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Enabling sustainable transportation: The model-based determination of business/operating areas of free-floating carsharing systems

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A B S T R A C T

Free-floating carsharing systems with (and without) electric vehicles are emerging and there is limited knowledge where such concepts will succeed, regardless of their environmental benefits. Within this knowledge gap, the definition of the business/operating area is a key aspect. Inside this area a carsharing vehicle can be picked-up and dropped-off everywhere at any time. This research develops a model that helps to determine business areas a-priori by predicting inner-city booking hot-spots. The approach is based on modeling success factors as independent variables, namely population density, housing rent, city center distance, and hotel/restaurant density. With the help of these variables predictions for geographic zones in cities are made that prove to be helpful for designing operating areas for free-floating carsharing systems — a key challenge for providers' success when approaching new cities.

1. Introduction

A variety of factors, such as rising oil prices and global warming, challenge the current individual mobility paradigm which is based on gasoline-fueled cars in private ownership. These challenges are amplified through regulatory measures (e.g. congestion charges) and social changes such as collaborative consumption. These drivers together with technological changes (e.g. battery innovations, information technology) are likely to lead to a new mobility paradigm — one based on new offerings and new business models. Energy-efficient, sustainable, low-carbon mobility services will emerge and electromobility and carsharing are very likely future scenarios (Fournier, Seign, Göhlich, & Würzer, 2012; Spickermann et al., 2013).

"Carsharing" means that a car is shared by a community and professionally organized by mobility providers, offering different vehicles at different places to their customers. Carsharing is widely recognized to contribute to sustainable transportation, offering advantages such as reduction in traffic, resource use, emissions, and ownership-hassles. In general, modern carsharing can be approached in two ways, station-based (round-trip and one-way) and free-floating carsharing. Station-based concepts offer vehicles at fixed stations whereas flexible or free-floating concepts allow customers to return a car anywhere in a given business or operating area (Weikl & Bogenberger, 2012). This modern form shows carsharing in a new perspective in the (on-going) austerity context. Whilst in the 1980's and 90's sharing a car was seen as sacrifice for economical or ecological reasons, with new free-floating concepts individual mobility is enhanced by offering more flexibility in urban areas than the use of a private vehicle. Inter-modal trips enable customers to choose the most efficient transportation mode depending on the situation. Out-bound and in-bound trips can be taken independent of each other whereas a private car has to be taken back to its origin.

Hence, for free-floating carsharing the design of the operating area in a city is a crucial factor whether the system is used by customers or not and accordingly, whether carsharing can help to enable sustainable mobility. This research aims to develop a model that helps to determine business areas a-priori by predicting inner-city booking hot-spots. The approach is based on modeling success

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factors. In the following paragraphs success is defined and potential measures of success as dependent variables for a regression model are evaluated. Similarly, potential independent variables which influence success—success factors — are determined, explored, and analyzed. This represents two crucial steps for the later model development and accordingly for the definition of the operating area. In the development of the model findings are combined in a regression analysis, resulting in a model that is finally evaluated for its applicability.

2. Literature review: the limited market knowledge in free-floating carsharing

Carsharing offers will concentrate in areas where high demand is expected (Böhler, Bongardt, Schäfer-Sparenberg, & Wilke, 2007). Generally speaking, the market potential depends on user characteristics, framework conditions, the service quality of carsharing, and the overall multimodal portfolio in a market. Since free-floating carsharing is very young, operators currently know little about the market and are exploring why their concepts work better in some cities than in others but experience is limited. Moreover, expansion decisions are often mainly based on local political situations. Some cities welcome carsharing providers with the possibility to park vehicles on-street, which is key for a free-floating carsharing operation, whereas others do not allow that possibility. Positive examples include Munich, which allows each free-floating carsharing provider to purchase up to 500 city-wide parking licenses for 1830 Euro per vehicle every year whilst limiting the operating area to certain areas (Jordan, 2013). Stuttgart and Austin are cities that even offer free parking, (Kortum & Machemehl, 2012; Nauke, 2012) and Amsterdam provides a charging infrastructure for E-carsharing (Henrich, 2011). The regulatory framework is therefore a key challenge that must be met with political dialogues in the respective cities (for more detail, see Loose, 2010), bringing the advantages of carsharing for society in attention of local decision makers.

Apart from regulations, there are widespread opinions regarding success factors for carsharing. Studies often focus on describing socioeconomic characteristics of customers to determine market potential (Böhler et al., 2007; Muheim & Reinhardt, 1999; Steininger, Vogl, & Zettl, 1996). The average age of mid 30 s to mid 40 s, incomes in the upper middle class, high education, a predominantly male gender, a below average household size, and below average auto ownership are typical characteristics of carsharing members. Furthermore, potential carsharing members live in urban areas, are concerned about environmental issues, and are considered to be innovators to which status matters little (Bundesministeriums für Umwelt Naturschutz Bau und Reaktorsicherheit BMUB, 2014; Burkhardt & Millard-Ball, 2006; Millard-Ball, Murray, Ter Schure, Fox, & Burkhardt, 2005). Here, forecast customer numbers vary greatly and even a correct estimation of potential customers does not necessarily lead to practical results as the decision to use carsharing depends on many more factors that are not accounted for in sociodemographic analyses (Le Vine, Sivakumar, Martin, Lee-Gosselin, & Polak, 2013).

Next to determining demographic markets, also geographic markets are studied. Here studies vary greatly in results and the number of single households, a high quality of public transportation, little car ownership, and a high population density are often found to be geographic success factors. Obviously, these factors are interrelated with demographic characteristics of users that will be correlated with certain features of the wider neighborhood (Millard-Ball et al., 2005). With these results, also first attempts were made to assess market potential for certain neighborhoods with the help of a geographic information system (GIS) (Celsor & Millard-Ball, 2007). This assessment however relies merely on location data for stations and does not include booking behavior. This is crucial since available cars might not be used. An alternative carsharing demand model, based on usage data, revealed that neither population density nor demographic factors play an overt role in the success of carsharing stations. According to the data, rather the age of a station, commuters that drive alone, street width, households with one vehicle and various public transit variables played an important role (Stillwater, Mokhtarian, & Shaheen, 2009). Another approach to combine findings from previous studies was chosen by the BeMobility project in Berlin, seeing population density, car density, public transportation, charging infrastructure, parking pressure, competition, living quality, and the mix of use in an area, as influences for demand (BeMobility, 2011).

However, all the above approaches are based on station-based carsharing systems. Transfer of knowledge to free-floating carsharing might not be possible since the scale and operating mode is very different (Barrios, 2012). Furthermore, a comparison of booking data of both concepts concluded that temporal and spatial booking behavior is very different — most likely due to different trip purposes (Schmöller & Bogenberger, 2013). Therefore, considering approaches from station-based systems would lead to wrong conclusions.

Besides this consideration, recent studies concerning the free-floating carsharing market include a gaming simulation exercise and the interpolation of results to estimate the overall potential of the concept for London (Le Vine et al., 2013). Another study provided three separate options for predicting membership in a carsharing program given city demographics: (1) a binary logit model to identify whether a census block will have members or not, followed by a linear regression model to estimate the percentage of population that might become a member in blocks expected to contain members or alternatively, (2) a logit model to estimate the membership percentage. Finally, (3) a Heckman sample selection model was developed to jointly estimate blocks with members and membership percentages in blocks with members, being the recommendation of the author (Kortum & Machemehl, 2012). This approach was later modified by the author by replacing the prediction of membership by a prediction of mode split and trip frequency (Kortum, 2014). However, coefficients of determination were relatively small and as the author points out, predictions might not be transferable to other cities than Austin.

Apart from this latest developments in free-floating carsharing market demand modeling, which have not been evaluated to the author's knowledge, predominant theoretical assumptions are disproved by reality. For example, Calgary (Canada), a city with a population of about one million people, experienced a much more rapid diffusion of carsharing than bigger cities where a bigger customer base and a bigger demand was suspected (Auto123.com, 2012). This limited knowledge poses a problem to providers when approaching new cities. Expansion, market development, and internationalization are key trends in the carsharing industry (Shaheen & Cohen, 2013). The market choice (choosing a city as well as choosing a market *within* a city) is essential for the chances of success as carsharing systems are embedded parts of local transportation infrastructures and the place of offer is the place of consumption.

This general market knowledge gap also poses a problem when designing market specific concepts for determined new or even existing markets since local customer needs must be fulfilled to suit the local context. Conditions vary from city to city but it is not only the local authorities and given structural traits of a city that foster carsharing. When implementing a free-floating carsharing system, there are many unknown variables a provider has to adjust in order