Optimization of Electric Vehicle Charging Station Distribution in Urban Areas

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: Ranfagni Vorname: Matias

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

Prüfer: Prof. Dr. Michael H. Breitner

Hannover, den 31.03.2019

Contents

1. Introduction

1.1 Relevance and Motivation

As the European Union (EU) sets stricter emissions limits for vehicle manufacturers fleets in order to reduce pollution, with a target of 95g CO_2/km for 2020 (VDA 2015), car manufacturers have no other option than to change their internal combustion driven vehicles to battery electric ones. This is especially so as more people decide to purchase SUVs, which are considerably heavier and consume more fuel than other car body styles like sedans or station wagons (IEA 2019). This has led up to a sharp rise in available car models, with fully electric and hybrid variants in all segments, from smaller microcars and hatchbacks to the luxury SUVs and sports coupés.
As in the developed countries increasingly more people are considering acquiring an Electric Vehicle (EV), in Germany surpassing the 50% mark by 2019 (PulsMarktforschung 2019), and a constant rise in the number of EV registrations throughout the entire EU (Appendix: Table 15), there is no doubt that governments should embrace measures to provide charging capabilities. To ensure a successful transition from vehicles powered by combustion engines to electric ones, the EU urges their member states to support the expansion electric charging infrastructure (European Union 2019). Estimations suggest that in 2025 1.3 million and in 2030 2,9 million public chargers will be needed respectively (Muzi 2020), a dramatic rise compared to the around 165,000 installed in the EU by 2019 (EAFO 2020).
With such a sharp increase in a relatively short period of time, the question arises on how the needed CSs can be optimally spread throughout the time in cities given the limited resources. With this paper a small contribution regarding this topic is made, as the electromobilty will have a radical impact on road transport in the years to come.

1.2 Research Questions and Structure

The objective of this study is to develop a mathematical model with the goal of establishing an optimal distribution of CSs in urban areas sizeable enough to maintain an urban rail transit. For this, a proper supply and demand model would have to be made. As the supply would be characterized by the charging stations, for which all kinds of information are widely available, such as capacity, charging duration, costs, among others, a more complex topic to determine is how to calculate the expected required charging demand.

RQ1: Which factors influence the effectiveness of charging points placement?

The following main point will be the formulation of the optimization model itself, which would need to be as realistic as possible in order to have results that can be used to compare with the situation of CSs networks installed nowadays in major cities.

RQ2: How to formulate an optimization model for an efficient distribution of CSs for EVs?

In the following chapter a literature analysis is realized as well as a literature matrix containing the referenced papers, providing an overview of the topics these have in common. In chapter 3 the different components of the EVs supplying infrastructure are compared as well as the EV market situation. Chapter 4 focuses on the mathematical model, which has the goal of minimizing the demand minus supply gap of charging stations. Chapter 5 takes the previously developed model and transcribes this in GAMS in order to achieve results. This optimization model will afterwards be run with data from Hannover, Madrid and Buenos Aires. In chapter 6 the future scenario of the cities will be taken as an example on how the situation regarding EVs and their charging infrastructure could be looked at the near future, with a special focus on the different problems to be faced in developed and developing countries. In chapter 7 some of the limitations are laid out as well as the impact. At the very end, a conclusion regarding the results from the research will be presented.

8. Conclusion

The purpose of this thesis was to research CSs and how they could be optimally distributed in urban areas, while focusing on how this problem could be best modeled. At first a literature review was done as well as a literature matrix, based on existing papers focusing in the topic. Secondly, the different charger types were mentioned and an overview of the EV market was presented.
Subsequently a mathematical model describing the optimal placement of CSs in urban areas was developed, considering the various factors that would affect the demand and how these could subsequently be satisfied. The described mathematical model was then transcribed in order to be processed it in GAMS.
The optimization model suggests possible points in which charging stations could be developed in a specific time period, with the goal of minimizing the demand minus supply gap throughout the network. For a representative result, the demand that could be fulfilled in each of the potential locations (in the model represented by urban railway stations such as trams, metro stations and train stations) and the constraints, especially the set budget for each period, play important roles. In the demand calculation, the fact that people live in an area but also move to others is considered, as not only statistical population values are taken into account but also specific buildings that tend to be frequented by drivers. Each location gets a score assigned, which grows over time as the proportion of EVs in the automotive sector of the cities region increases. Afterwards the modeled results for two of the selected cities were compared with the existing networks, and by so proving that the model shows plausible outcomes for different cities with varying network complexity.
When taking a look into the future, it can be noticed that as basically all automobile manufacturers join the EV market, the economies of scale will have such an impact that the possibility that the prices for new EVs will fall below the prices of motor vehicles are considerably realistic. As wealthier countries have more resources in order to develop an effective charging network, countries with less resources will face the challenge of how to progress to make EVs more attractive, in order to reduce pollution in their urban centers while at the same time not disadvantaging other vital necessities of their citizens.

Since the model was able to deliver promising results, it can be assumed that it could be applied to other cities worldwide. This paper can be used in order to develop a more complex optimization prototype, including additional factors that would give a more precise outcome. Future research on the behavioural differences between EV drivers who own CSs in their homes, in contrast to those who do not would be of great interest, as the dependency on publicly available one would significantly drop.