Effects of Parking on Urban Traffic Performance

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Urban Parking & Traffic Performance

Under a given demand?

Long term effect

Direct effect
Dissertation Outline

I. Parking as the bottleneck
   *Parking Search*

II. Parking causes bottleneck
    *Parking Maneuvers*

III. Data collection/usage
     *Parking Data*

On-street parking spots

Parking Patrol

Guidance
Parking search

Existing studies

- Empirical studies
- Multi-agent simulations
- Traffic assignment

Only ...

- Localized conclusions
- High data requirements
- Core: behaviour
- Assume drivers know
- High data requirements
- Core: traffic distribution

Macroscopic Model

**YES!**

Parking

Dynamic

Traffic
Parking-state based transition matrix

3 parking-related states:

- Non-searching
- Searching
- Parking (parked)

Traffic system

Parking system
Parking-state based transition matrix

**Transition events:**

- **Enter the area**
- **Non-searching**
- **Start to search**
- **Searching**
- **Leave the area**
- **Depart parking**
- **Parking (parked)**
- **Access parking**

Cumulative over time

“Queuing” Diagram

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Transition matrix \(\rightarrow\) queuing diagram

Cumulative number of vehicles going through each transition event

Total travel time

Time Slices

“Queuing diagram” of vehicles on urban networks
Parking-state based transition matrix

Separate time into very small slices…

Matrix

transition events
searching state

Parking

# vehicles parked
# available parking

Traffic

# vehicles driving
travel speed
Methodology

In each time slice, how many vehicles
### Introduction

Parking search

Parking maneuvers

Parking data

Conclusion

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**Homogenous Network**

**Parking spots**

**Searchers**

- $\# \text{ available spaces}$  

$100\%$

- Enough parking

- NOT enough

- Parking are all taken

- Cars all find

- Travel distance

- Travel distance

$N_s$

Parking supply

- $\# \text{ available spaces}$
Application

Searching
- # searchers
- share of searching traffic
- searching time
- searching distance

Traffic
- density
- speed
- travel distance

Parking
- occupancy

Pollution
Real example → City of Zurich (Jelmoli area)

- 332 off-street parking spaces
- 207 on-street parking spaces
- 106 links
- 7.7 kilometers
Real example → City of Zurich (Jelmoli area)

# searchers

![Graph showing # searchers over time](https://example.com/graph.png)
Real example → City of Zurich (Jelmoli area)

Search time (FIFO)
Real example → City of Zurich (Jelmoli area)

We validated available parking

![Number of available parkings over time](image)
Part I: Conclusion

Limited number of inputs
- Demand
- Supply
- Traffic
- Network

Macroscopic outputs
- Traffic
- Parking
- Searching
- Environmental

Applications
- Parking policy
- Traffic control
- Parking information

Potential extensions
- Heterogeneous networks
- Demand variations
- Pricing/reservation
Parking causes bottleneck

*Parking Maneuvers*

On-street parking spots
Parking near intersections

Waste green time $\rightarrow$ intersection service rate reduction $\rightarrow$ lingering delay

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Methodology (downstream maneuver)

Traffic demand
Signal control
Parking location
Parking skills
Methodology (downstream maneuver)

Distance boundaries for different levels of delay:

\[ l_1 = \left(1 - \alpha - \frac{\Delta t}{g}\right) \cdot \beta \]

\[ l_2 = \begin{cases} 
(x - \frac{\Delta t}{g}) \cdot \beta & \text{if } x \in (1 - \alpha, 1] \\
(1 - \frac{\Delta t}{g}) \cdot \beta & \text{if } x \in (1, \frac{c}{g}] 
\end{cases} \]
Methodology (downstream maneuver)

Except for very low traffic demand…
There is service rate reduction caused by parking

The reduction depends on parking location
Comparison between upstream and downstream parking maneuvers

<table>
<thead>
<tr>
<th></th>
<th>undersaturated</th>
<th>highly oversaturated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduction caused by parking</td>
<td>far upstream, downstream</td>
<td>upstream, far upstream</td>
</tr>
</tbody>
</table>

Reduction caused by parking
Model validation

Zurich
73% case <20% error

Munich
81% case <20% error
Part II: Conclusion

Outputs
- Service rate reduction
- Parking location suggestion

Applications
- Guide parking provision
- Evaluate general delays

Potential extensions
- Multiple lanes
- Multiple parking turnover
- Network
Data collection/usage

Parking Data
Part III/1: Parking patrol survey

Patrol survey is often used for
- average parking duration
- turnover

Research Questions

Accuracy  Survey intensity  Cost
Methodology

Analytical

Parking duration

**Uniform**

- Survey Error – Survey Intensity
- Intensity <1/3, result not usable

\[
Y = \frac{\delta}{T} \cdot \frac{1}{1 - X} - 1 = \frac{1}{1 + \beta} \cdot \frac{1}{\frac{1}{2} \cdot \beta - \sqrt{\beta^2 - 1} \cdot X} \cdot \frac{1}{1 - X} - 1
\]

\[
Y = \frac{4Z\beta^2 - 4Z}{4Z\beta^2 - 2\beta - 1 - (\beta - 2Z)^2} - 1
\]

Simulation

Parking duration

**Gamma & hyper-exponential**

Survey Error, Y

Gamma parameter = 2

Survey Intensity, X

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Validation

Ballston garage (2800 stalls)
Washington, D.C., US

Max-bill-Platz (60 stalls)
Zurich, Switzerland

Survey intensity

1/3

error

1/3

Survey intensity

error

estimated
real error

Not usable

k=1

k=4
Survey correction method

![Error vs Budget (unit L)](chart)

- **Budget is too low**
- **Result not usable**

Survey error vs Error after correction:
- At 100 unit L, error is 13%.
- At 160 unit L, error is 4%.
- At 200 unit L, error is 3%.

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Part III/2: Parking guidance system

PGIs
- Parking information
- Reduce searching

Research Questions
PGIs useful?
When? How much reduction?
Probability find parking

without PGIs

\[
p = \begin{cases} 
    1 - (1 - \frac{v \cdot t}{L})^{N_p}, & \text{if } t \in [0, \frac{L}{v \cdot N_s}] \\
    \frac{N_p}{N_s} + \left[ \frac{N_p}{N_s} - 1 + \left( 1 - \frac{1}{N_s} \right)^{N_p} \right] \cdot \log_{N_s} \left( \frac{N_p}{N_s} \cdot \frac{v \cdot t}{L} \right), & \text{if } t \in \left[ \frac{L}{v \cdot N_s}, \frac{L}{v} \cdot \frac{N_p}{N_s} \right], \text{ if } N_p \leq N_s \\
    1 - (1 - \frac{v \cdot t}{L})^{N_p}, & \text{if } t \in \left[ \frac{L}{v \cdot N_s}, \frac{L}{v} \right], \text{ if } N_p \geq N_s \\
    1 + \left( 1 - \frac{1}{N_s} \right)^{N_p} \cdot \log_{N_s} \left( \frac{v \cdot t}{L} \right), & \text{if } t \in \left[ \frac{L}{v}, \infty \right)
\end{cases}
\]

with PGIs

\[
p_{opt} = \begin{cases} 
    \frac{N_p}{N_s}, & \text{if } N_p \leq N_s \\
    1, & \text{if } N_p \geq N_s
\end{cases}
\]
PGIs effectiveness under static conditions

PGIs
Effectiveness Indicator

\[ \beta = N_s \cdot \int_0^\infty (p_{opt} - p) \, dt = \begin{cases} N_s \cdot \int_0^{\frac{N_p}{N_s}} (p_{opt} - p) \, dt, & \text{if } N_p \leq N_s \\ N_s \cdot \int_0^{\frac{N_p}{N_s}} (p_{opt} - p) \, dt, & \text{if } N_p \geq N_s \end{cases} \]

A: total parking supply

# searchers / A

# available spaces / A

=1- occupancy
PGIs effectiveness under *dynamic* conditions

**Input**
- Parking demand
- Parking occupancy

Construct hypothetical condition where PGIs are equipped.

\[
\begin{align*}
occ_{opt}^i &= occ_{opt}^{i-1} + \frac{1}{A} \cdot (p_{opt}^{i-1} \cdot N_{s\,opt}^{i-1} - N_d^i) \\
N_{p\,opt}^i &= (1 - occ_{opt}^i) \cdot A \\
N_{s\,opt}^i &= N_{s\,opt}^{i-1} \cdot (1 - p_{opt}^{i-1}) + N_i
\end{align*}
\]

**Potential searching time reduction**

\[
T - T_{opt} = \sum_{i=1}^{I} (N_s^i - N_{s\,opt}^i) \cdot t
\]
Real example → City of Zurich (Jelmoli area)

Effectiveness Indicator

10:30-11:30
Reduction 59%

15:00-16:00
Reduction 51%

Other time
Reduction 7%
Part III: Conclusion

Generalized

- Can be used under various conditions
- Findings

Directly usable tools

- Correction method for patrol surveys
- Cruising reduction estimation due to PGIs

Applications

- Parking operators
- Traffic manager and local authorities
- Parking consultant companies
Final Conclusion

Part I: Macroscopic view of the overall system
Part II: Microscopic of parking caused traffic bottleneck
Part III: Practical issues in parking data collection/usage

Contribution

Methodological
- Macroscopic model
- Generalized conclusions

Pragmatic
- Generalized findings
- Directly usable tools

Method
- Analytical
- Simulation
- Field measurements

Validation
- Mostly real data

Future work
- Heterogeneous networks
- Real time parking estimation
- Parking policy/pricing
Publications


