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Time Series Analysis Of Booking Data Of A Free-Floating Carsharing System In Berlin

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Abstract

The most rapidly growing carsharing system in North America and Europe is the free-floating one (FFCS). In a FFCS system customers can book and return vehicles of the fleet in every place of a defined operating area. While first studies tried to characterize the user of such a system and explain the booking behavior this work focuses on the short times prediction of FFCS bookings.
Booking data of the FFCS operator DriveNow in Berlin are the basis for the forecast. They enable modeling time series for vehicle bookings by hour. The forecast provides predictions for every hour of a future week. To include spatial differences of FFCS bookings forecasts are calculated for every zip code area. Two methods of time series analysis are used to compare their performance for the present data: A seasonal ARIMA model and exponential smoothing with Holt-Winters-Filter.
These two models are realized each with four settings. They are based upon data of a whole year, a half-year, a quarter or just a month and compared regarding their precision and practicability. Preliminary analyses such as the spectral analysis show that FFCS booking frequencies have weekly recurring trends. Additionally, it is visible that in areas with a high booking density this level lasts for the whole time. By this, spectral analysis can be applied as a spatial clustering method.
The comparison of the two tools of time series analysis yields to the Holt-Winters Filtering (HWF) as the favorite method. Finding the optimal parameters for the ARIMA models is computationally intensive and results in just equally good or even worse forecasts than with exponential smoothing.
The best prediction is performed with Holt-Filters-Filtering using three months of booking data. The forecast predicts bookings with an average error of only 0.84 vehicles per hour. The largest average absolute error of all compared forecast models is around 20% higher but makes the model still useful in practice though.

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1. Introduction

The following analyses in this work are based on a free-floating carsharing system (FFCS). In contrast to classic station-based carsharing systems or other vehicle sharing services (Shaheen et al. (2012, [21]) the customer does not need to finish the trip where he started but can park the car in any part of the operating area. This area covers most

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parts of the city and has often additional areas in the periphery of the city like the airport or college campuses.
A user of this kind of carsharing system normally finds an available vehicle via app on his smartphone. The reservation of a car can be done up to 15 minutes in advance for free. This marks the great flexibility of the system that is on the one hand an advantage for the customer but on the other hand a disadvantage regarding the reliability of the system especially in areas with a low vehicle density.
The analyzed data in this work come from a FFCS system in Berlin which started in September 2011. In the beginning the fleet consisted of 300 vehicles but soon has increased. Within 15 months the customer base has grown to 30 000 (see [3]). Today around 900 cars are available in the 3.4m-strong city. The carsharing company counts totally more than 300 000 customers in five German cities (see [11]).

2. Motivation

Before starting with an overview of former studies and a detailed description of the approach a few conceivable applications of the short-time forecast shall be mentioned.

- *preventing bottlenecks*: The enormous flexibility is an advantage for the customer but can be a challenge for the operator of the system. Spots with a high demand can easily have a too low supply. The operator can't really measure the theoretical demand. His chance to prevent loss of revenue due to non-fulfilled customer demands is to estimate the expected numbers of bookings in an area by using a forecast model.
- *maximizing convenience*: If one wants to get to a place he is also interested in how to get back from his destination. Using a car offers the highest certainty to solve that problem. Public transport systems run their services after scheduled timetables and have therefore a good reliability. But a FFCS system currently does not provide any information about the vehicle distribution for the upcoming hours. A forecast can change this circumstance. Instead of just showing the current vehicle positions the mobile app can show in future the expected availability of cars. By this, the customer would get more confidence in the FFCS system.
- *saving costs*: The forecast model helps the customer not only to get better information about available vehicles in future times but also to save costs. Since the customer has to pay for a reservation being longer than 15 minutes he can see the estimated demand of vehicles. This information facilitates the decision if a reservation is useful or not.

3. Literature review

In the last years, research about shared mobility services dealt with a lot of aspects mainly concerning the change of users' travel behavior, the characterization of the carsharing customers (e.g. Millard-Ball et al. (2005), [13]), the explanation and long-time prediction of the varying demand of the systems (e.g. Balac et al. (2015), [1]) and the optimization of the performance of the system (e.g. Weikl (2015), [23]). For a well investigated research about all current works and studies considering carsharing the work of Jorge and Correia (2013, [9]) is highly recommended.
The focus of this paper lays especially on short-time prediction of bookings. There will be given an answer to what forecast method works well for this purpose and what time period of historical booking data is necessary and sufficient.
Forecasting data found its way into traffic engineering long time ago. As soon as modeling road traffic began there were predictions of road volumes etc. necessary to estimate capacities. The techniques were all quite similar and did not change over the time. Spectral analysis was e.g. already used in 1974 to predict traffic flow volumes (Nicholson and Swann (1974, [15]) and was again used in Tchrakian (2012, [22]) for forecasting real-time traffic flow.
Even though shared mobility is a quite new research topic there have been some works published about forecasting booking behavior. The focus has been only to bikesharing systems so far. Gallop et al. used temporal weather impacts for modeling booking data of a station-based bikesharing system in Vancouver (Gallop et al. (2012, [5]). Two articles relate to a similar working system in Barcelona. Froehlich et al. created in 2009 ([4]) a Bayesian network for the prediction and yields a quite well-working model with the biggest error during peak hours. Another approach for the same system was done by Kaltenbrunner et al. (2009, [10]). Their results show an average prediction error