Car Sharing Flexibilization: Station-based and Free-floating Mathematical Model and Optimization

Masterarbeit

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1 Introduction

1.1 Motivation and Relevance

Sustainable mobility solutions are the trend of modern times. This is due to the ever-increasing noise and air pollution caused by a continuously raising amount of vehicles on roads. The focus is on finding sustainable mobility solutions which reduce the number of private vehicles inside the cities with the effect to reduce traffic congestion and emissions by vehicles in urban networks. Various solutions such as car sharing, non-motorized use of transport and park-and-ride concepts pursue this goal.
The principle of car sharing means that a vehicle is shared by a community which is professionally organized by mobility providers, so called car sharing operators (CSO). CSOs offer different vehicles at different prices and places with different services to their customers. Basically, modern car sharing services can be approached in two ways, station-based car sharing including round- and one-way trips as well as free-floating car sharing. The station-based concept offers a variety of vehicles at fixed stations where they can be rented by customers with previous reservations. In contrast, free-floating car sharing services allow customers to pick up and drop-off vehicles spontaneously in a defined business operating area.

A long time station-based and free-floating car sharing were seen as a contradiction and competing offers. However, nowadays a combined approach can generate synergies due to the offset of negative characteristics of each approach. Thus, the combination of station-based car sharing and free-floating results in an system that is able to satisfy every requirement and creates a significantly improved customer satisfaction (Loose, 2015, p. 1).

Characteristics	„Traditional“ staion-based car sharing	Free-floating car sharing	Traditional car sharing in combination with free-floating
Full replacement of own car	+	-	+
Planning of trips/ Possibility of reservations	+	-	+
Spontaneous use	(+)	+	+
Best Case: km + minute tariff, with automatic transition to hour-/daily-/weekly tarrif	(-)	(-)	+
Variety – minicar to transporter	+	-	+
Reserved parking space, easy parking	+	-	+
One-way-trips: Flexible Pick up and drop off in operating area	-	+	+
Open-end-trips	-	+	+

Table 1: Overview of the combined approach
Source: Own representation based on Loose (2015, p. 3)

As indicated in table 1, the combined system provides advantages from both car sharing concepts: For shopping and family trips, which are well planned in advance, a reservation at fixed

stations for a favored car can already be made months earlier. The vehicles are at the desired time for the booked duration at the stations reliably available. Spontaneous trips can be additionally covered by the station-independent free-floating offer. Thereby customer needs are conjunct in the overall system instead of using several car sharing providers. From a customer perspective, every conceivable trip is covered in one booking-, access-, tariff system. Consequently, the need for owning a car will be reduced.
CSOs also have incentives for the introduction of combined offers. In certain neighborhoods the search for new car sharing stations is becoming more difficult, because private areas for renting are there no (longer) available. Moreover, stations on public roads are very rare due to the lack of a legal basis. This problem can be solved by introducing station independent vehicles, which make it possible to create offers even closer to the customer in order to meet demand. Another reason for a combined system is, that especially younger customers are addressed, who previously are not interested in only station-based offers. Hence, they are also introduced to the traditional car sharing via free-floating as an alternative to private car ownership (Loose, 2015, p. 2).
First evaluations have shown that combined systems are differently used than pure free-floating approaches. Among transport policy, researchers found out, that in line with combined offers users are less encouraged to short urban trips. Furthermore, not one-way trips are in the center of customers interests but the ability to use vehicles without reservation and without setting a time limit in advance for return. On average, these vehicles are used for much longer trips that go far beyond the extent of the business area. Therefore, a trip-related competition with public transport is almost eliminated completely, due to convenience of customers (Bundesverband CarSharing e.V., 2016a, p. 2).
The head of Bundesverband Carsharing e.V. Willi Loose also appraises a combined approach as a great advantage for other factors. For an relieve of traffic and the environment, the different means of transport need to be optimally coordinated. Thus, combined car sharing systems are an important step to enable the integration of free-floating into the environment alliance (Bundesverband CarSharing e.V., 2016a, p. 2).

Based on the before described relevance, the focus of this thesis is to develop a strategic optimization model that combines both, the station-based as well as the free-floating car sharing concept. Therefore the following research questions can be drawn:

1. How can a traditional station-based car sharing service be extended and combined with free-floating car sharing to meet various customer demand while maximizing profit?

2. How can the business area for free-floating car sharing be determined to realize a profitable combined car sharing service?

1.2 Course of Investigation

As an orientation, this chapter explains the structure of the thesis that is divided into eight chapters. After a short introduction, which makes the reader accessible to the focus of the work, the background and theoretical foundations of car sharing are described in chapter 2. At first, the definition of car sharing and its history is outlined, followed by an overview of different car sharing services. In this regard, a car sharing service can be seen from various perspectives for optimization which are explained next. In relation to the focus of this thesis, existing offers by combined CSOs are described and subsequent the most critical success factors are identified. The adjacent literature review summarizes the most important papers to provide a theoretical overview for further research. Additionally, two interviews are conducted that extend the theory with practical aspects from existing combined CSOs (see A.1 and A.2). The last part of this chapter provides as transition the methodology regarding design science research as well as the operation research process.

The following chapter 3 depicts the main part of this thesis, the optimization model. The basic algebraic model is provided by Olivotti et al. (2014) and focuses on a strategic–tactical optimization with station-based car sharing. According to the before mentioned literature review, interviews and success factors, additional assumptions are derived and subsequently implemented in the model to obtain the extension to a combined approach under consideration of station-based and free-floating car sharing.

Chapter 4 aims to test the developed model. For this purpose, a data set of Seattle is created where the model is applied on. Based on identified benchmark values, the evaluation with the help of a sensitivity analysis is conducted. For validation a second sensitivity analysis with a data set of San Francisco is executed.

After the evaluation, the results are summarized in chapter 5. Therefore, a generalized overview is provided that contains how input values influence decision variables within the optimization model.Based on the previous outcome, a discussion of results is placed in chapter 6 which reconsiders assumptions, the mathematical model as well as the evaluation. Subsequent to the critical review, limitations of this thesis with focus on the optimization model are situated and concrete suggestions for improvements are derived in chapter 7.The thesis concludes with chapter 8 where a summary of findings is given as well as an outlook for further research is proposed.

a share is assumed as focus group. However, this method leads to a distortion of the actual demand, since it cannot be granted that all considered users incorporate all required characteristics. In this regard, the total number of potential users needs to be identified that fulfills all characteristics at the same time. For this approach, very sensitive data is necessary, which is not on official governmental information websites available. Furthermore, potential stations are located at areas where high demand is assumed. In this regard, the calculation based on the population in blocks and demographic data, leads to missing demand at public places like the airport.

8 Conclusion and Outlook

The concept of car sharing not only depicts a lucrative business model but also has positive effects on the environment due to less private cars and reduced air pollution. In this regard, car sharing can be part of a sustainable mobility solution in urban networks. However, increasing the desire for flexibility in terms of transportation, new services and innovative business models have to be offered to meet customers needs. This has led to the focus of the presented work to flexibilize car sharing services and therefore to introduce a combined car sharing network which takes station-based car sharing with round trips as well as free-floating for spontaneous car sharing into account.

In the course of this thesis, an existing station-based car sharing optimization model was adjusted and expanded by free-floating car sharing. A city needs to be divided into well-sized segments and according to appropriate characteristics, a factor has to be identified to determine the business potential for each segment. The most significant factor for an efficient free-floating factor depicts the demand density. Based on the data set creation, which is part of the thesis, demand locations were identified and therefore the demand density for each segment can be calculated which represents the business potential.
In a preprocess, the segments that exceed a predefined minimum demand density, are selected as part of the free-floating area. This is done with a flexible percentile which can be varied, according to the decision makers experiences as well as the size of the CSO. After identifying the optimal free-floating area, the number of stations, assigned vehicles as well as free-floating vehicles are optimized to gain a combined car sharing network. By adapting the model with additional operational aspects like prices and average trips, a profit maximizing optimization model is introduced which is closer to reality and supports decision makers in finding a suitable solution.

While the applicability and usefulness of the optimization model of the underlying model were evaluated and demonstrated of the major American cities of Seattle and San Francisco, certain

limitations were identified. Next to potential deviations in operational aspects for trips and prices, a relocation was not considered. Although there is in reality no established operator-based relocation, the conducted interviews outlined that a solution has to be developed to react on such possible vehicle concentrations at areas and stations.
Concerning the developed model, implications for additional research can be derived. Especially the model itself affords opportunities for further refinements which should be realized by the scientific community to achieve constant progress in the mobility solution for car sharing. On this subject, the interaction of station-based and free-floating car sharing needs to adjusted, which needs to be based on the determination of the demand. One of the most promising approach in this regard is a further enhancement and customization of the demand due to the fact that one success factor for a model always depends on the applied input data. This could help to ensure better transferability during the OR process, especially in the realization phase.

In conclusion, it can be emphasized that a combined car sharing network, including station-based and free-floating services, can be profitably implemented. Thereby, the developed model supports the strategic planning phase by providing decision support.
The strong growth and steadily increasing popularity will support car sharing as an urban mobility concept for the future. However, it is essential to adapt existing concepts to the changing customer needs and demands. In this way, the thesis and especially car sharing as a whole, can contribute to suit actual requirements and support society, while contributing to a reduction in environmental pollution.