From Modeling Parking Search to Establishing Urban Parking Policy

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From Modeling Parking Search to Establishing Urban Parking Policy

Outline

1. How did it all start?
2. Model base
3. Introducing PARKAGENT
4. “Mean Field” Parking versus PARKAGENT
5. Applications of PARKAGENT
Tel Aviv background

High demand for parking, often exceeding supply

**Effects:**
- For driver: long search time, long walking distance
- For residents: illegal parking, air pollution
- For municipality: inefficient traffic system, enforcement overhead
Why does Tel Aviv (and most western cities) have to improve their parking policy?

• Many unanswered questions:
  – Increase on-street parking fees?
  – Maintain existing system of parking zones?
  – Introduce parking restrictions for various driver groups (local residents, workers, visitors, etc.)?
  – Increase enforcement levels?

• Answers require insight in:
  – Impact on parking behavior of individual driver
  – Impact on collective parking dynamics of commuters, residents and visitors
  – Impacts on traffic within the regulated area and in its surrounding
  – Balance between on-street and off-street parking
  – Income generated by the policy and costs of enforcement

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Establishing parking policy requires understanding of drivers’ behavior

Drivers may have different
• Destination
• Parking search behavior
• Arrival time, duration of stay, departure time
• Willingness-to-pay for parking

Main types of drivers
• Residents
• Commuters
• Visitors of several types

Let us then simulate parking dynamics at the resolution of individual car, destination, and parking place
Modeling basis of PARKAGENT: Geosimulation

Integration of Infrastructure Objects and Animated Agents within one model

- Each real-world entity is presented in the model:
  - Inanimate infrastructure objects: street segments, destinations, parking lots, parking places
  - Animate agents: drivers

- Entities “behave”:
  - Change properties: infrastructure objects
  - Change properties and location: driver agents

- Spatial information and referencing:
  - Geographical Information Systems (GIS)
PARKAGENT

... is linked to high-resolution urban GIS maps
... assigns specific spatial and behavioral parameters to each driver
... allows simulating drivers’ behavior and overall parking dynamics
... works with practically unlimited number of drivers
... is generic, can work on any road network
PARKAGENT links to GIS layers of land uses, streets and parking places

Typical set of the PARKAGENT layers

Street network that includes traffic directions and turns, thus enabling simulation of driving to the destination

Parking permissions along the streets, off-street parking places and lots, thus enabling estimation of parking space supply

Residential buildings, public buildings, offices and businesses, thus enabling estimation of parking demand
Agents

• **Types of driver agents**
  – Residents, Guests, Commuters, Customers

• **Driver’s characteristics:**
  – Destination, arrival time, maximal cruising time, willingness to pay, duration of stay

• **Parking agents’ behavioral rules**
  – Route choice
  – Decision to park before reaching destination
  – Decision to park after passing destination

• **Behavioral rules in case of cheap on-street and expensive off-street parking**
Behavioral rules: Driving to destination, one of

a) Choose the turn taking you to the junction that is closest to your destination

b) Optimal path

Which turn to choose?

This junction is closest to the destination

The chosen turn

Destination

N. Levy, I. Benenson, K. Martens, IGU2010, Tel-Aviv, July, 2010
Behavioral rules: decision to park before destination

• Estimate the fraction $p_{\text{free}}$ of free parking places on the way as

$$p_{\text{free}} = \frac{N_{\text{free}}}{N_{\text{free}} + N_{\text{occupied}}}$$

• Estimate expected number of free parking places on the way to destination

$$F_{\text{expected}} = p_{\text{free}} \times \text{Distance to destination/length of the parking place}$$

• Decide whether to park or to continue driving towards destination

• Continuously update $p_{\text{free}}$ and $F_{\text{expected}}$ while driving to destination

N. Levy, I. Benenson, K. Martens, IGU 2010, Tel-Aviv, July, 2010
Behavioral rules:
Drive and decide on parking after the destination is missed

- Extend the search area, at a rate 30 m/min; park at any place within
- At a turn, next junction is selected from the set of junctions within the search area
Parking lots:

1. Capacity $N \rightarrow N$ parking place within the lot

2. Queue at the entrance of max length $K \rightarrow K$ places on the line representing the queue
The model output: driver’s view

Distribution of search time

Distribution of distance to destination

Over the given 
Area,

During given 
Time Interval

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The model output: planner’s view

Number of drivers searching for a parking place

Over the given Area,
During given Time Interval

Number of free parking places

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The model output: municipality’s view

Illegal parking

<table>
<thead>
<tr>
<th>Type of illegal parking</th>
<th>Number of cars</th>
<th>Overall places of a given type</th>
<th>Fraction occupied illegally</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red-White</td>
<td>232</td>
<td>240</td>
<td>0.967</td>
</tr>
<tr>
<td>Blue-White, no region label</td>
<td>120</td>
<td>1400</td>
<td>0.086</td>
</tr>
<tr>
<td>Other illegal</td>
<td>25</td>
<td>28</td>
<td>0.893</td>
</tr>
</tbody>
</table>

Revenues from legal parking

<table>
<thead>
<tr>
<th>Type of parking</th>
<th>Revenue/hour</th>
</tr>
</thead>
<tbody>
<tr>
<td>On-street</td>
<td>1154</td>
</tr>
<tr>
<td>Parking Lot N 1353</td>
<td>2027</td>
</tr>
<tr>
<td>Parking Lot N 1401</td>
<td>632</td>
</tr>
<tr>
<td>Parking Lot N 1481</td>
<td>3014</td>
</tr>
</tbody>
</table>

N.Levy, I.Benenson, K.Martens, IGU2010, Tel-Aviv, July, 2010
PARKAGENT: What are the necessary field data?

- Spatial distribution of parking demand
- Parking behavior parameters (e.g. willingness-to-pay)

→ Can be obtained in relatively simple, low cost, surveys

**Graph**

Distance of parking from destination

- $N = 694$
- $P_{95} = 171.803$
- $P_{99} = 271.752$
Verifying PARKAGENT
“Mean field” model of parking (MFP) enables analytical analysis of parking as a collective phenomenon

Assuming homogeneity in parking supply and search behavior...

\[ N(t + \Delta t, t) = a(t), \]
\[ N(t + \Delta t, t - \Delta t) = N(t, t)*p(t), \]
\[ N(t + \Delta t, t - 2*\Delta t) = N(t, t - \Delta t)*p(t), \]
...\[ N(t + \Delta t, t - n*\Delta t) = N(t, t -(n-1)*\Delta t)*p(t); \]
\[ C(t + \Delta t) = C(t ) + (a(t) − e(t))*\Delta t - F(t); \]
\[ F(t) = N(t, t - n*\Delta t) ; \]
\[ p(t) = 1 − e(t)/C(t); \]

\[ N(t, t - k*\Delta t) - \text{the number of cars that entered the system at } t − k*\Delta t, \text{ and still search for parking at } t, \ k = 0 ÷ (n − 1); \]
\[ p(t) - \text{fraction of cars that fail to find a parking place between } t \text{ and } t + \Delta t; \]
\[ F(t) - \text{number of cars that failed to find a parking place}; \]
\[ C(t) - \text{overall number of cars in the system at } t; \]
\[ a(t) - \text{arrival rate}; e(t) - \text{egress rate}; \]
\[ n*\Delta t - \text{maximal driver's search time}; \]
Dynamics of parking is, unfortunately, dynamics of a queue...

Either the service is under-used (arrival < egress)

Or it is insufficient (arrival > egress)

A stable equilibrium does not exist!

N. Levy, I. Benenson, K. Martens, IGU2010, Tel-Aviv, July, 2010
PARKAGENT versus Mean Field Parking
Dependence of average search time on the occupation rate

Overall parking capacity = 7,000
Average arrival rate = average egress rates, turnover = 15%/hour
Overall parking capacity = 7,000
Turnover = 15%/hour

PARKAGENT versus Mean Field Parking
Share of cars searching for longer than 300 and 600 sec

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Why do we need PARKAGENT?

Mean field model works good in case of *homogeneous* distribution of destinations and, hence, parking demand over space. It’s good for theoretical analysis and as a reference point but ...

For the real-world city we need PARKAGENT!

... to investigate parking dynamics in case of *spatially and behaviorally heterogeneous* situation

N. Levy, I. Benenson, K. Martens, IGU2010, Tel-Aviv, July, 2010
Applications of PARKAGENT®
Example 1: Parking dynamics around a single large-scale destination

Cinema scenario first and second arrival

Abstract versus real-world road network

The closer to the cinema, the higher the chance to park!

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**Example 2:**

Parking within the residential area

Residents’ overnight (O) and end-of-day (E) demand for, and supply of, on-street parking places in NBH1, and NBH2

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Part of Basel neighborhood</th>
<th>NBH1</th>
<th>NBH2</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area (km²)</td>
<td></td>
<td>0.442</td>
<td>0.936</td>
<td>1.378</td>
</tr>
<tr>
<td>Number of buildings</td>
<td></td>
<td>530</td>
<td>1032</td>
<td>1562</td>
</tr>
<tr>
<td>Street length in meters</td>
<td></td>
<td>8807</td>
<td>16331</td>
<td>25138</td>
</tr>
<tr>
<td>O: on-street supply of parking places</td>
<td></td>
<td>3751</td>
<td>7134</td>
<td>10340</td>
</tr>
<tr>
<td>O: on-street parking demand</td>
<td></td>
<td>3943</td>
<td>7678</td>
<td>11621</td>
</tr>
<tr>
<td>O: on-street demand/supply</td>
<td></td>
<td>1.11</td>
<td>1.13</td>
<td>1.12</td>
</tr>
<tr>
<td>E: On-street supply between 17:00 – 21:00</td>
<td></td>
<td>1313</td>
<td>2497</td>
<td>3810</td>
</tr>
<tr>
<td>E: On-street parking demand between 17:00 – 21:00</td>
<td></td>
<td>1693</td>
<td>3398</td>
<td>5091</td>
</tr>
<tr>
<td>E: On-street demand/supply between 17:00 – 21:00</td>
<td></td>
<td>1.29</td>
<td>1.36</td>
<td>1.34</td>
</tr>
</tbody>
</table>

*The calculation of the resident’s overnight on-street parking supply encompasses 95% of the total amount of on-street parking places, as we assume that 5% of parking places are used by overnight visitors.*

About 50% of the residents’ cars remain on-park during the daytime.

The demand/supply ratio among the residents who use their cars for getting to work is 1.30 – 1.40.

N. Levy, I. Benenson, K. Martens, IGU2010, Tel-Aviv, July, 2010
Assessment of impacts of new off-street parking facility on residents on-street parking dynamics

Number of drivers per hour who search for parking more than 10 minutes

400 - 450

250 - 300

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Example 3: Analysis of interrelationship between parking turnover, parking occupancy rate and cruising for parking.

Share of cars that search for parking longer than (A) 600 seconds and (B) 300 seconds

turnover rates 15%, 30%, 50%, 70% per hour

(C) Average cruising time in seconds; (D) Share of cars parking without cruising

turnover rates 15%, 30%, 50%, 70% per hour

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Example 4: Replacement of surface parking lots by multi-storey underground parking facility

“Bursa” – Diamond Exchange area

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“Byalik” parking, new underground multistory facility

– What is the usage of already existing parking facilities?
– Who will use Byalik parking facility?
– What should be the capacity of Byalik parking?
– What should be the prices of parking there?
– The feedback impact of new facility on parking demand in the area?
Transportation mode of Bursa employees

<table>
<thead>
<tr>
<th>Car</th>
<th>Public transport</th>
<th>Two wheel</th>
<th>Walk</th>
<th>Other</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>~59%</td>
<td>~26%</td>
<td>~6%</td>
<td>~7%</td>
<td>~1%</td>
<td>100%</td>
</tr>
</tbody>
</table>

For existing demand and supply
There is no need for a new parking lot!

N. Levy, I. Benenson, K. Martens, IGU 2010, Tel-Aviv, July, 2010
Lot choice, No Information on Parking Availability

The outcome of the model study for “No information system” scenario: The traffic will stop before the new parking lot will be full.
The lot that is closest to the destination and not fully occupied

Shortest path to selected lot

The outcome of the model study for “Active information system” scenario:
New parking lot capacity as a function of the development schedule in an area
In sum ...

PARKAGENT® is a powerful decision-support tool ...

• .. that is linked to municipal GIS layers

• ... that is based on survey data that are relatively easy to obtain

• ... that can provide data on collective characteristics of parking dynamics in the area

• ... that can estimate the consequences of local policy/construction decisions

And the outlook:

• ...we are including through traffic to investigate the influence of cruising on traffic situation in the area
Thank you!