

Network Assignment Model with Parking under Uncertain Parking Conditions

Adam J. Pel

Civil Engineering and Geosciences
Delft University of Technology, The Netherlands

Emmanouil Chaniotakis

Centre for Research and Technology Hellas,
Hellenic Institute of Transport
Email: chaniotakis@certh.gr

1 Introduction

Parking is a critical issue in urban areas, found to contribute negatively to mobility and traffic. Related research has estimated that drivers driving around searching for parking (cruising for parking) could reach up to 50 % of the total traffic (Shoup, 2006). Solutions to problems associated with parking have been widely addressed by parking policies (e.g. pricing, permits) (Liu et al., 2014) and Parking Guidance and Information systems (PGIS) (Caicedo, 2010). Although latest studies conclude that parking-related policies implemented have reduced the impact of parking to traffic (Montini et al., 2012), social and political considerations limit their applicability, while it is evidenced that they might negatively impact competitiveness of businesses (D’Acierno et al., 2006). Intelligent Parking Services (IPS) have been suggested as a mean to alleviate the remaining effects of parking by reducing the searching process (Geng and Cassandras, 2012). The evaluation of such systems requires the modelling of the road transportation system including parking. Parking modelling can be distinguished in choice and allocation (or assignment) modelling.

This article presents a bi-level network assignment model with parking facilities under uncertainty, based on the behavioural characteristics of the parking search process (Chaniotakis and Pel, 2015). It contributes to the existing literature (Guo et al., 2013; Leurent and Boujnah, 2014) by defining a parking decision process model, that serves as the base for the equilibrium parking assignment model proposed.

2 Drivers' Parking Choice model

Chaniotakis and Pel (2015) conducted a stated preference research and concluded that individuals take decisions concerning parking facilities to be visited before trips given their previous experiences and concluded to a set of parameters that describe the parking choice under uncertainty, that can be directly connected to network characteristics (strategic decision making). The Multinomial Logit model version is presented in Equation 1 (tvalues given in parenthesis below the estimated coefficient values).

$$V_{o,p,d} = \underset{(22.85)}{-0.735} \cdot C_p - \underset{(-8.78)}{0.001} \cdot T_{o,p} - \underset{(-2.44)}{0.011} \cdot W_{p,d} + \underset{(3.43)}{0.119} \cdot O_p + \underset{(6.84)}{0.569} \cdot Pr_p^0 + \underset{(16.54)}{1.180} \cdot Pr_p^8 \quad (1)$$

where $V_{o,p,d}$ is the utility of visiting parking facility p given origin o and destination d , C_p the parking cost, $T_{o,p}$ the travel time from origin to parking facility, $W_{p,d}$ the walking distance from the parking facility to the destination, O_p dummy variable for parking type (set to 1 for off-street parking type) Pr_p^0 the probability to find a vacant parking spot upon arrival Pr_p^8 the probability after 8 min.

3 Networks Assignment Model with Parking Facilities

3.1 Formulation

Individuals who are familiar with an area are assumed to follow a habitual pattern when it comes to parking. This assumption is supported by the behavioural research performed by (Chaniotakis and Pel, 2015). The habitual pattern includes the devise of a strategy (pre-trip) consisting of visits to sequential parking facilities until a vacant parking spot is found. The choice model, is used to describe this sequence of parking facilities (parking search route) to be visited by each individual searching for parking, in a bi-level equilibrium assignment (Figure 1). This assignment includes a Stochastic User Equilibrium Assignment for the estimation of travel times and flows $SUEr$ and a Stochastic User Equilibrium assignment for the estimation of the parking search routes chosen facilities $SUEp$. The decomposition of the assignment on two levels lays on the fact that both equilibrium levels have travel time as a common attribute. Travel time is related to the route flows, which is affected by the chosen parking destination derived by the parking search route assignment (SUEp).

It is assumed that individuals would maximize the total utility of each parking search route, defined as the summation of the utilities of each visited parking location multiplied by the probability to find a vacant parking spot at the examined parking facility, multiplied one minus the probability of finding a vacant parking spot at each previously visited parking facility. Based on the probabilities to find a vacant parking spot and the choices to drive to a parking facility, the expected number of individuals driving to each parking

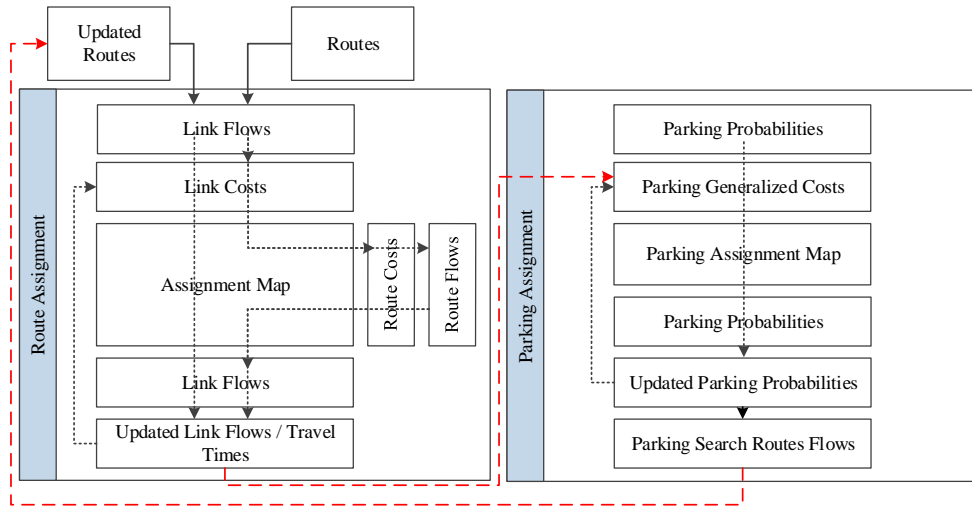


Figure 1: Bi-level parking assignment procedure

destination for each random OD is defined. The probabilities to find a vacant parking spot upon arrival and after 8 minutes are defined based on the capacity of the parking destination the number of occupied parking spots, the number of arriving vehicles (arrival process) and the number of departing vehicles (departure process).

3.2 Verification

The assignment model was implemented in MATLAB and examined on three simple test networks that would allow for its verification and identification of possible problems. Six scenarios are examined for varying characteristics (parking price, capacity, parking type, walking distance to destination, travel time). In all cases examined the assignment model performs as expected, with individuals choosing parking search routes that would maximize the total obtained utility (minimize cost). Focus is given on the sensitivity of the SPSR to different prices and capacities and also to the different results that yield with a Logit scale factor (λ) of 1 and a large scale factor that is closer to DUE assignment.

4 Conclusions and Future Work

This paper presents a network assignment model with parking under uncertain parking conditions. The model suggested is built upon the research findings of Chaniotakis and Pel (2015) including the parking related behavioural characteristics and the estimated choice model. For individuals familiar with the area to park, a habitual pattern is assumed on the strategic behavioural level (pre-trip), and a novel parking search route consisting of sequential parking destinations to be visited is suggested. The successful verification of the assignment illustrates the performance of the model suggested and its capabilities to

be implemented in large scale networks.

References

- Felix Caicedo. Real-time parking information management to reduce search time, vehicle displacement and emissions. *Transportation Research Part D: Transport and Environment*, 15(4):228 – 234, 2010.
- Emmanouil Chaniotakis and Adam J. Pel. Drivers parking location choice under uncertain parking availability and search times: A stated preference experiment. *Transportation Research Part A: Policy and Practice*, 82:228 – 239, 2015.
- Luca D’Acierno, Mariano Gallo, and Bruno Montella. Optimisation models for the urban parking pricing problem. *Transport Policy*, 13(1):34 – 48, 2006.
- Yanfeng Geng and Christos G. Cassandras. A new smart parking system infrastructure and implementation. *Procedia - Social and Behavioral Sciences*, 54(0):1278 – 1287, 2012. Proceedings of EWGT2012 - 15th Meeting of the EURO Working Group on Transportation, September 2012, Paris.
- Liya Guo, Shan Huang, Jun Zhuang, and AdelW. Sadek. Modeling parking behavior under uncertainty: A static game theoretic versus a sequential neo-additive capacity modeling approach. *Networks and Spatial Economics*, 13(3):327–350, 2013.
- Fabien Leurent and Houda Boujnah. A user equilibrium, traffic assignment model of network route and parking lot choice, with search circuits and cruising flows. *Transportation Research Part C: Emerging Technologies*, 47, Part 1:28 – 46, 2014. Special Issue: Towards Efficient and Reliable Transportation Systems.
- Wei Liu, Hai Yang, Yafeng Yin, and Fangni Zhang. A novel permit scheme for managing parking competition and bottleneck congestion. *Transportation Research Part C: Emerging Technologies*, 44(0):265 – 281, 2014.
- Lara Montini, Andreas Horni, Nadine Rieser-Schüssler, Kay W Axhausen, Kay W Axhausen, and Kay W Axhausen. *Searching for parking in gps data*. Eidgenössische Technische Hochschule Zürich, IVT, Institute for Transport Planning and Systems, 2012.
- Donald C. Shoup. Cruising for parking. *Transport Policy*, 13(6):479 – 486, 2006.