaviour to maximise the range of electric vehicles.