Test Based Optimization and Evaluation of Energy Efficient Driving Behavior for Electric Vehicles

Bachelorarbeit

Zur Erlangung des akademischen Grades „Bachelor of Science (B.Sc.)" im Studiengang Wirtschaftsingenieur der Fakultät für Elektrotechnik und Informatik, Fakultät für Maschinenbau und der Wirtschaftswissenschaftlichen Fakultät der Leibniz Universität Hannover

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1 Introduction

1.1 Relevance and Motivation

In 2009 when the German Government set the goal to have one million electric vehicles on German streets by the year 2020 (Bundesregierung 2009), expectations for a revolution in the automotive industry were high. Today, six years after the announcement and with only five years remaining, critics get louder that the goal will not be reached. The latest numbers from the Kraftfahrtbundesamt concerning the usage of electric vehicles show that only 126,702 electric powered vehicles are licensed in Germany (Kraftfahrtbundesamt 2015). This equals only 0.29% of the entirety of vehicles on German streets and roughly 10% of the amount aimed for 2020. The market share of electric vehicles looks the same in almost every other country besides Norway with less than 1% (Figure 1).

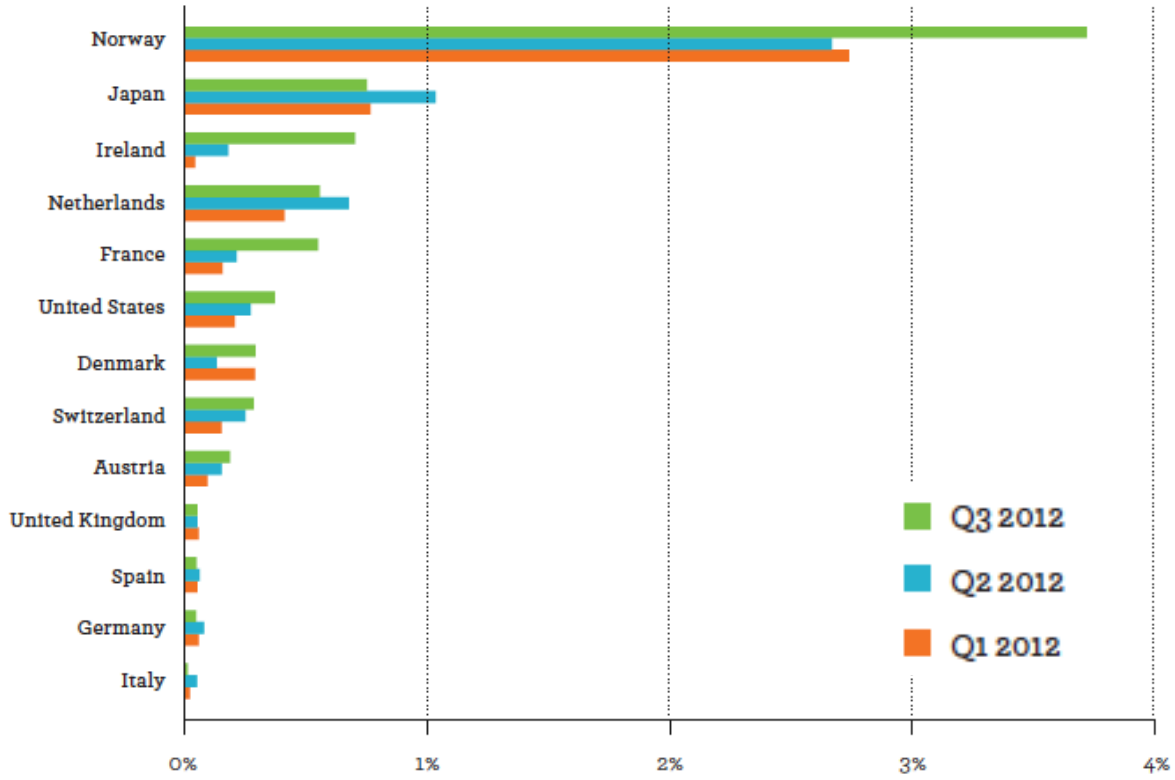

Figure 1: Market Share of Electric Vehicles Worldwide in Q1-3 in 2012 (IEA 2013)

Why is that? Why has not this great innovation taken off as expected? Reasons for that are not related to the people's unwillingness of reducing energy consumption and thus decreasing the environmental burden. Instead convenience issues are the main argument for the tentative purchasing behavior regarding electric vehicles. The weak spots are still too dominant compared to what conventional vehicles offered for

decades. People complain the most about the short-range, long-charging cycles and the insufficient developed network of charging points (Yang and Hu 2007). Overcoming these obstacles with sustainable solutions will be the challenge for automotive industry in the upcoming years.

The extension of the range however is one aspect that is influenced not only by the car itself but also by the driver. This is why scientists have recently began to focus research on the topic of reducing the energy consumption through the driving behavior in order to extend the range.
Most of the active scholars in this field refer to Watson et al.'s (2010) research on the impact of information in the scope of energy management.

"Energy + Information < Energy"

"Energy added with information results in less energy", is basically the main idea of the research, which has been shown to be right. This simple equation seems to be a solution to lower the energy consumption and consequently, in case of automotive transportation, lower fuel costs thereby extending the range of electric vehicles.
The implementation of this idea into a working principle is realized by an approach called Eco-Driving Assistance System (EDAS). EDAS has been mostly tested on conventional vehicles so far (Tulusan et al. 2012 and Vagg et al. 2013) and positive results have already been accomplished. Nozaki et al. (2012) found that an EDAS that communicates with the driver is capable of saving even more energy. The logical consequence to realize Nozaki et al.'s (2012) claim seems to be an EDAS mobile application. Degirmenci et al. (2015) have already proved with field experiments the usability of those applications in order to save energy and extend electric vehicles' range. However, the functionality and user friendliness of the applications used left room for improvements (Degirmenci et al. 2015).
Moreover none of these mobile applications have been explicitly focused on electric vehicles yet. As a consequence the department of Information Systems Research of the University of Hanover wants to fill this gap by developing an application specialized on the needs to extend the range of EVs, which summarizes the motivation for this bachelor thesis.

1.2 Purpose and Structure of the Thesis

In order to reach this goal, the purpose of the thesis is to generate valid data on energy efficient driving behavior with electric vehicles. The results are then implemented into the mobile application. The generation of this data is supposed to be collected with the aid of test drives with a battery electric vehicle (BEV) which will be conducted in the scope of this paper.

Therefore the thesis is organized as presented in Figure 2 and described in the following. After a brief introduction into the theoretical foundations on the working principle of an electric vehicle, a literature review on energy management and eco-driving research follows. Section 3 presents the methodology to answer the research question from section 2. After the presentation of the methodology, the field experiment with the test drives is provided. Based on its data, an ideal driving behavior is recommended as the conclusion of the test drives. Limitations and a suggestion for further research are given afterwards. Finally the conclusion of the proposed work and an outlook are summarizing the thesis in section 5.

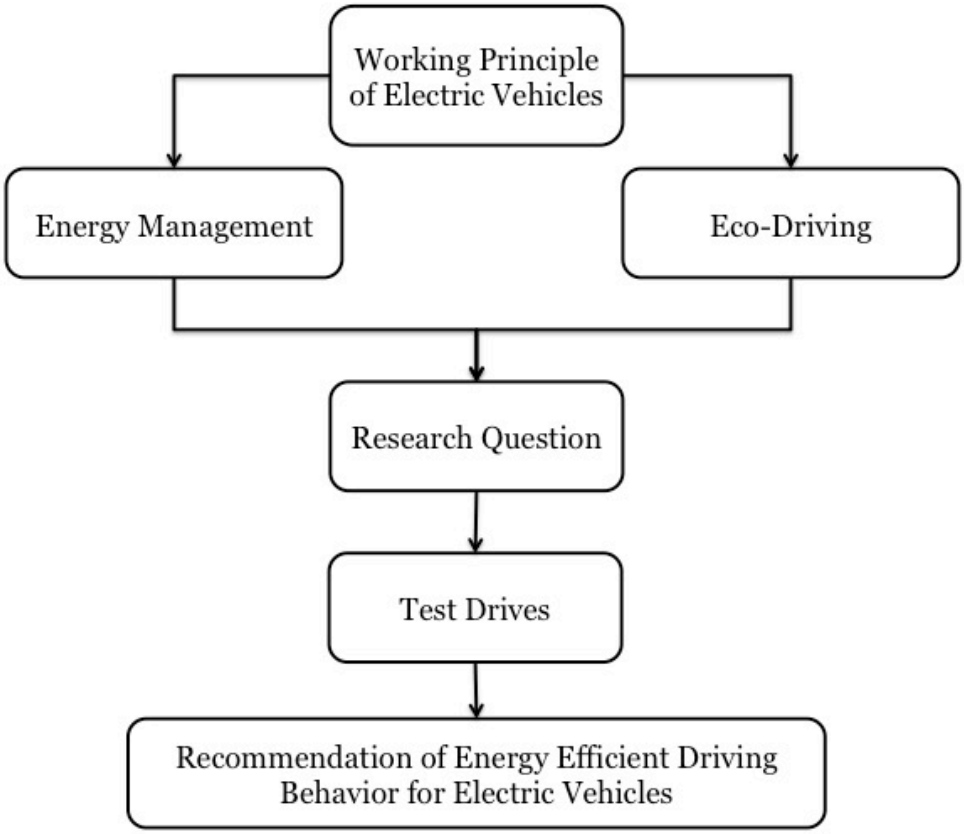

Figure 2: Structure of the Bachelor Thesis

5 Conclusion and Outlook

In times of the climate change alternative solutions in the transportation sector are sought. Electric vehicles have been introduced to solve this problem but they have not overcome the status of a niche product yet. This is probably down to the fact that it still has some major disadvantages compared to combustion engine vehicles.

Due to the fact that one of the weak spots of electric vehicles is their much shorter driving range, the purpose of this thesis was to find a way to improve this inconvenience. To do so, the influence of different driving behaviors on the energy consumption respectively its range were investigated. Through the literature review it has been found that not much research had focused on this topic so far. It was only known that “smooth driving” might has the ability to reduce the energy consumption of electric vehicles.

The research question set the focus of the research approach of this thesis on acceleration and deceleration behaviors. Test drives were the used method for investigation of their influence.

The test drives’ design of experiments was divided into six separate series of test with a Volkswagen e-up!. Experiment 1 investigated the influence of the driving profiles and Experiment 2 the impact of different types of accelerations. The recuperation settings were examined in the third series of test. The fourth experiment analyzed how acceleration and recuperation are connected whereas the fifth series of tests looked into the deceleration behavior. The last test was a long-term study, which included most of the characteristics of the previous experiments.

The results of the test drives have shown that the driving behavior is able to reduce the energy consumption by almost 20%. For reaching this saving, the pre-installed driving profiles, which should be an aid towards the reduction of the energy consumption according to Volkswagen, do not have an impact. The accelerations behavior on the other hand, has been proved to be a major influencer. Gentle accelerations have been found to be the ideal behavior. The test drives have also revealed that the highest recuperations setting regenerates the most energy and therefore should be selected when extending the range is intended. Concerning the deceleration, coasting has proved to be much more efficient than intense braking. The regeneration of the energy can be up to 3.8 times higher in this case.

Concluding it is to say, that the driving behavior has the potential to reduce the energy consumption by almost a fifth. With this in mind people might overcome their skeptical disposition towards the usability of electric vehicles and start to actively take part in the solution process by adjusting their driving behavior. This could increase the chances of EVs becoming more and more mainstream and thus gain a greater influence in the scope of creating a sustainable environment.