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Drivers' parking location choice under uncertain parking availability and search times: A stated preference experiment

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ABSTRACT

To assess parking pricing policies and parking information and reservation systems, it is essential to understand how drivers choose their parking location. A key aspect is how drivers' behave towards uncertainties towards associated search times and finding a vacant parking spot. This study presents the results from a stated preference experiment on the choice behaviour of drivers, in light of these uncertainties. The attribute set was selected based on a literature review, and appended with the probabilities of finding a vacant parking spot upon arrival and after 8 min (and initially also after 4 min, but later dropped to reduce the survey complexity). Efficient Designs were used to create the survey design, where two rounds of pilot studies were conducted to estimate prior coefficients. Data was successfully collected from 397 respondents. Various random utility maximisation (RUM) choice models were estimated, including multinomial logit, nested logit, and mixed logit, as well as models accounting for panel effects. These model analyses show how drivers appear to accept spending time on searching for a vacant parking spot, where parking availability after 8 min ranks second most important factor in determining drivers' parking decisions, whilst parking availability upon arrival ranks fourth. Furthermore, the inclusion of heterogeneity in preferences and inter-driver differences is found to increase the predictive power of the parking location choice model. The study concludes with an outlook of how these insights into drivers' parking behaviour can be incorporated into traffic assignment models and used to support parking systems.

1. Introduction

One of the negative effects that can be associated to parking in urban areas is the presence of cruising traffic. That is, drivers may need to drive around whilst searching for a vacant parking spot. This leads to additional traffic on the urban network. Studies by Axhausen et al. (1994), Arnott and Inci (2006), and Shoup (2006) found that at certain moments during the day up to 50% of the traffic is related to cruising for parking. This evidently is a contributor to problems regarding congestion levels, travel times, emissions, and traffic safety (McCoy et al., 1990; Shoup, 2006). These problems can be addressed by parking policies (e.g., pricing policies and/or parking permits) as well as through the use of Parking Guidance and Information (PGI) and Parking Reservation systems. Many studies in the literature have particularly focused on designing efficient pricing

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policies (Gillen, 1978; Anderson and de Palma, 2004; Calthrop and Proost, 2006; Mei et al., 2010; Ottosson et al., 2013; Millard-Ball et al., 2014) and permit schemes (Liu et al., 2014a,b; Barata et al., 2011), also in light of drivers' willingness to pay for parking (Hess and Polak, 2004; Ibeas et al., 2014). At the same time, others argue that what can be achieved via parking pricing and permit policies is limited due to social and political constraints (Verhoef et al., 1995; Lam et al., 2006). In this regard, Intelligent Transport Systems (ITS) aimed at informing and guiding drivers towards vacant parking spots and at allowing drivers to reserve parking spots have good prospects (Thompson and Bonsall, 1997).

In accordance to the solutions proposed, researchers have developed traffic assignment and simulation models to be used for their evaluation. To name but a few, Thompson and Richardson (1998) presented a simulation parking search model in which individuals search for parking space and accept or reject the vacant parking spots based on a disutility function as well as a function to represent the likelihood to select a particular turning movement. Lam et al. (2006) proposed a model for user equilibrium flows that accounts for the departure time, parking location and parking duration. A Bureau of Public Roads based (BPR) function is used as a cost function and the model includes multiple user classes and car parks. In the same direction, Gallo et al. (2011) derived a simulation-based parking assignment model with a hierarchical structure simulating parking location choices on a trip, a cruising and a walking layer, whereas Guo et al. (2013) presents an assignment model for strategic parking route choice decisions under uncertainty. Leurent and Boujnah (2014) give a very detailed analysis of the network flows under the assumption of drivers choosing their parking location and rerouting based on expected conditions in combination with the stochastic realisation of actual parking occupancies. Others have employed a different modelling approach by specifically considering the searching behaviour of drivers. For example, Young and Taylor (1991) describes PARKSIM as a model that describes the parking search within a car park, and Benenson et al. (2008) and Levy et al. (2015) developed PARKAGENT; an agent-based model to explicitly simulate the spatial search process and navigation behaviour of drivers.

Evidently, the (model-based) design and evaluation of such parking-oriented ITS and the derivation of policies on parking require a valid understanding of drivers' choice behaviour amongst alternative parking locations, as well as their willingness-to-pay, usage, and acceptance towards these systems. In this paper, we focus on the former, here termed as parking location choice behaviour, which can improve the assignment and simulation models developed for evaluation and has also clear implication for parking-related policies.

Earlier studies on parking location choice have aimed at identifying the determining factors for drivers' parking decisions (Gillen, 1978; Van Der Goot, 1982; Polak et al., 1991; Brandley et al., 1993; Hunt and Teply, 1993; Lambe, 1996). Other studies have investigated parking location choice in combination with related travel decisions, such as trip purpose (Van der Waerden and Oppwal, 1995; Shiftan and Burd-Eden, 2001) and mode of transport (Hensher and King, 2001; Hess, 2001; Coppola, 2004), as well as route choice of cruising traffic (Guo et al., 2013; Leurent and Boujnah, 2014). Typically, the influence of these factors is studied through the estimation of discrete choice models, where these models are based on stated preference experiments. Attributes that are recurrently reported are parking costs, walking distance to destination, access time, expected search time or waiting time at parking location, and to a lesser degree driver's age, type of parking facility, and parking duration. With respect to the design and evaluation of parking information, guidance, and reservation systems, what is especially of interest is how drivers' parking location choice is affected by uncertainties in finding a vacant parking spot. In this regard, the study by Van der Waerden (2012) explicitly accounts for the chance (probability) of finding a vacant parking spot. There, parking availability probabilities are found to be significant for the choice set generation, where a higher probability to find a vacant parking spot relates to a higher probability to choose that parking location. In line, Kaplan and Bekhor (2011) presented a theoretical framework with a hierarchical structure where on-route the preferred parking type determines the preferred parking location, which in turn determines the preferred route towards this destination.

The experiments reported in this paper were part of a larger study to investigate the viability of parking-oriented ITS. Here the main target group of a (future) parking guidance and reservation system was chosen to be drivers who make a trip for shopping purposes and park for a duration of 2–3 h. Hence, this is also the context for the remainder of this paper.

This way, this paper first of all adds to the existing body of the literature (including the studies by Kaplan and Bekhor (2011) and Van der Waerden (2012)) using stated preference experiments to understand parking location choice behaviour in case of uncertain search times and parking occupancy levels. Second of all, we analyse drivers' parking location choice and show the importance of uncertain parking availability as a determining choice factor, as well as the heterogeneity in preferences and inter-driver differences in this respect. Third of all, we estimate choice models that can be readily incorporated in both disaggregated microscopic simulation models as well as aggregated macroscopic traffic assignment models. Finally, we discuss the quantified behavioural findings and conclusions within this paper with respect to their implications on parking–related policies and transportation modelling.

The structure of this paper is as follows: We first introduce the stated preference experiments on drivers' parking location choice in Section 2. The estimated parking location choice models are then presented in Section 3. The main behavioural findings from these models are discussed in Section 4. In Section 5, we conclude with an outlook towards including drivers' parking location choice behaviour in traffic assignment models to support the evaluation of parking systems.

Note that throughout the paper, uncertainty concerning parking availability and search times refers to the situation in which the outcome is unknown, but the set of possible outcomes and their probabilities are known. This terminology is consistent with the larger body of parking-related literature. However, note that in many other lines of research this situation would typically be referred to as risk (whilst uncertainty would be used to indicate that the set of possible outcomes and their probabilities are unknown).