Flexibilization of Carsharing Networks: Electric Cars and One-Way Drives

Masterarbeit

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1 Introduction

1.1 Motivation and Objective

Nowadays, almost half of the world population lives in cities. As this is an emerging trend, an increasing number of people faces the problems that arise with urbanization like pollution, shortage of space, rising energy costs and decreasing availability of raw materials. In this regard, a shift takes place from owning a private car to the usage of alternative means of transport. One possibility in this context depicts the carsharing model. Due to the technological progress, the mobility market develops faster than ever before. This change can also be transferred on the carsharing concept, which has gained in popularity in recent years and therefore represents one of the most important trends of the 21st century. Carsharing enables users to satisfy their mobility needs by paying trip-dependent fees. Especially young people use this flexible kind of mobility and share a vehicle instead of owning a private one. This tendency is in particular due to the fact that the costs of a shared car are lower, since fixed costs like insurance, taxes or leasing rates can be split up among the users. Positive impacts also arise regarding the general enhancement of the transport efficiency. The carsharing concept enables a decrease in the total number of vehicles and thereby increases the usage of the public transport system.

Likewise, the dependence on fossil fuels, characterized by an instability in supplies and prices with regards to mobility needs has increased the interest in electric vehicle usage in recent years. Moreover, due to the increasing progress in battery technology as well as other external factors like shortage of resources, environmental consciousness and the growing responsibility of following generations regarding the reduction of greenhouse effects, electric cars became more and more popular. These factors led to a more eco-friendly, efficient and sustainable mobility demand in society. However, the higher prices as well as the limited range are the greatest challenges that arise with the diffusion. In this context, alternative business models like carsharing can enhance a faster commercialization, since people can gain first-hand experience with the new technology.

To enhance the interest in carsharing and thereby support the achievement and diffusion of electric mobility, the optimal planning of the fleet size as well as the location and size of carsharing stations depicts a critical success factor. In this regard, also the flexibility of the system greatly influences the popularity and capacity utilization of a carsharing organization (CSO). The traditional station-based approach requires users to pick up and return a vehicle at the same station. Since this partly prevents users from flexible planning and spontaneous traveling, the focus of this thesis is to develop a strategic optimization model that considers on the one hand an electric fleet, but also supports besides two-way drives the more flexible one-way concept, where users are able to return the vehicle to a different, self-chosen station. In this regard, besides the objective function, several other constraints are elaborated including additional pa-

rameters. Thereby, feasibility is ensured and realistic results can be displayed. To verify the profitability of one-way drives combined with a fleet consisting of electric vehicles, the adapted model is tested using the example of two major American cities.
In this context, the following research questions can be drawn:

1. How can an existing carsharing model be expanded to allow for a combination of one- and two-way drives and which additional parameters need to be considered?

2. Which challenges need to be addressed due to the integration of a fleet exclusively consisting of electric vehicles?

1.2 Course of Investigation

To ensure a better orientation, in the following, the structure of the thesis is explained, which is divided into eight chapters. After a short introduction, the second chapter gives an overview regarding the theoretical and practical basics of the carsharing concept. In this context, firstly the general approach of carsharing is defined and the history is reviewed. Based on this, different models are presented. Besides the peer-to-peer carsharing, the focus is also on the station-based as well as the free-floating approach. In this regard, the following chapter highlights the differentiation of station-based carsharing in one- and two-way drives and the respective advantages and disadvantages are displayed. Chapter 2.5 deals with the theoretical background of electromobility and explains corresponding challenges. To summarize the results, chapter 2.6 depicts the objectives and benefits of the carsharing concept. The following literature review provides an overview about already existing literature and reveals the research gap. Subsequently, chapter 2.9 explains the applied methodology in this thesis.
The derivation and formulation of the optimization model is part of the third chapter. Firstly, the basic model of Sonneberg et al. (2015) is described, including respective assumptions and notations. Based on this the adapted optimization model is presented. The following chapter 3.3 explains the implementation in the "General Algebraic Modeling System" (GAMS).
Since the optimization process requires a data set, chapter 4 exemplifies the respective data set creation process. Afterwards, applied benchmarks are shown and the evaluation of the results on the example of two major American cities is conducted. The following chapter then shows a generalization of results. The thesis is afterwards critically reviewed with a discussion as well as identified limitations and recommendations are presented. Chapter 8 concludes the work with a short summary and outlook.

fluctuations. Furthermore, the considered pricing does not exhibit a sufficient level of detail, since prices are not connected to the point of usage. Most CSOs provide a different charging for different time frames. In this regard, not only the weekly demand should be varied, but also fluctuations throughout the day need to be considered. In addition, benefits for a driven distance or special fees are not part of the calculation.

Another limitation has to be pointed out regarding the data set creation process and the determination of the demand level at demand locations, which is estimated based on governmental information. The required value of the demand is calculated by identifying specific characteristics, such as the average age or education of a carsharing user. Subsequently, for each characteristic a percentage number of people is computed, that fulfills the requirement. By multiplying the percentage of each characteristic, the probability of potential users per block is calculated. Since not all potential users actually make use of the carsharing concept, only a specific share is assumed as focus group. This approach, however, leads to a distortion of the actual demand, since it cannot be taken as granted that all considered users incorporate all required characteristics. In order to actually compute the total number of potential users, people, who fulfill all characteristics at the same time, need to be identified. To follow this approach, very sensitive data would be necessary, which is not easily available on the internet. In addition, potential stations have been located especially in areas where a high demand is assumed. In this regard, the calculation, based on the population within blocks and the corresponding demographic data, leads to missing demand in public places like e.g. the airport. Therefore, districts where the implementation of one-way drives respectively the placement of carsharing stations could be highly profitable, are neglected.

A last limitation can be identified with regard to the offer of free-floating carsharing. This type of carsharing is not covered in the developed model so far, since the required charging infrastructure for electric vehicles prohibits an efficient implementation. Due to the limited range and the lack of charging facilities, the free-floating model is not feasible with the considered fleet. Nevertheless, this concept would be practicable when considering a heterogeneous fleet. By separating the fleet into vehicles used for station-based carsharing, which would include electric cars, and vehicles used for the free-floating approach, that could consist of cars with a combustion engine, a combined carsharing network could be established.

8 Conclusion and Outlook

In the course of this thesis an already existing carsharing model was adapted in order to provide decision support with regard to the planning of the optimal size and location of carsharing stations. To enable a more flexible approach, besides the classical two-way system, the created model also allows for one-way drives. In this regard, additional challenges that arise with this amendment have been identified and considered within the mathematical formulation. Since the integrated fleet consists exclusively of electric vehicles, further critical aspects had to be addressed. The applicability of the underlying model was evaluated and analyzed on the example of two major cities in the US. To ensure feasibility, for both cities a smaller as well as a more extensive data set were created and tested.

Compared to the base model of Sonneberg et al. (2015), the adapted model provides a more sensitive approach in order to calculate the profit. Moreover, due to the integration of one-way drives, the amount of parking lots per station has to be addressed. In this regard a specific parking lot factor has been introduced, which regulates the number of additional parking lots. In line with the base model, two different infrastructures are considered for the charging process of the electric fleet. Whether a parking lot is equipped with a regular or a fast charging infrastructure depends on the satisfied demand level at an opened station. In case the respective satisfied demand exceeds a minimum demand level, the additional required parking lot is equipped with a fast charging infrastructure.

Due to the identified limitations, further research is necessary. Especially with regard to the implementation of one-way drives, the relocation aspect should be addressed in an operative approach. Moreover, the integration of a heterogeneous fleet depicts a possible profitable amendment. Since the demand estimation plays a decisive role, the data set creation process needs to be critically reflected.

Although one-way drives gained in importance in recent years, this carsharing concept so far is not in the focus of many CSOs, since possible imbalances with regard to the number of vehicles and parking lots need to be addressed in an operative approach, which could lead to a significant increase of the total costs. However, in combination with an exclusively electric fleet, considerable potential with regard to sustainability, profitable installation and flexible carsharing can be emphasized.