A parking search model to assess parking policies in urban areas

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Abstract
Parking is a key element of urban transportation systems. In recent years, parking has become an ever-increasing concern in most dense urban areas. Supply is generally limited and has not often been able to keep up with the growth of parking demand. A shortage of parking places leads to cruising mostly in peak periods and affects deeply traffic congestion and pollution levels as well. Traffic managers recognize that defining a parking policy constitutes an important challenge. Consequently, a parking model is needed to assess and evaluate different policy scenarios. Most of previous parking models are theoretical in nature and few of them have been applied to real life situations because of the computational complexities of considering spatial dimension and capacity constraints of parking lots.
This paper proposes a novel traffic equilibrium model that simultaneously considers parking and route choice on a transportation network including parking facilities and explicit search circuits. Supply is represented by parking type and location, management strategy including the fare, capacity and occupancy rate of the parking lot, and network location, in relation to access routes. Demand is addressed in a disaggregate way. Different user classes are defined according to travel purpose, parking duration and individual perceptions of parking and network quality of service.
We assume that mode and destination choice are pre-trip decisions, that the user has already a certain knowledge of parking supply but ignore instantaneous availability of a slot in the desired lot. Each traveller is supposed to make a two-level choice of, first, network route from the origin point to a prior target lot in his destination zone on the basis of the expected overall travel costs and, second, in case of initial lot saturation, a sequence of local diversion to a neighbouring lot up to parking success.

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Parking capacity is modelled by lot; its occupancy determines its availability to a user. Lot diversion is modelled as a discrete choice on the basis of transition costs and the expected cost of search and parking from the initial lot. Search circuits are explicitly considered on the basis of the success probability to get a slot at a given lot and also of transition probabilities.
The basic model variables are the route flows, success probabilities and transition probabilities. These variables give rise to the cost of a travel route up to a target lot and to the expected cost of search and park from that lot. For simplicity, the setting is static, by assuming that the parking slots are made available in a continuous way due to the departure of their previous occupants. This assumption typically describes the morning peak hour in urban nuclei, when night occupants give place to day occupants.
A traffic equilibrium is defined where the individual user selects only a route of minimum expected overall cost to himself. Traffic equilibrium is solved by a joint problem of variational inequality for route choice and fixed point for success as well as transition probabilities. Equilibrium is shown to exist under mild conditions and is solved by Method of Successive Averages.
The proposed model was applied to a real-scale network, the downtown of the Cité Descartes in the East of Ile de France region with about 5800 inhabitants.
Detailed spatial supply data were used. These data include a road network (663 road links, 473 of which were parking access links, and 626 nodes), parking facilities (243 nodes representing on-street parking and some off-street parking lots) and buildings (124 nodes). On-street parking capacities were computed from high spatial resolution aerial photography where parking slots were visually identifiable and quantifiable. For private parking, estimations were made according to housing and jobs data. For the simulation period, parking demand volume was estimated, by segment, on the base of local data provided by the city authorities and local travel surveys. We consider three major travel demand segments: commuters, visitors and train riders.
A scenario framework was carried out. The first scenario was intended to simulate the current parking situation in the area. The second and third scenarios dealt respectively with a more sustainable parking policy based on pricing and enforcement implementation for on-street lots and changing supplied capacities.
The results have shown that the model is able to simulate user parking and search behaviour as well as parking supply loading. We compared results for each scenario across three main axes. First, for parking supply, we compared lots occupancy levels, total parking demand by lot and the pressure on each type of facilities. Hence, parking congestion zones were depicted at micro-local scale. Then, by demand segment, we analyzed the variation of average costs (travel time, search time and walk time and parking charge). Finally, at the network level, taking into account the spatial distribution of road flow, we compared the variation of the total traffic volume and the proportion of cruising flow.

In the light of the results mentioned above, three main findings are obtained. (1) On-street parking pricing is shown to be effective to reduce parking and traffic congestion mostly when joined to high enforcement levels. It contributes significantly to more balanced occupation rates between different lot types. (2) Supply oriented parking policies may decrease the total search flow on the network, but does not eliminate cruising. This improvement is almost a short term effect and should be carefully treated since more supply may generate more parking demand. (3) Shared parking spaces over mixed land use areas decrease resource consumption and enhance off street parking utilization.
This model is a useful tool for studying key features of parking system at strategic level. It can be used by policy makers to assess and evaluate various parking policies effects.