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A Relocation Strategy for Munich's Bike Sharing System: Combining an operator-based and a user-based Scheme

Svenja Reiss [a,*], Klaus Bogenberger [a]

[a]University of the Federal Armed Forces, Werner-Heisenberg-Weg 39, 85577 Munich, Germany

Abstract

Based on a detailed GPS-Data Analysis for a free-floating Bike Sharing System, mobility patterns of the bike usage were identified spatially and temporally. Depending on different factors like seasons, weather conditions, time of the day and holidays/weekends, we built up a demand model in order to forecast the upcoming demand at certain time and place. This model reveals optimal fleet distributions for different zones in the operating area and for different time slots. To redistribute the fleet a reasonable relocation strategy was created in order to obtain an optimal distribution of bikes within the operating area. Two different kinds of relocation methods are evaluated: an operator-based relocation strategy, where at least one vehicle redistributes a part of the fleet. Additionally, a user-based relocation scheme was created: based on pricing benefits for the user, at least a share of the needed relocations are conducted by users, almost cost-neutral. There is a certain threshold though, when the necessary fleet relocations are too urgent and an operator-based intervention is inevitable. At the end, we carried out a validation to show what kind of effects a real life relocation could imply.

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Keywords: Bike Sharing Systems; Data Analysis; Demand Modelling; user-based Relocation; operator-based Relocation

* Corresponding author. Tel.: +49-89-6004-2529; fax: +49-89-6004-2501.
E-mail address: svenja.reiss@unibw.de

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1. Introduction and Literature Review

Public Bike Sharing Systems (BSS) provide a progressive option for urban mobility, as observed by Raumkom (2011), not only for commuters but also for spontaneous users and tourists, see Shaheen et al. (2010). Such systems are only reasonable, if the bikes are available where the users need them at a certain time though.

In the past years, many vehicle sharing systems were launched in Europe and North America, including both cars and bikes. The main issue remains the same in both cases: from time to time, the fleet gets imbalanced as vehicles accumulate in specific spots and hence areas with a low vehicle density arise.

There are many previous studies concerning Car sharing both station-based and free-floating systems: Correia et al. (2014) solved the imbalance problem in stationary Car Sharing Systems by maximizing the operator's profit. They carried out a simulation case study by modifying fleet size, size of stations and their locations. Weikl and Bogenberger (2015) developed a mesoscopic relocation method for free-floating car sharing systems by maximizing the booking numbers through satisfying the estimated occurring demand. Similar approaches can be found for BSS, e.g. by Chemla et al. (2013) and Raviv et al. (2013); however – to the best of our knowledge - not yet for the free-floating case. Martinez et al. (2012) for example built up a relocation method for station-based BSS. In order to maximize the operator's profit, they figured out optimal station locations and fleet size based on a simulation case study.

All these relocation strategies are operator-based, i.e. the algorithm yields a recommended routing for the operator to relocate parts of the car resp. bike sharing fleet. Within this paper we created a user-based strategy, that incents the user to relocate the fleet by themselves, or at least supports the relocation process conducted by the operator. Several user-based methods have been designed e.g. by Cepolina and Farina (2012); however it was applied to a car sharing system and a standalone method, hence no intervention of the operator was projected.

This work is based on the "Call a Bike" booking data of the operating period from March 2014 to December 2014, which provide the time of each trip as well as the GPS-coordinates of the start and end position of each trip. This BSS is free-floating, i.e. there are no stations, but a defined operating area, where users can rent and return the bikes. For more details on the system, see Call a Bike (2014).

2. Data Analysis of Bike Sharing Trips

At first, the temporal analysis considered the booking trend over the entire operating period 2014. We found out that there are huge variations in daily trip numbers. On one hand, good resp. bad weather conditions lead to higher resp. lower bookings - see also Reiss, Paul, Bogenberger (2015) - but on the other hand, the type of day has a strong impact as well. There is a huge discrepancy between workdays and weekends concerning trip number distribution and trip durations.

In figure 1a the different usage patterns between weekdays and weekends are displayed: on weekdays (blue line) a peak between 6 a.m. and 10.a.m. and between 4 p.m. and 8 p.m. is in evidence, as there is a lot of commuter traffic. On weekends (red line), such a clear cluster is not visible, but a broad usage pattern between 12 p.m. and 8 p.m.
Taking a look at the averaged trip durations at certain time slots (see figure 1b) short bike rides (between 18 and 23 minutes) are high likely made on weekdays, whereas on weekends, the average trip duration is around 30 minutes. These first results give hints on possible imbalances, as e.g. between Sunday and Monday the users' behavior changes and therefore the bikes might be idling in areas where they are not needed. To investigate the actual spatial usage patterns, we divided the operating area into zones, which represent fictive stations. Therefore we analysed historical booking data and based on a Facility Location Problem, see also Daganzo (2010), we created 40 zones, see figures 2a and b. The zones are not the same size, because they are based on empirical booking data and trip numbers, i.e. the more bookings on average were made, the smaller is a zone and vice versa.
Hence, we examined areas, where the demand is rather high in the morning, i.e. residential areas and detected areas with a high demand in the evening, for example in the city center. In figures 2a and 2b this state is shown: in the morning almost no rentals are made in the city center (figure 2a) and in the evening the zones in the city center seem to be the most popular ones (figure 2b). To determine the imbalances of the fleet, we carried out the following analysis: rentals and returns on weekdays and weekends at all five time slots as depicted in figure 1b earlier. The results are a crucial component of our demand model, which is described in the following chapter.