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Spatially explicit modeling of parking search as a tool for urban parking facilities and policy assessment

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ABSTRACT

The engineering view of a measurable, supply-independent, demand for parking that can be expressed by "minimum parking codes" has been generally rejected during the last two decades and is gradually being replaced by "maximum provision" codes, limited parking development, and demand pricing. To assess new planning practices one has to estimate the drivers' reaction to proposed spatial–temporal parking limitations. The paper applies a high-resolution spatially explicit agent-based model termed "PARKAGENT" as a tool for this assessment. The model is used for evaluation of parking demand in the Diamond Exchange area in Ramat Gan, a city in the Tel Aviv metropolitan area, for estimating the effectiveness of planned parking facilities for different development scenarios in the area and assessing electronic signage system that directs drivers to vacant parking lots. The results strongly indicate the advantages of agent-based modeling over the current dominant engineering approach and show the potential benefits of using an intelligent parking guidance system.

1. Urban parking policy revolution: from satisfying demand to regulating car usage in the city

Parking, in the practical engineering view, is seen as a utility to be supplied based on measurable demand. For various land uses, such as a large shopping center, high tech park, or restaurants, common sense procedures based on surveys are sufficient for estimating demand. For example, parking demand generated from an office building is usually estimated based on usable floor area, factors for employees and visitors per unit of floor area, and the percentage of employees and visitors using cars to get to the office. In other cases, the number of students in a college or number of chairs in an auditorium can serve as a basis for estimating the demand for parking. The classic survey of this sort is published by the Institute of Traffic Engineers (USA) "*Trip Generation Manual*" now in its 9th edition. The manual contains trip generation rates for private cars for hundreds of land uses, from drive-in banks to sports stadiums. By calculating the demand for car trips at different times of the day it is possible then to calculate the parking supply needed to satisfy this demand.

In order to further standardize parking provision and avoid the need for further surveys, cities and states created parking "codes" that, similar to the surveys, set up a number of parking places to be provided by land uses. The first residential parking requirement originated in Columbus, Ohio in 1923 – one parking place per apartment. In 1939 the city of Fresno California created the first non-residential parking requirement for hospitals and hotels, in parallel to the 1939 German *Reichsgaragenordnung* (Order on Garages of the Third Reich) which introduced off street parking regulations to Germany and Austria (Knoflacher, 2006). A widespread adaptation of standardized parking codes started in 1950s, with the lofty goal to "alleviate or prevent traffic congestion and shortages of curbside parking places" (parking code of Pasadena, California, http://greatergreater.com/files/200802/nnzoningparking.pdf). These codes specify the number of parking places per unit of a floor area, for example of a regional shopping center, local commercial areas, banks, etc. Estimating parking demand then becomes a matter of arithmetic that translates a building program to parking places to be provided for both employees and visitors according to the proposed land use.

In this standard view, a lack of parking at a facility planned in accordance with a standard type parking code indicates a need to revise the code upwards. This was the case for many years in Israel, with the minimum provision of parking for a residential unit being adjusted consistently upwards from 0.5 or 0.75 places per unit to 2.0 places in many cases today.

The critical assumption of the above approach – an ability to supply unlimited amount of parking, is now obviously problematic. Besides space limitations (that can be overcome at great

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expense by underground parking garages and above ground structures), it contains another, hidden, assumption that a supply of road capacity is also unconstrained, even in the critical peak periods of travel to and from work, studies and recreational trips. The latter has proved untenable even in the most car oriented North American cities. Moreover, transportation researchers noted the phenomenon of "induced demand," namely, an unconstrained free provision of parking and road capacity increases the rate of use of both (Cervaro and Hansen, 2002). This, in turn, is accompanied by an increase in average trip length, in the rate of car ownership, and in the percentage of trips made by private car thus further increasing the need for parking and road capacity. Road congestion, staggering amounts of land allocated to road space and parking, and the environmental penalty in air and noise pollution call into question the very basis of the view of transportation planning as a kind of traffic plumbing providing adequate road "pipes" and parking "reservoirs".

Recognizing these inherent problems, transportation planners have moved away from the supply-focused view of parking to the policy driven model, which focuses on the encouraging public transportation and non-motorized transport (bicycle, walking) as the primary solution of urban mobility problem. This new attitude initially found voice in the modification of the standard parking code to require less parking in central business districts or areas with good public transport provision. A good example of the development of this approach is the new Jerusalem parking code, which establishes a *maximum* rather than minimum number of parking places for each land use. In areas within walking distance of existing or future mass transit lines, the maximum is severely limited, especially for employee and shopper parking (Local Masterplan #5166, 2003, amended 2007). The origins of similar policies could be seen in San Francisco in the 1970, with the implementation of the BART rapid transit system, and in 1985 limits on downtown office parking https://livablecity.org/livable-neighborhoods/parking-reform-for-a-livable-city/.

The new paradigm "maximum parking standard" serves as a basis for establishing parking policy in many cities such as Zurich, Amsterdam and Strasbourg, which limit the amount of parking places in city centers (Kodransky and Hermann, 2011). The view of parking supply as a component of the urban transportation system is further reinforced by transportation economists, who see the employment of market forces as the most efficient arbiter of scarce parking and road resources (Shoup, 2004; Shoup, 2006; Litman, 2010). Should a market-determined price be set for either, demand would bring itself in line with supply automatically. It is now clear that increase in area's capacity for parking is not an automatic solution, but in fact become a source of urban transportation problems (Tam and Lam, 2000).

At a country level, the new laws in Israel, Switzerland, United Kingdom and Italy (Israel Ministry of Transport, 2005; Kodransky and Hermann, 2011) also aim at limiting the amount of parking places in the cities. The assumption is that an excess demand will drive up parking prices and thus move demand to walking, biking or public transport. Other reforms, such as the imposition of property taxes on private parking areas, even if they do not charge for parking (employee parking for example) put further pressure to provide less parking or charge for its use to offset costs.

All this essentially complicates transportation planning – instead of simple mathematical calculations, estimating parking demand must account for the cost of parking and its economic justification in light of the present and future demand in the area. We also cannot be sure that population reaction to the restrictive public policy will result in increasing use of public transport and non-motorized transport in urban areas. Estimating these and other effects demands an adequate model of driver's reactions to limits on parking supply.

This paper makes a step in this direction. To assess drivers' reaction to the potential, yet limited, parking supply, we employ high-resolution spatially explicit dynamic agent-based PARKAGENT model and apply this model for the planning of a new parking facility in a central business area of the Tel Aviv metropolitan area. Section 2 presents a short view of the modeling of the parking search in the city with the stress on the agent-based simulation modeling; Section 3 presents the PARKAGENT model; Section 4 describes a case study of the Diamond Exchange district in the Tel-Aviv metropolitan area and the "engineering" and PARKAGENT views of the parking problem there. We discuss the obtained results in Section 5.

2. Combining optimal supply of parking facilities with simulation of cruising for parking

What is an adequate parking supply? Most parking research considers this question from an economic point of view and assumes that the driver is a rational actor who seeks to minimize the total cost of parking (Young and Thompson, 1991; Young, 2000). This view is implemented in the models based on statistical relationships between the parking demand and driver's decision making based on the parking availability, price and currently and previously available information on parking occupation (Bates and Bradley, 1986; Polak et al., 1990; Axhausen and Polak, 1991; Khattak and Polak, 1993). The relationships employed in these models were based on stated preference experiments and accounted for the hierarchy of the traffic mode choice and type of parking (on- or off-street, etc.) and were used to estimate the effect of changes in transport and parking services on the choice of travelers' traffic mode and parking type and location (Young and Taylor, 1991).

Shoup's model (2005) aims at optimizing parking prices by considering equally priced on- and off-street parking and estimates the amount of parking that results in zero cruising (Shoup, 2005). However, the model does not account for the distance between the parking place and the destination: if parking lots are far from the destination, drivers will yet prefer to cruise in order to find unoccupied and close on-street parking. Calthrop and Proost (2006) suggest that street parking should be priced equivalent to the marginal cost of providing an additional off-street space, while Arnott and Inci (2006) in their "bathtub model" investigate the relation between on-street parking, parking price and traffic congestion in the city accounting for the walking time from the parking place to the destination. Further studies of Arnott and coauthors (Arnott and Inci, 2010; Arnott and Rowse, 2013; Arnott, 2014) demonstrate that pricing can be an effective and adequate tool of parking policy that causes reduction of cruising while preserving high levels of parking occupancy. The bathtub model makes it possible to recognize underpriced curb parking and establish the price level that will result in minimal potential cruising. Higher parking fees will raise municipality revenue while causing no harm to local businesses since all parking places are still occupied. Arnott (2013) also demonstrates how parking capacity and pricing should be simultaneously adjusted to minimize cruising.

All above models focus on the equilibrium ratio of parking demand and supply and the question is what should be this equilibrium and how it can be maintained in practice. This view of the parking supply, popularized by Shoup (2006), aims at 85% occupation level by prices varying in space or during the day, a rate at which cruising behavior is minimized. Levy et al. (2013) show that the 85% level can be raised to 92–93%. However, this ratio varies in time and space and its value at a certain location is very sensitive to the parking situation over the surrounding area. To account for this, we need a high-resolution and dynamic view