**Effective Usage of Short-Term Parking Zones by Offering Real-Time Information on the Utilisation of Parking Lots**

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## 1 ABSTRACT

In many cities area-wide short-term parking zones were introduced to reduce traffic in search of a parking place and to enhance the life quality. Nevertheless, in many cities with parking restrictions the volume of traffic is still high and parking search traffic is one reason for this problem. Previous attempts aim to overcome this issue by guiding drivers to the next available parking space. These systems are expensive and politically controversial, because they indirectly encourage car use. On the other hand, a pre-trip information service informing road users prior to departure about the occupancy of parking spaces at the destination could have a higher steering effect and encourage people to use alternative transport means. Based on these assumptions a real-time information system for the occupancy of short-term parking zones was developed and tested in two areas in Vienna (Austria). Instead of relying on roadside infrastructure this system uses position data of the mobile phone parking service as an indicator of the occupancy of parking zones. In addition, the potential of two more data sources to improve the reliability of forecasts was tested: model-estimated traffic flow data and counts of short-term parking customers in parking garages. The prediction model was developed and validated with an empirical parking survey. This novel technology helps to administer the scarce resource of parking space in urban environments more effectively and supports people in choosing sustainable transport modes.

## 2 INTRODUCTION

In recent years the automobile industry and academic researchers developed numerous driver assistance systems (Pellecchia et al., 2005). For example, several techniques have been evolved, which provide drivers with real-time information on the occupancy of car parks. However, developing an analogous information service for on-street parking spaces is much more demanding, because entries, exits, and parking spaces are less well defined and inappropriate for counting. In table 1 different approaches are listed, which have been developed to provide this information.

| System | Function | Disadvantages |
|---|---|---|
| Vehicle detection with panoramic street images | Use of laser-ranger finder and a line-scan camera taking epipolar-plane images | Delivers only static snap-shots, but no real time information. (Hirahara and Ikeuchi 2003) |
| Linked parking meters | Parking meters identify free parking spaces via infra-red sensors, the meters are connected with each other via radio frequency transceivers | Impractical system to cover large areas, electrical infrastructure necessary, high deployment and maintenance costs (Sifuentes et al., 2011) |
| Wireless sensor networks with autonomous sensor nodes | Sensors or induction loops identify free spaces and communicate via radio frequency transmitters; information is available on mobile devices or VMS, | High costs for equipment and maintenance (Federal Highway Administration, 2007; John Markoff, 2008) |
| Vehicle to vehicle (V2V) communication | Protocols can be used by vehicles to share information about available parking spaces via V2V communication | Only for cars equipped with the necessary expensive techniques |
| Community-based system | Enables users to indicate (release) free on-street parking spaces and to find these spaces via a mobile app | Requires high share of market penetration to provide a complete picture |

Table 1: Approaches for the development of a real-time information system on the occupancy of on-street parking spaces

Up to now detection of on-street parking spaces relied on area-wide infrastructure on street or within vehicles, which causes high costs. Such systems are also controversially discussed, because they aim at navigating drivers quickly to the next free parking space and making car use more convenient. It is therefore more preferable to inform road users early about the current and predicted parking situation at the destination. A reliable forecast of the occupancy could support the use of other alternatives (public transport, Park & Ride) and reduce parking search traffic at the destination.

## 3 STUDY IMPLEMENTATION

The objective of the study was to develop a non-invasive real-time information system for the occupancy of short-term parking zones, which operates without the need for roadside infrastructure (see Figure 1). Instead of showing the status of individual parking lots, it aims to provide a sufficiently accurate description and reliable prediction of the parking pressure in a broader target area. Three existing real-time data sources were tested for their usability in such an information system:

- position data of short term parking customers, who buy their electronic parking ticket with their mobile phone using an SMS payment service;
- counts of short-term parking customers in car parks in or close to the target area;
- traffic flow volumes derived from more than 300 automatic counting sites in Vienna.

The city of Vienna was chosen as case study area. In the inner city district, parking search traffic amounts to 20 % of total traffic, at peak times up to 90 %. The city offers an SMS payment service for short-term parking fees, which is called "HANDY Parken". More than 40 % of all short-term parkers pay their ticket by using this service. Each electronic ticket generates information about the duration and location of a parking transaction and is therefore expected to provide an indicator for the number of parked vehicles and the total occupancy in an area. The two further real-time data sources were tested concerning their influence on the reliability of the forecasts. The real-time occupancy model was developed and calibrated with data of an empirical parking space survey in two test areas in Vienna. The study was to form the basis for an online prototype, equipped with a visualisation on Google Maps and a data-interface for integration into existing travel information services.

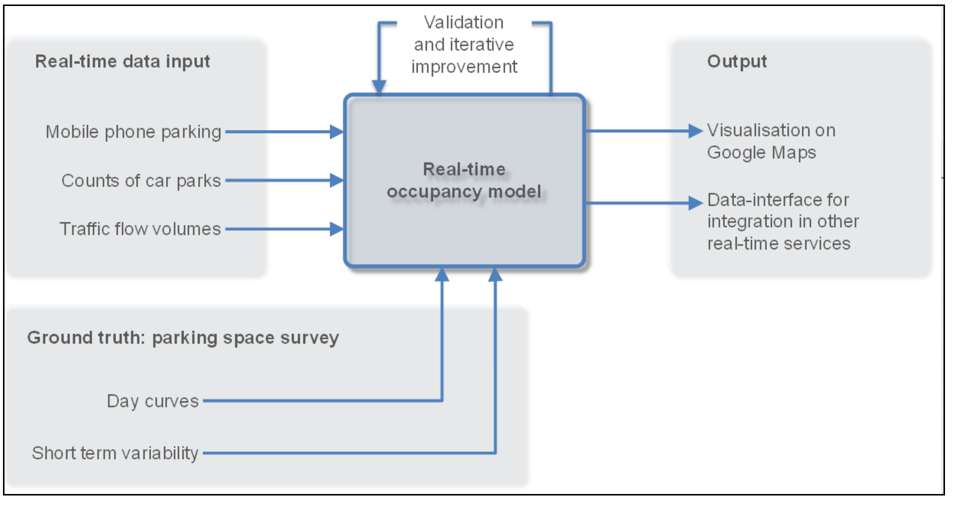


Figure 1: Data flow in the real-time occupancy model

### 3.1 Real time data sources

The HANDY Parken service has an agreement with mobile network operators (MNOs), the largest of which participated in the research project. Reading out all SMS-tickets booked in a given time interval is technically and legally feasible, but for the model also the coordinates of the active network cell from which the mobile phone sent the HANDY Parken SMS was necessary. Due to data protection concerns, the responsible officers of the MNO decided against a data transfer despite an initial agreement. As a consequence, the HANDY Parken data could be made available for calibrating the model, but is currently not available as real-time information source for operation. The counts of short-term parkers in the car parks were obtained by an agreement with five of the six car park operators in the test areas. The provided data included separate counts of long term and short term parkers entering and exiting the car park throughout the duration of the parking space survey. Traffic flow data is already collected at a central point, where they feed into a transport model. A data exchange protocol has been defined, enabling data exchange at any time.

### 3.2 Parking space survey

A parking space survey has been conducted in order to obtain a 'ground truth' for calibrating and validating the occupancy model and to estimate the day curves of vehicles, which have a permanent parking permission, any other special permission, or no permission at all (fee dodgers). This survey was necessary because parkers without a HANDY Parken ticket leave no electronic trace for real-time indication. The survey was conducted in two test areas with a total of 3,000 parking spaces. The areas have different characteristics concerning the residents-visitors ratio, supply of on- and off-street parking, spatial functions, and demographic structure. The survey was carried out in three periods in February, March and April 2012. The demand of parking spaces was observed periodically every 30 minutes from 8 am to 10 pm. Each parked vehicle was registered along with the type of parking permission: permanent permission, fill-in ticket, or no visible permission. The latter could be fee dodgers or users of the mobile parking service. In order to distinguish between the two, we recorded the license plates of these vehicles and checked them against the HANDY Parken database, which allowed us to determine, how many cars in a certain part of the test area had valid electronic tickets during the observation period.

Based on this survey it could be shown that there are strong differences in the day curves for both test areas. The share of short-term parkers is approx. 40 % in the city centre (area 1), whereas it is only 20 % in the residential area (area 2). The occupancy in the city centre is highest during the day and during the opening hours of pubs in the evening, whereas the residential area shows the highest occupancy in the morning before the residents leave and in the evening when they are back.

# 4 RELATIONSHIP BETWEEN REAL TIME DATA AND OCCUPANCY RATE

## 4.1 Counts of short term parking customers in car parks

Several correlations of car park data with parking space occupancy were computed, but no systematic relationship between car park inflow and parking space occupancy were found. This indicates that the car park inflow is no suitable indicator of the occupany rate. The commonly held view that the garage inflow indicates an overflow of on-street parking demand was not confirmed by the survey data.

## 4.2 Traffic flow volumes

Traffic flow data from 830 major roads in the Vienna region was examined. The data were derived from a traffic model, which uses data of more than 300 automatic counting sites in the city. In order to check the suitability of the traffic flow data for predicting parking space occupancy, the correlation coefficients between the traffic flow and mean occupancy rates was computed. It turned out that there is no significant relationship between traffic flow data and parking occupancy rates. The flow data were therefore not included as input for the real-time occupancy model.

## 4.3 Mobile phone parking data

As mentioned earlier, the mobile network operator refused to provide the location data of mobile phone parkers for privacy concerns. However, for the vehicles observed in the parking space survey this information could be derived from the HANDY Parken database. The initial assumption was that mobile phone parkers are a congruent subset of all short term parkers, and that the latter can be added to the number of permanent parkers, which evolves according to its own independent day curve. Table 2 shows the relationships of the number of electronic tickets with other kinds of permissions and with the total occupancy rate.

| Kind of permission | Area 1 | | Area 2 | |
|---|---|---|---|---|
| | *r* | *p* | *r* | *p* |
| fill-in tickets | 0.515 | 0.000 | 0.503 | 0.000 |
| permanent permissions | -0.259 | 0.000 | -0.269 | 0.000 |
| cars without permission | -0.372 | 0.000 | -0.418 | 0.000 |
| all other permissions | -0.067 | 0.241 | -0.238 | 0.000 |
| total occupancy rate | 0.659 | 0.000 | 0.115 | 0.043 |

Table 2: Correlation coefficients (r) and significance (p) between electronic parking tickets and other parking permissions in in 1st district (area 1) and 6th district (area 2)

Table 2 shows a strong positive correlation between the number of cars with electronic tickets and fill-in tickets, but a moderate negative correlation with permanent permissions as well as fee dodgers (without permission). As a result, the hypothesis that the number of permanent parkers evolves independently from short term parkers has to be rejected. Area 1 shows a high positive correlation between electronic tickets and total occupancy rate, whereas in area 2 the correlation is very low. The reason for this difference is the higher share of short term parkers in area 1, which results in a stronger relationship between electronic tickets and total occupancy rate than in area 2. A linear regression model of the occupancy rate given the number of electronic tickets explains $r^2 = 43.5$ % of the occupancy rate variance in area 1 and only $r^2 = 1.3$ % of the variance in area 2.

### 4.4 Real-time model

In order to measure the improvement in prediction accuracy gained from the real-time information two reference models were defined. One was a constant average model, which is based on the assumption that the occupancy rate stays at a constant average level at any time; and the other was an average day curve model, which is based on the assumption that on all days the occupancy rate follows the average day curve. The second model accounts for 65.8 % of the variance of the occupancy rate in area 1 and 54 % in area 2, respectively.

Although, the real-time indicator has a lower explanatory value for the occupancy rate than the average day curve model, it might still improve the predictive power if added to the average day curve model. This was tested for estimations of the occupancy rate in a) the current time interval, b) in future time intervals, and c) in exceptional situations, where the occupancy rate differs strongly from the usual level.

A linear regression model taking into account the number of electronic tickets increases the fraction of explained variance of the occupancy rate in the current time interval by 10 % in area 1 and 1.7 % in area 2. The attempt to improve the prediction of the occupancy rate of a time interval in the near future was based on a linear model of the day curve of electronic tickets. A separate model was developed for both areas and subject to three cross-validation rounds. Within each round, two of the three survey weeks served for calibration, while the remaining week served for validation. The result was that the real-time indicator could in most cases not reduce the prediction error of the average day curve model.

However, the real-time model outperformed both reference models in exceptional situations. This could be shown for the Shrove Tuesday, during the first week of the parking space survey. In this particular case it turns out that the real-time model predicts the occupancy rate better than the average day curve model. The error improvement is strongest in the current time interval, but it still appears in predictions of future time intervals. This result indicates that the real-time information about electronic parking tickets might increase the accuracy of an occupancy model in situations, in which the demand of parking place deviates from the usual level.

## 5 CONCLUSION AND OUTLOOK TO MODEL APPLICATION

This paper reported on the development of a real-time occupancy model of short-term parking zones, which operates without roadside infrastructure. The following points can be concluded from the presented work:

- The number and location of electronic tickets of the HANDY Parken service can help to indicate and predict the occupancy rate in short term parking zones, whereas traffic flow data and counts of short-term parking customers in car parks show no significant correlation. Due to privacy concerns of the major mobile network operator this indicator is currently not available for online operation of the service.
- The occupancy rate of on-street parking spaces follows a recurrent pattern. An average day curve model thus predicts the occupancy at a given time interval very well and can hardly be outperformed by a real-time model which does not account for these daily patterns.
- However, unusual deviations from the day curve due to exceptional events can only be predicted by the real-time model.

The unavailability of the location data of electronic parking tickets is the result of data protection concerns of the Mobile Network Operator. However, the decision is subject to interpretation of the legal regulations, so that there is still a chance for a positive decision in a second attempt.

An elemantary way to make the information service available to the users would be a stand-alone webpage as shown in figure 2, where the user can choose the area and time for which the occupancy information shall be provided. A second option could be to integrate the service into existing information services. The end users' benefit of the information service is in either case a better knowledge of the current and predicted occupancy of on-street parking spaces at the destination in a short-term parking zone. It could also include recommendations for alternative options in case of high parking pressure such as off-street parking facilities, intermodal transport, or public transport. It can serve as a role model for other cities, since mobile phone parking is state of the art in many European cities, and its use will increase elsewhere as well.

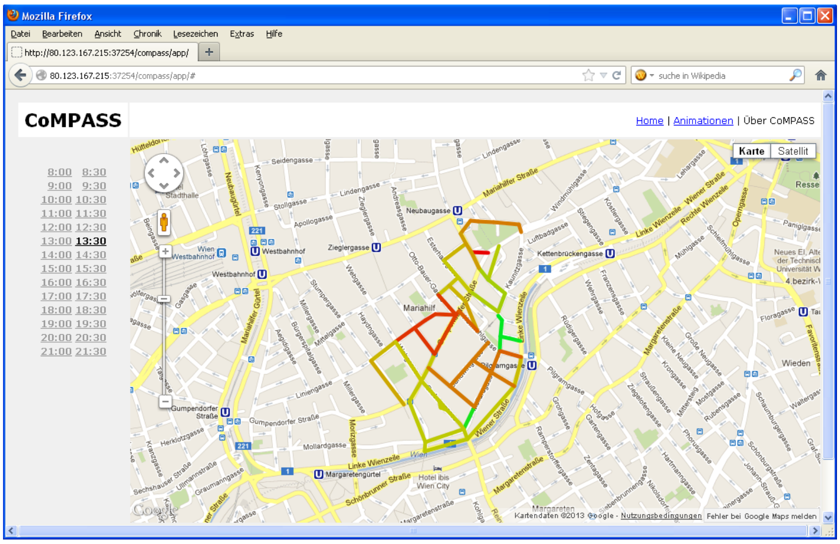


Figure 2: Internet information tool based on the real-time model

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