Effects of Parking on Urban Traffic Performance

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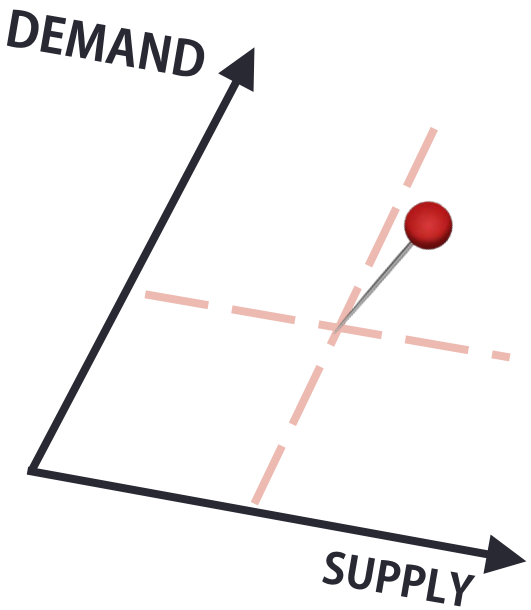
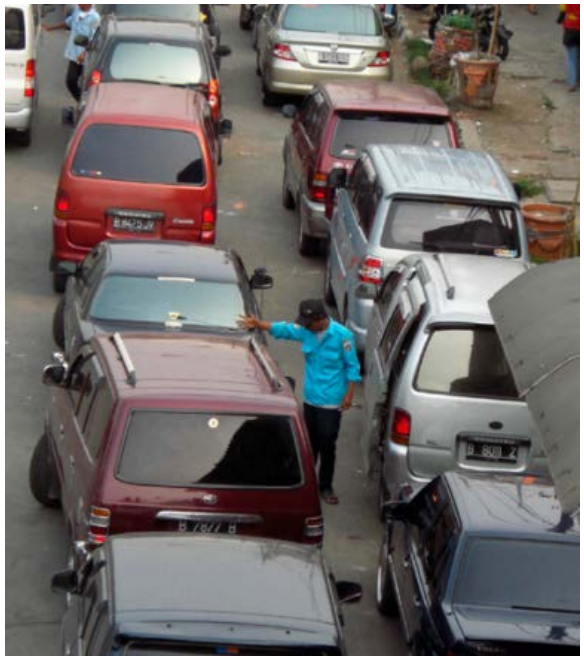
Urban Parking & Traffic Performance



Long term effect

Under a given demand?



Direct effect

Dissertation Outline

I

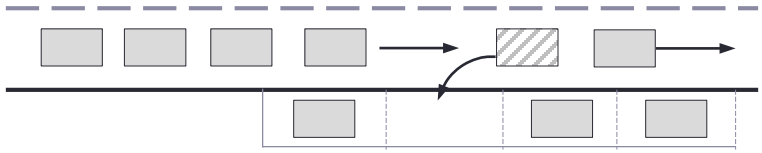
Parking as the bottleneck

Parking Search

II

Parking causes bottleneck

Parking Maneuvers

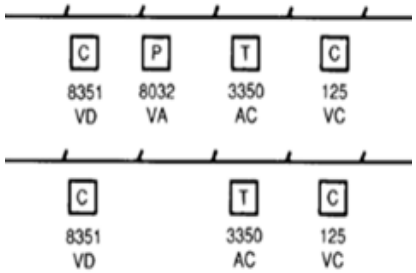


On-street parking spots

III

Data collection/usage

Parking Data



Parking Patrol

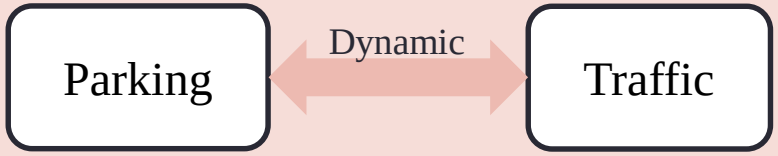
Guidance

Parking search

Existing studies	***Only …***
Empirical studies	Localized conclusions
Multi-agent simulations	High data requirements Core: behaviour
Traffic assignment	Assume drivers know High data requirements Core: traffic distribution

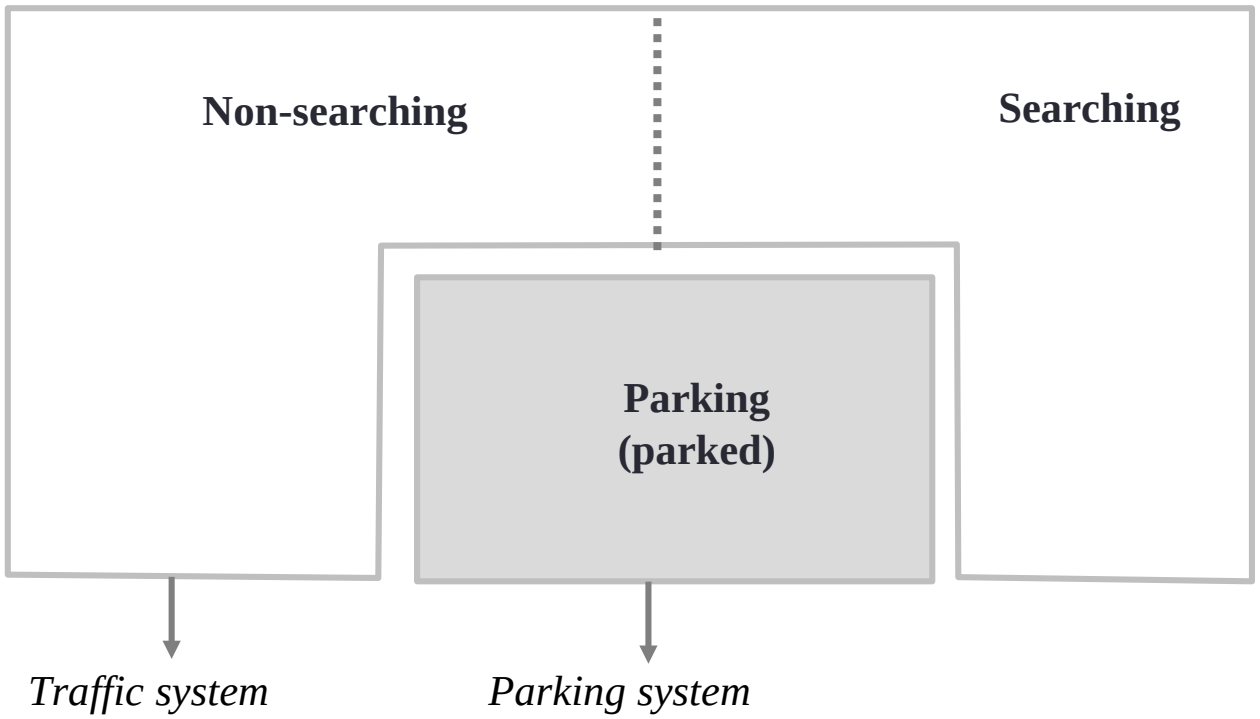
YES!

Macroscopic Model



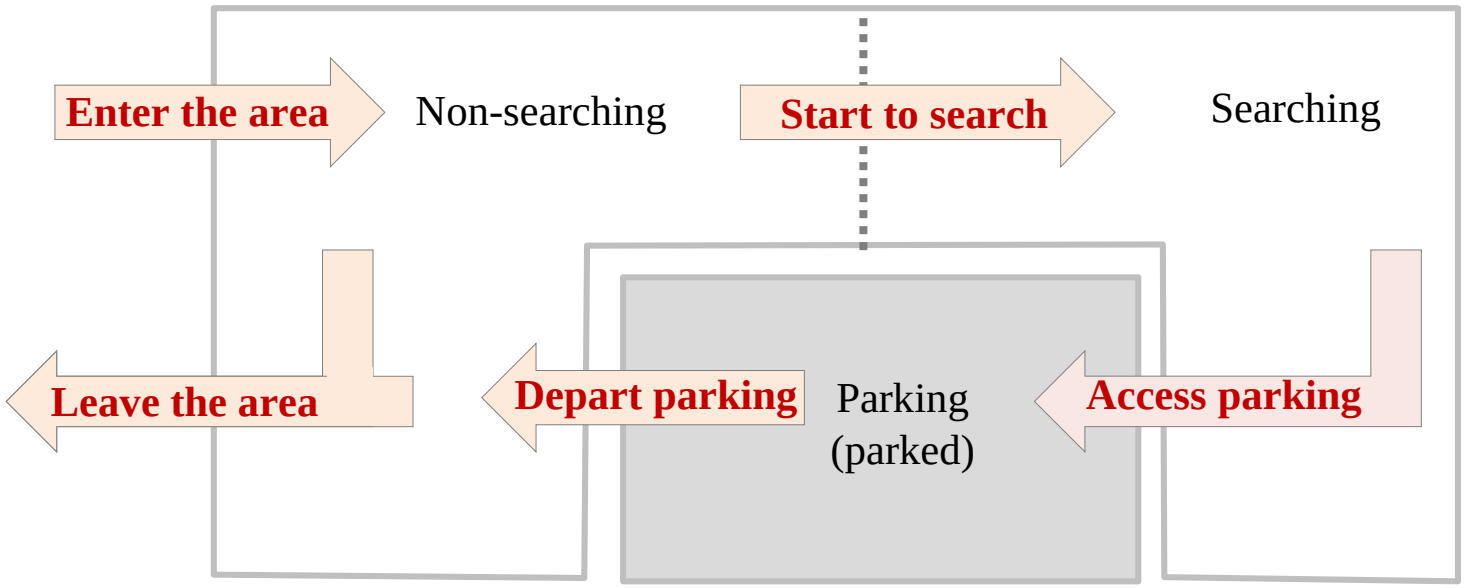
Parking-state based transition matrix

3 parking-related states:



Parking-state based transition matrix

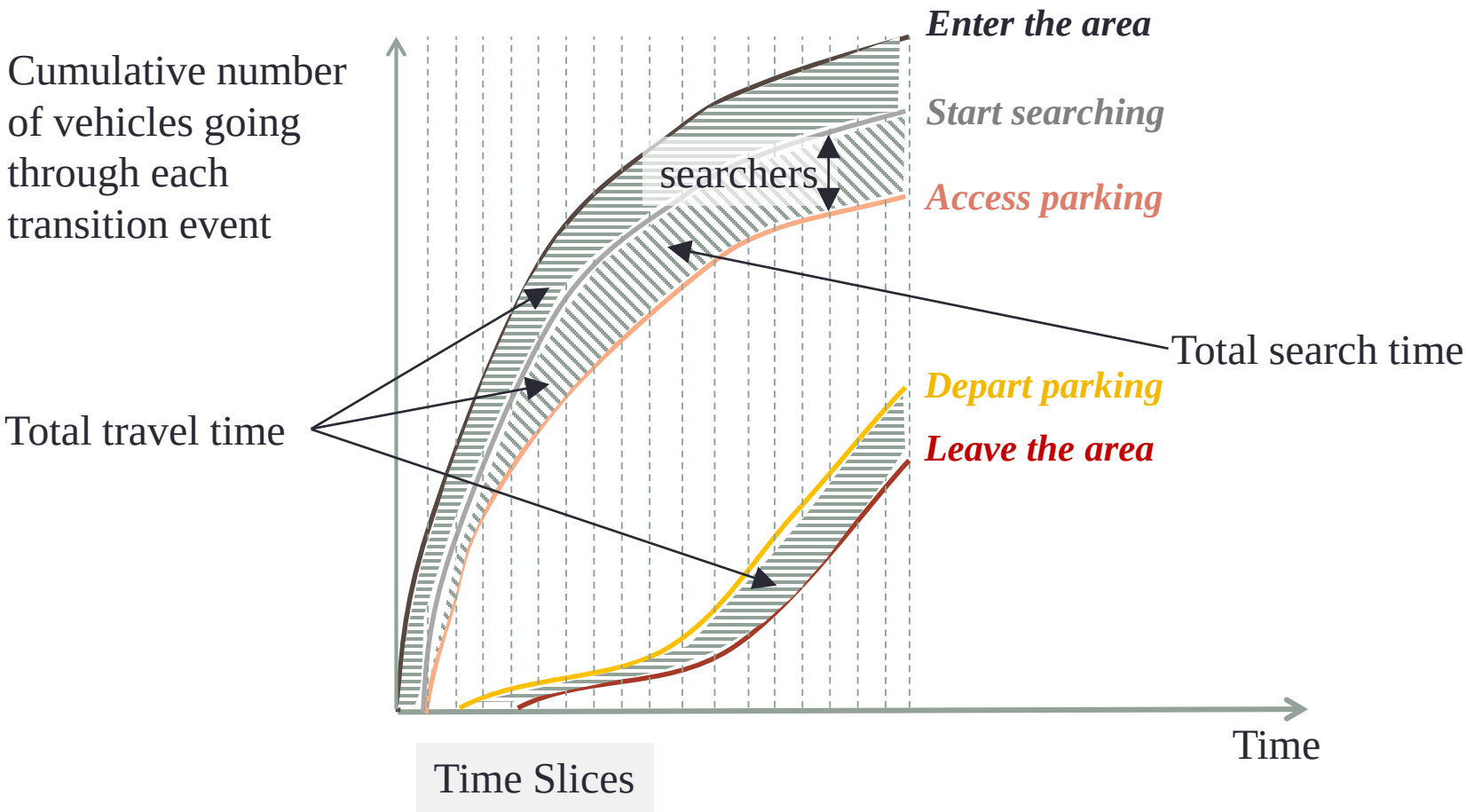
Transition events:



Cumulative over time

"Queuing" Diagram

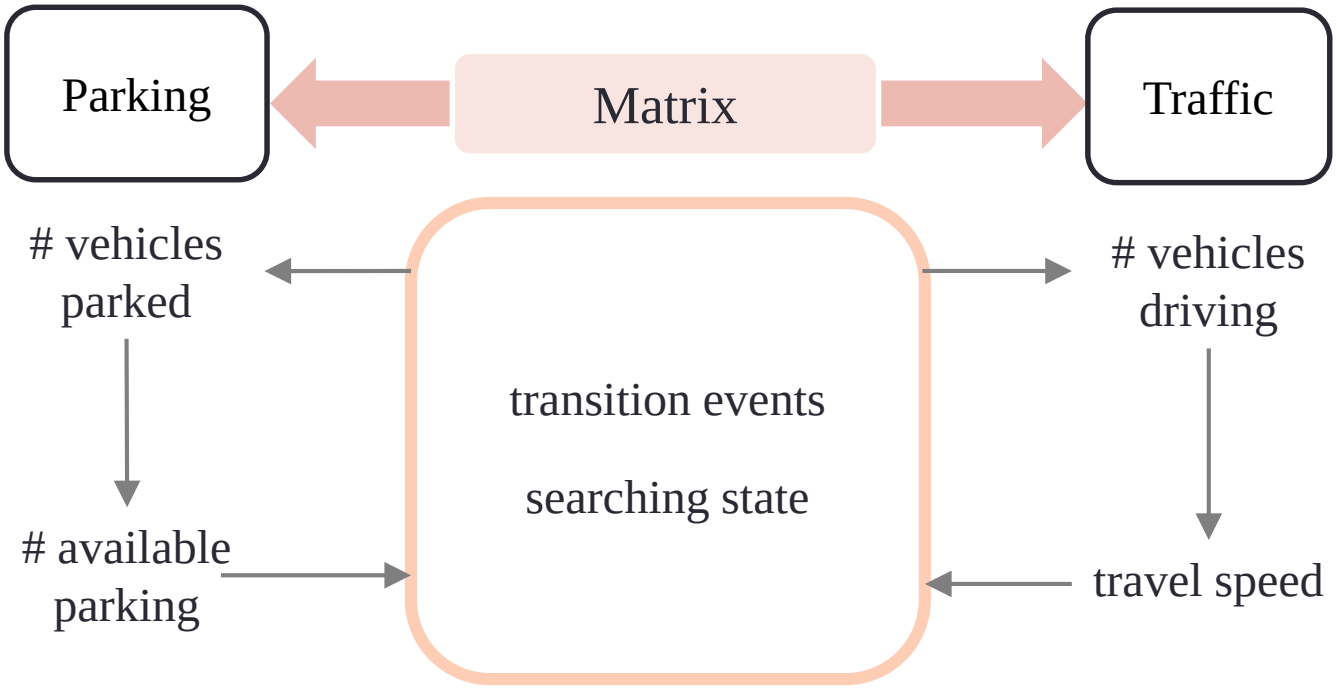
Transition matrix → queuing diagram



"Queuing diagram" of vehicles on urban networks

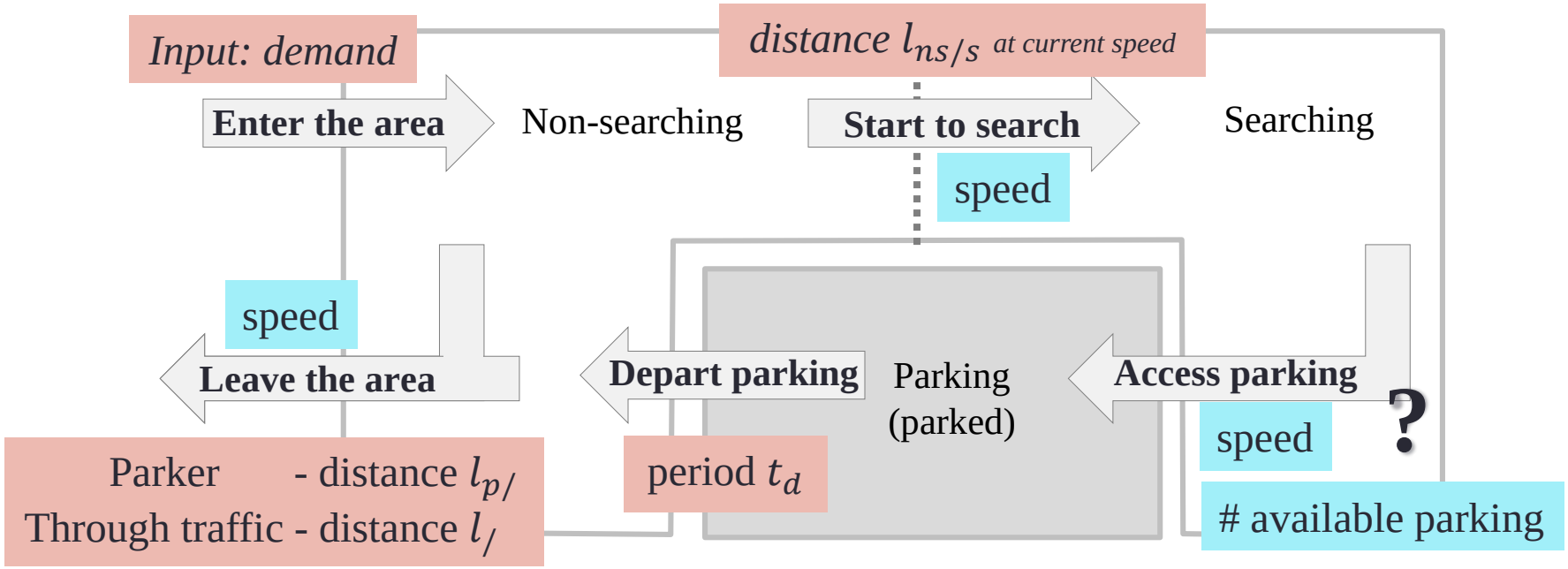
Parking-state based transition matrix

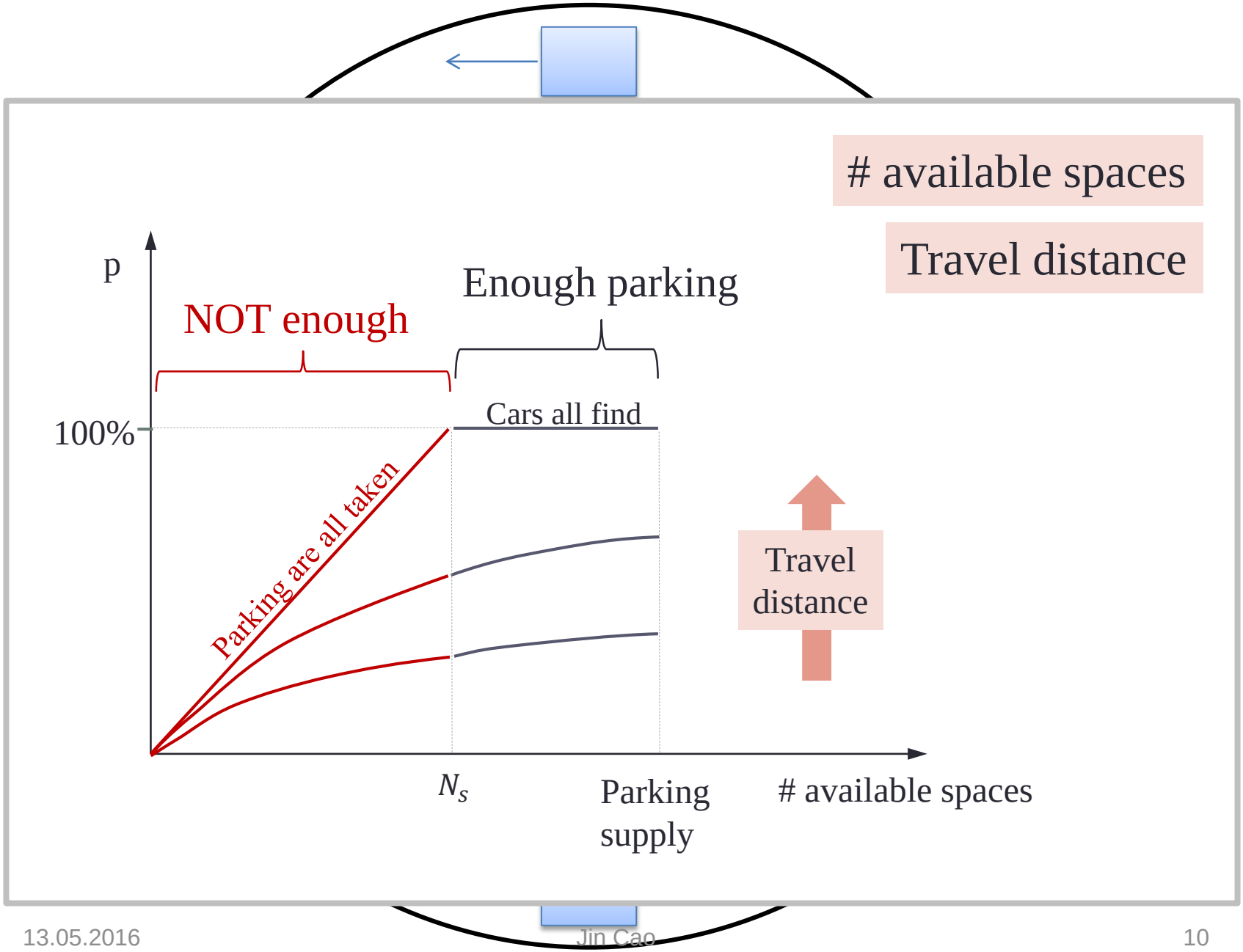
Separate time into very small slices…



Methodology

In each time slice, how many vehicles




available spaces
Travel distance
p
NOT enough
Enough parking
100%
Cars all find
Parking are all taken
Travel distance
N_s
Parking supply
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)

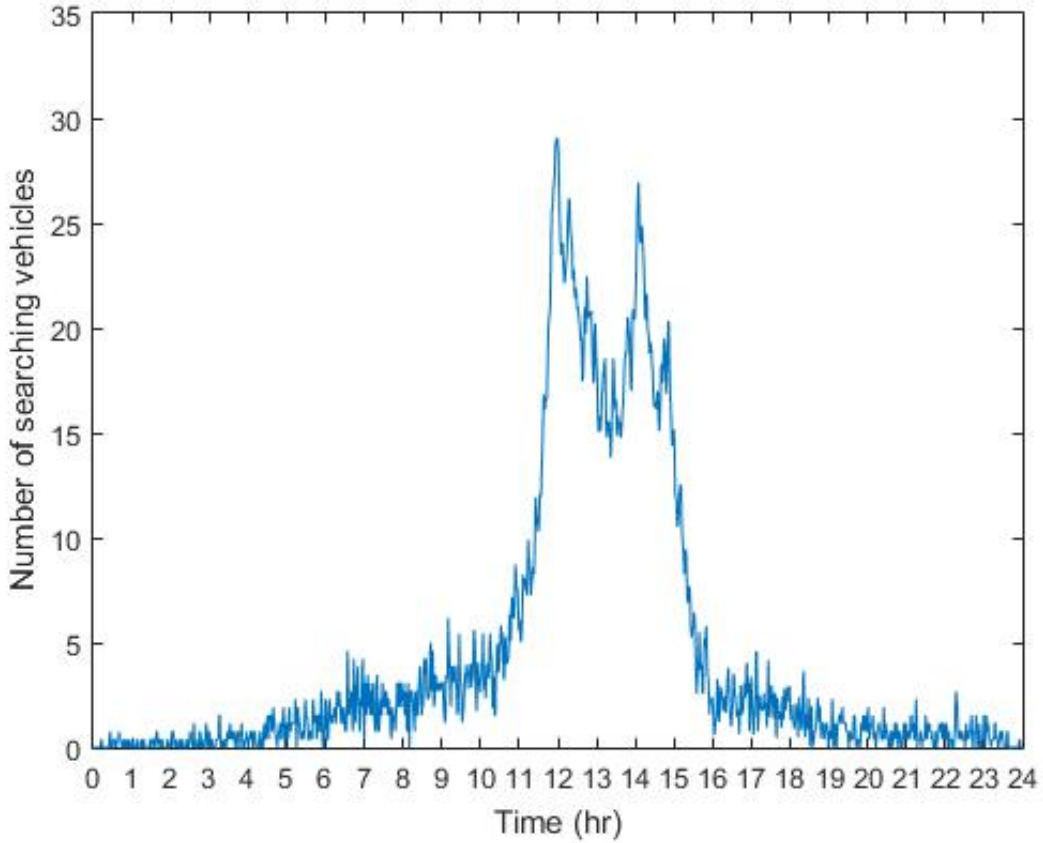
332 off-street parking spaces

207 on-street parking spaces

106 links
7.7 kilometers

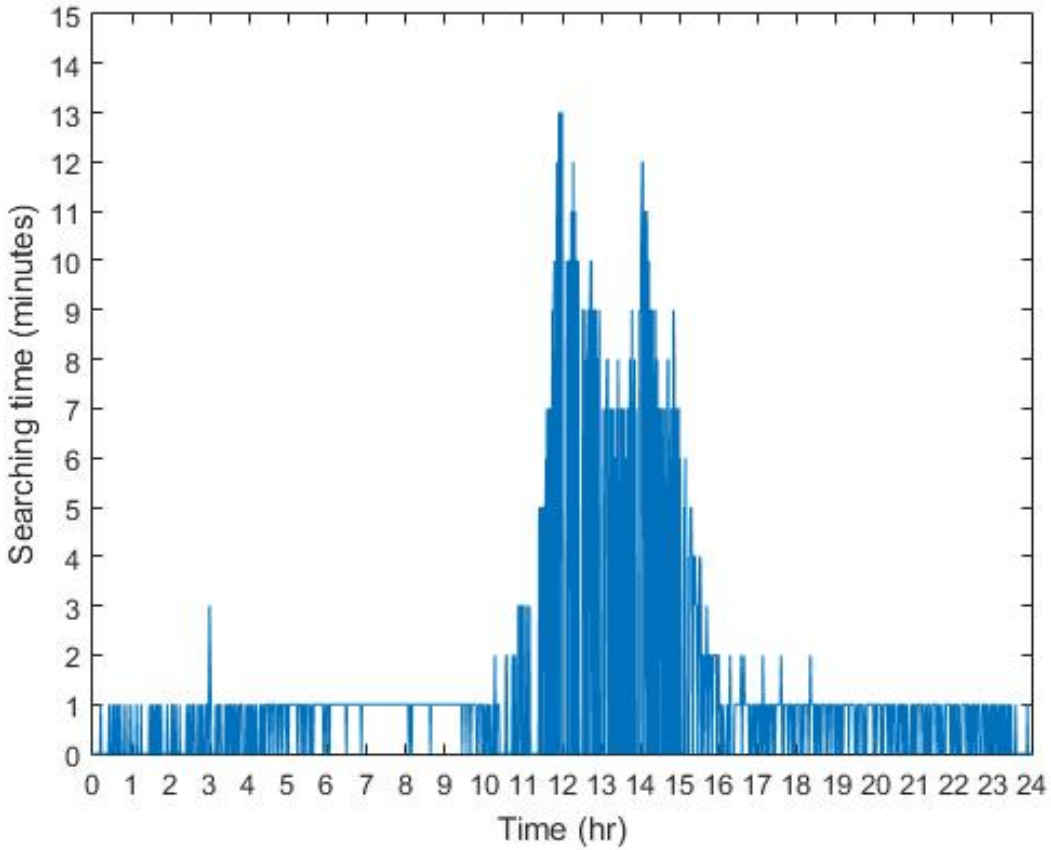
Real example → City of Zurich (Jelmoli area)

searchers



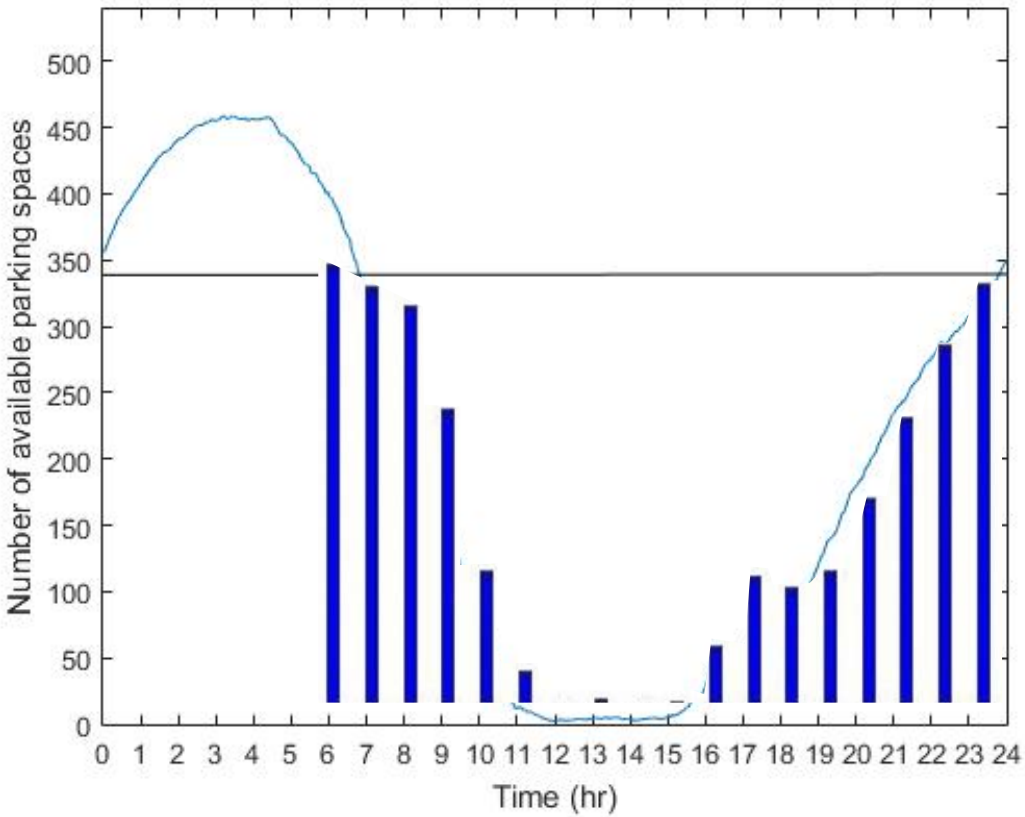
Real example → City of Zurich (Jelmoli area)

Search time (FIFO)



Real example → City of Zurich (Jelmoli area)

We validated available parking



Number of available parkings over time

Part I: Conclusion

Limited number of inputs

- Demand
- Supply
- Traffic
- Network

Macroscopic outputs

- Traffic
- Parking
- Searching
- Environmental

Applications

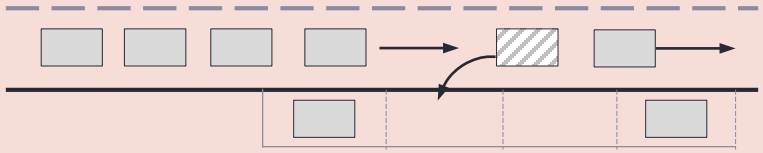
- Parking policy
- Traffic control
- Parking information

Potential extensions

- Heterogeneous networks
- Demand variations
- Pricing/reservation

Parking causes bottleneck

Parking Maneuvers

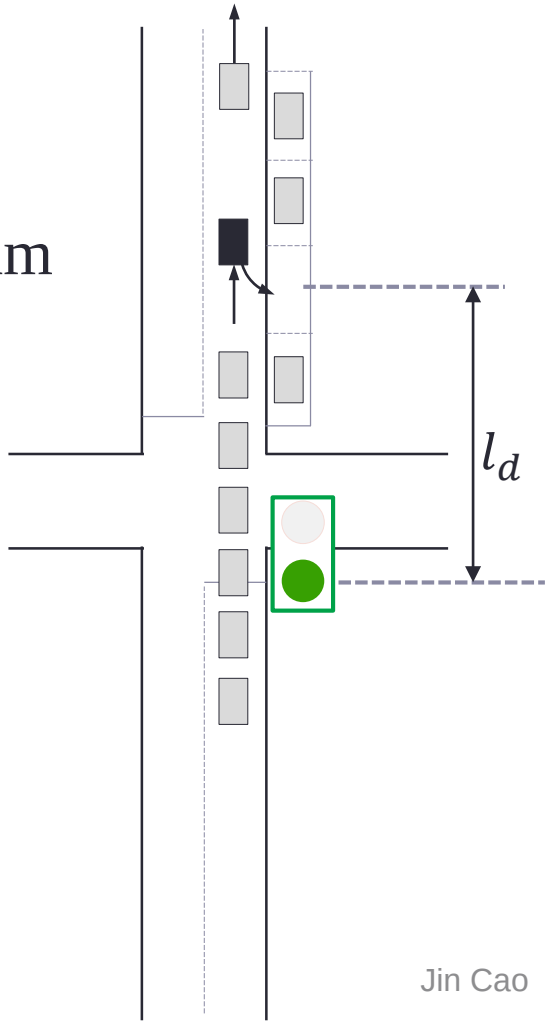


On-street parking spots

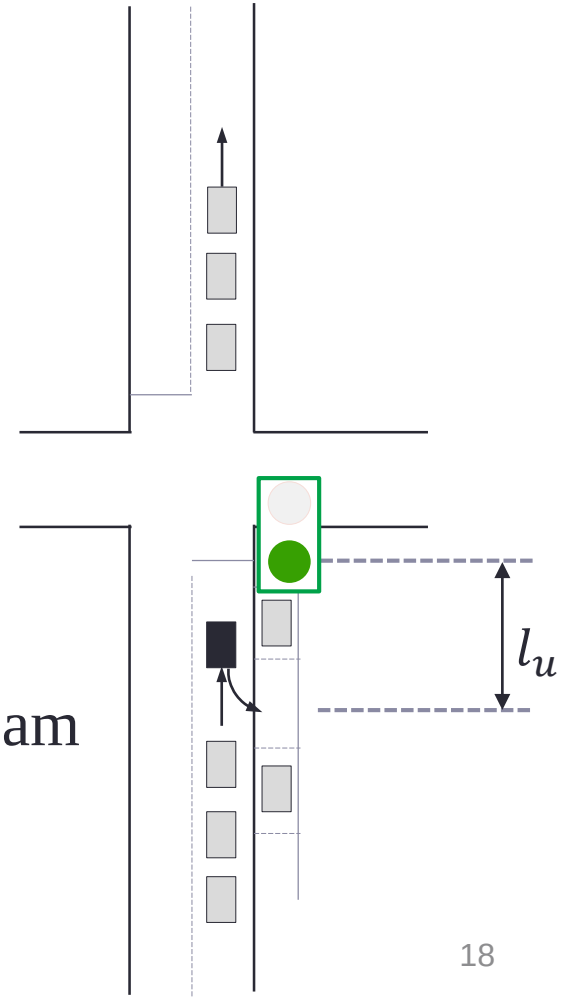
Parking near intersections

Waste green time→ intersection <u>service rate reduction</u>→ lingering delay

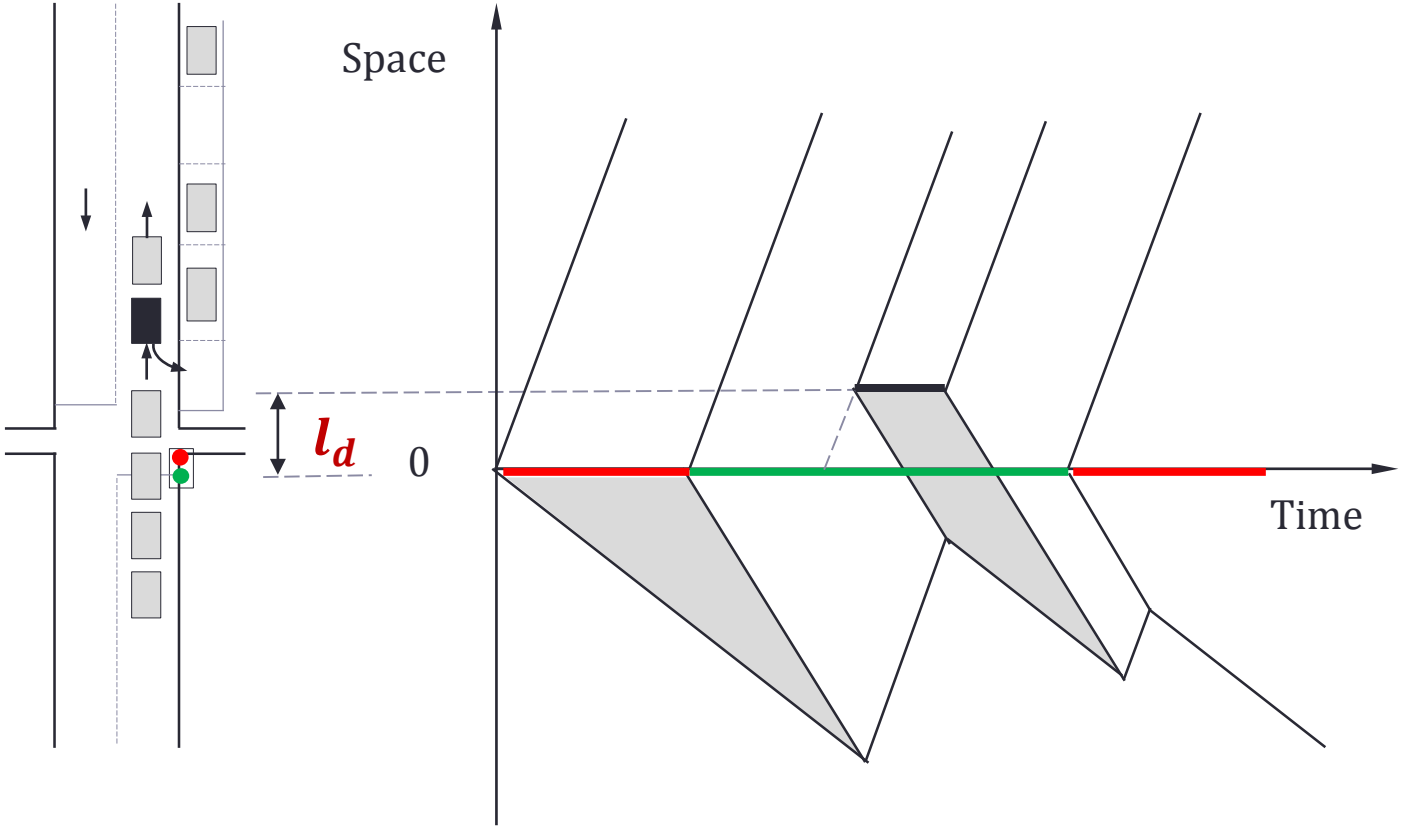
Downstream



Upstream

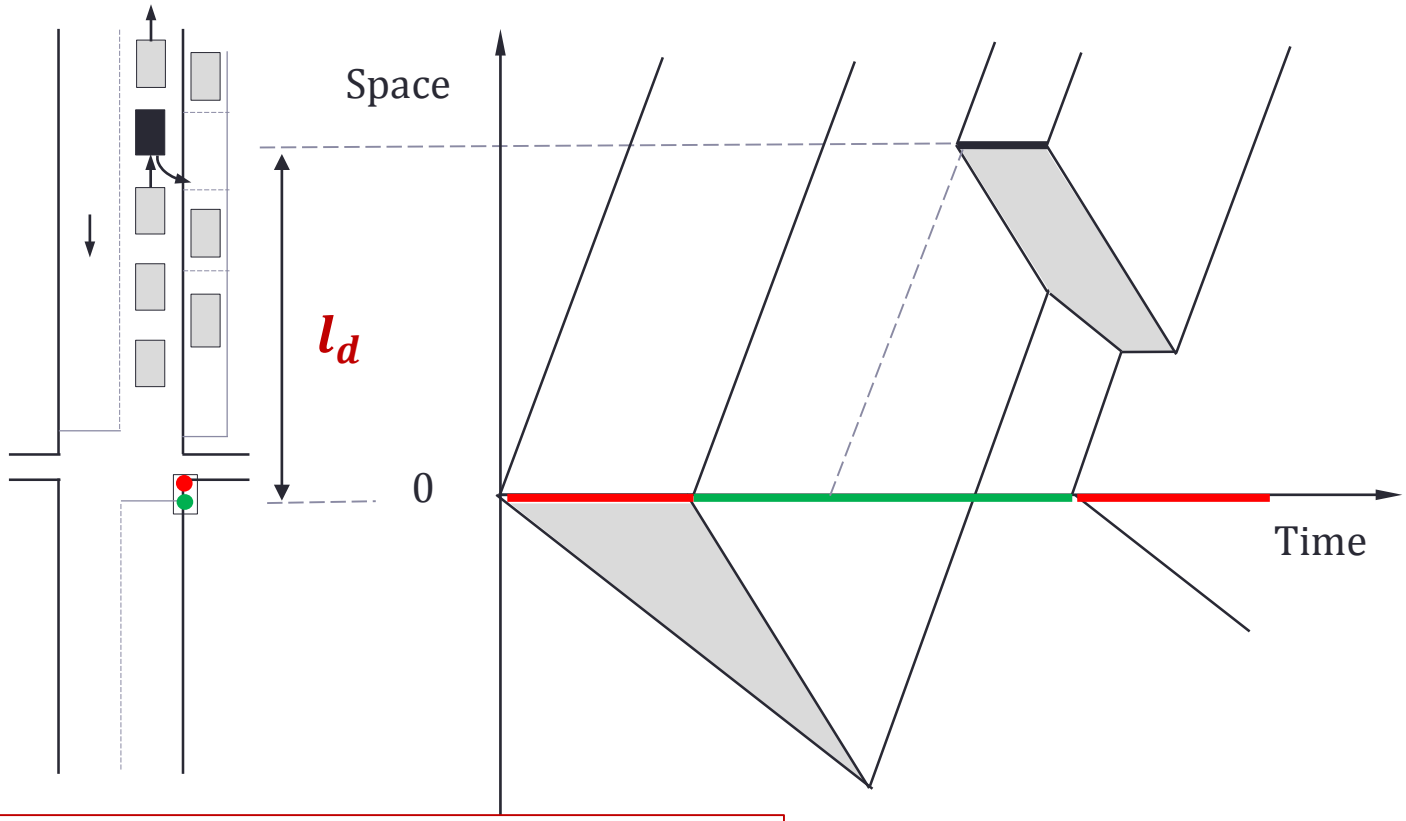


Methodology (downstream maneuver)



Traffic demand | Signal control | Parking location | Parking skills

Methodology (downstream maneuver)



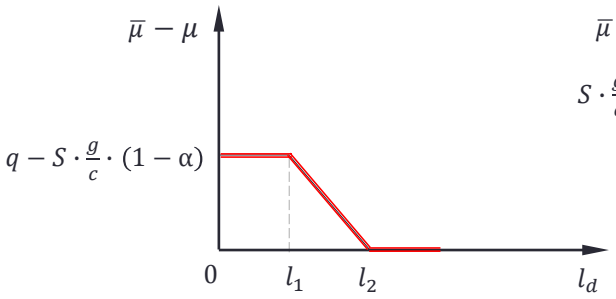
Distance boundaries for different levels of delay:

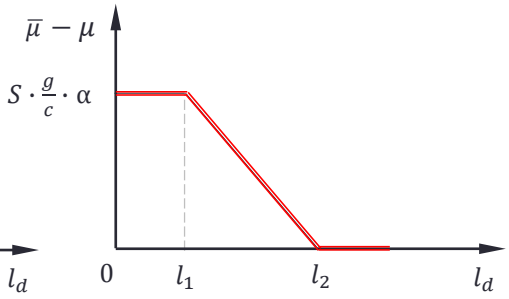
$$l_1 = (1 - \alpha - \frac{\Delta t}{g}) \cdot \beta \qquad l_2 = \begin{cases} (x - \frac{\Delta t}{g}) \cdot \beta & \text{if } x \in (1-\alpha, 1] \\ (1 - \frac{\Delta t}{g}) \cdot \beta & \text{if } x \in (1, \frac{c}{g}] \end{cases}$$

Methodology (downstream maneuver)

Except for very low traffic demand…

There is service rate reduction caused by parking



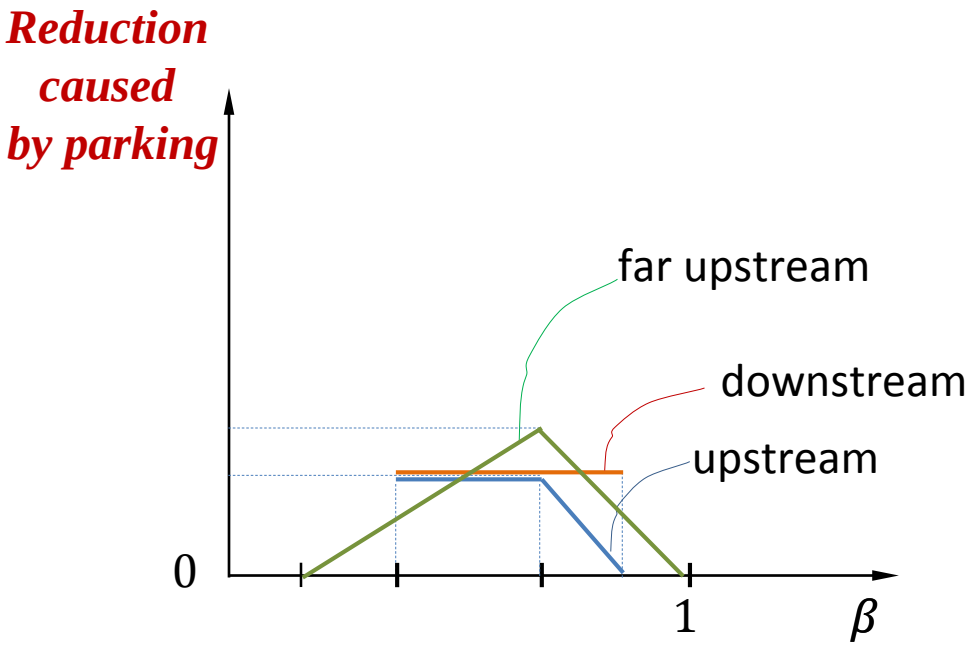


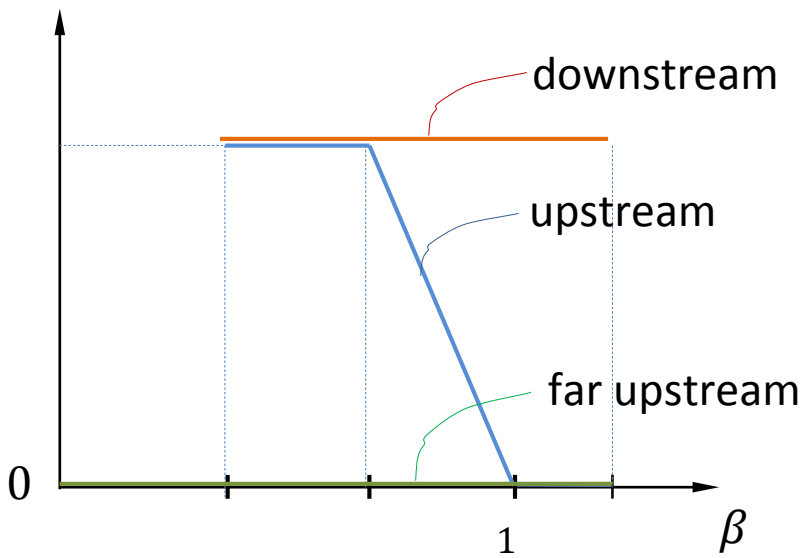
The reduction depends on parking location

Comparison between upstream and downstream parking maneuvers

undersaturated

highly oversaturated

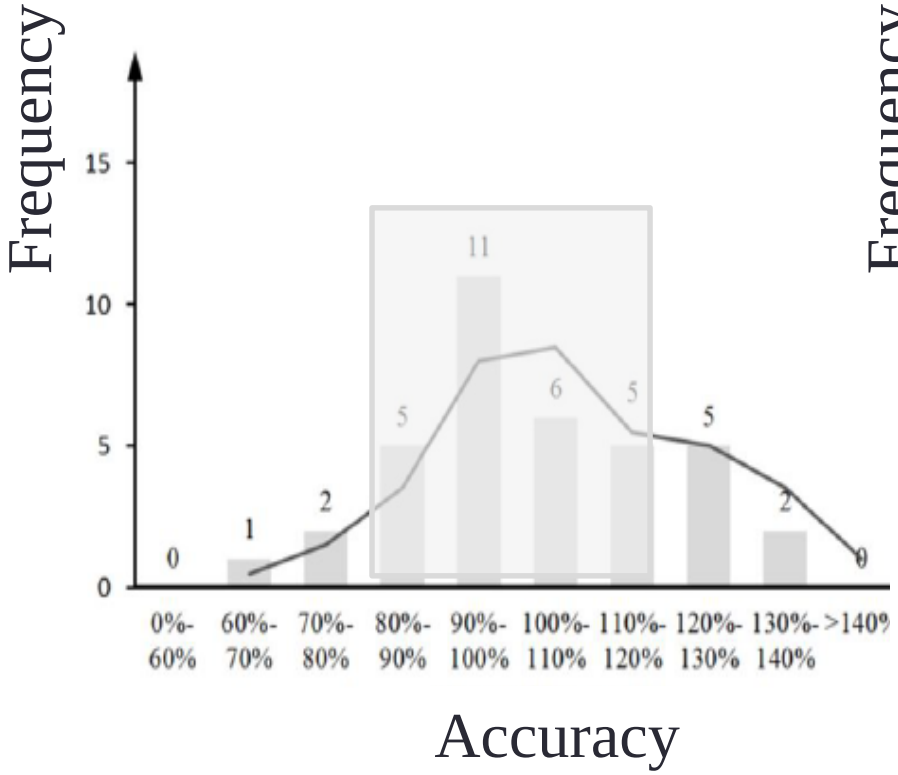




Model validation

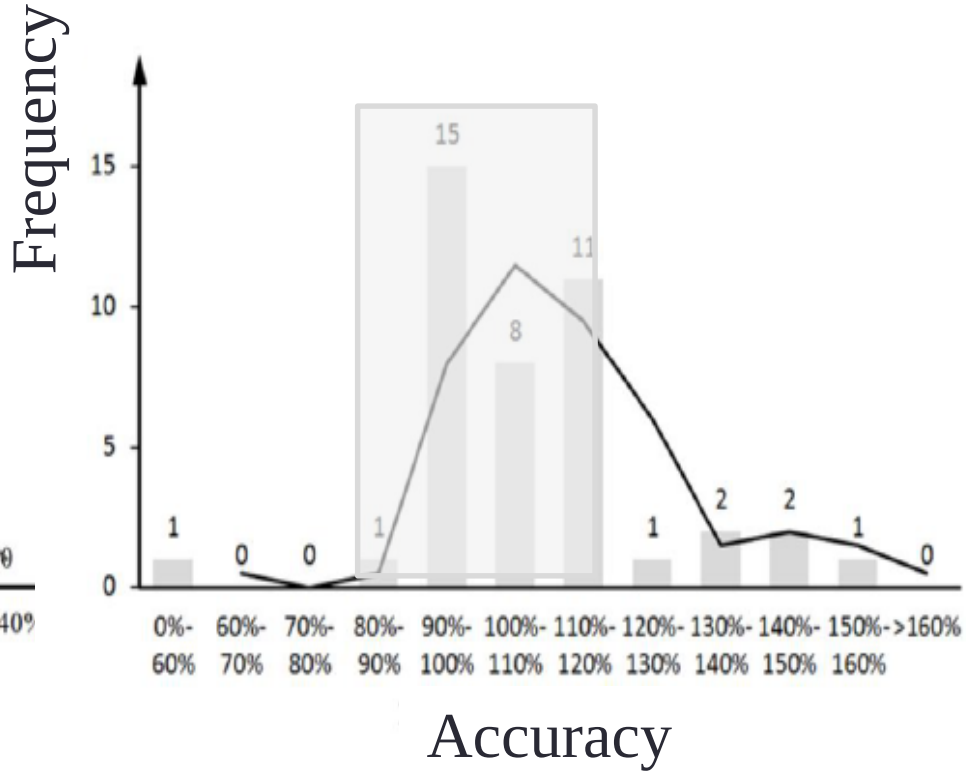
Zurich

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

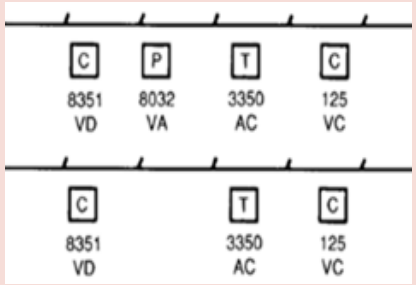
Potential extensions

- Multiple lanes
- Multiple parking turnover
- Network

III

Data collection/usage

Parking Data



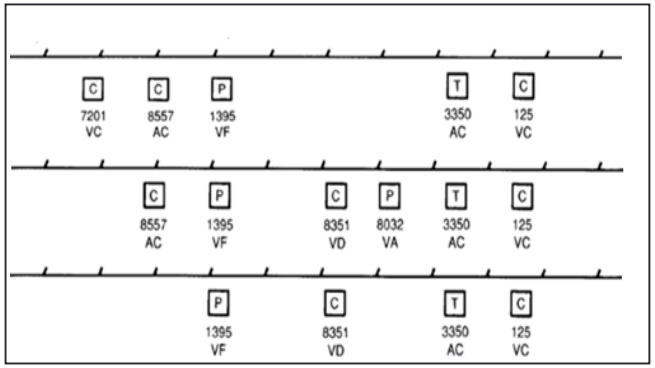
Parking Patrol

Guidance

Part III/1: Parking patrol survey

Patrol survey is often used for

- average parking duration
- turnover



Parking Patrol

Research Questions

Accuracy ⟷ Survey intensity

Survey intensity → Cost

Methodology

Analytical

parking duration

Uniform

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

$$Y = \frac{\delta}{\overline{T}} \cdot \frac{1}{1-X} - 1 = \frac{1}{\frac{1+\beta}{2} \cdot \frac{1}{\beta - \sqrt{(\beta^2-1)\cdot X}}} \cdot \frac{1}{1-X} - 1$$

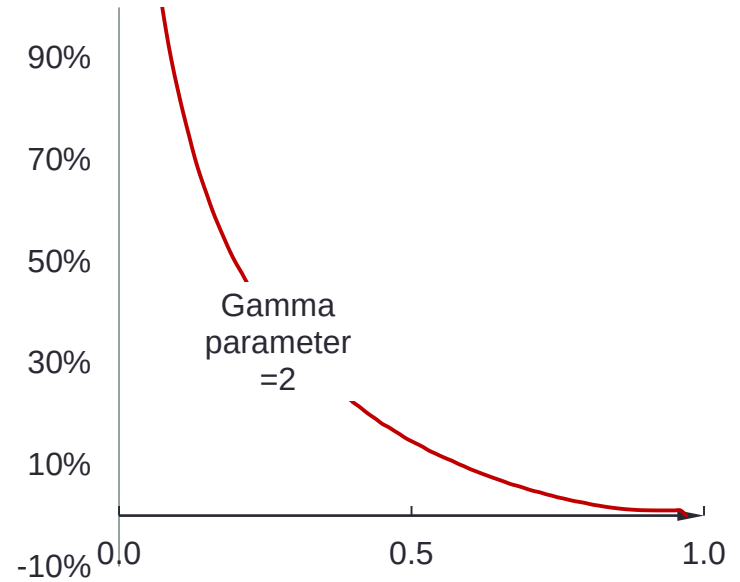
$$Y = \frac{4Z\beta^2 - 4Z}{4Z\beta^2 - 2\beta - 1 - (\beta - 2Z)^2} - 1$$

Simulation

parking duration

Gamma & hyper-exponential

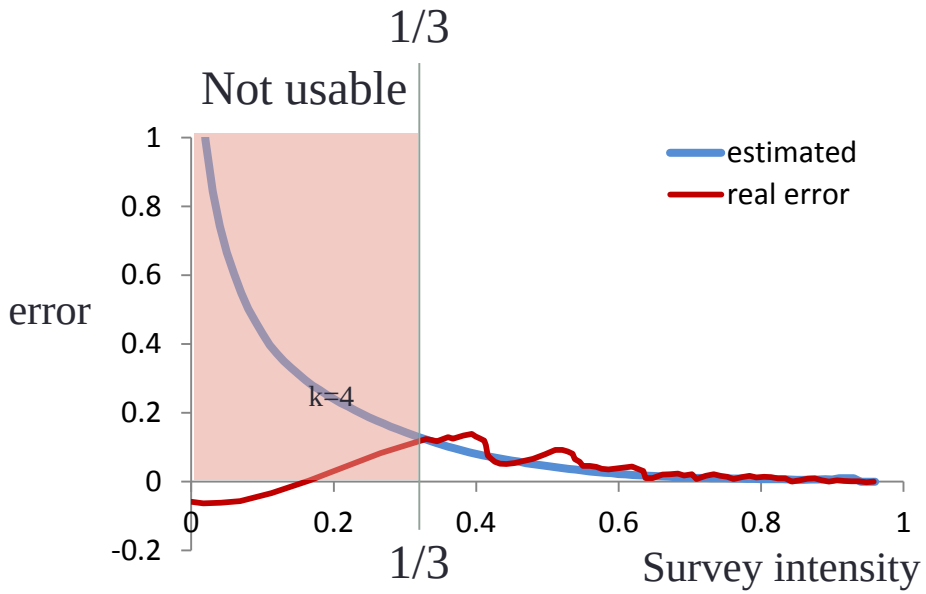
Survey Error, Y



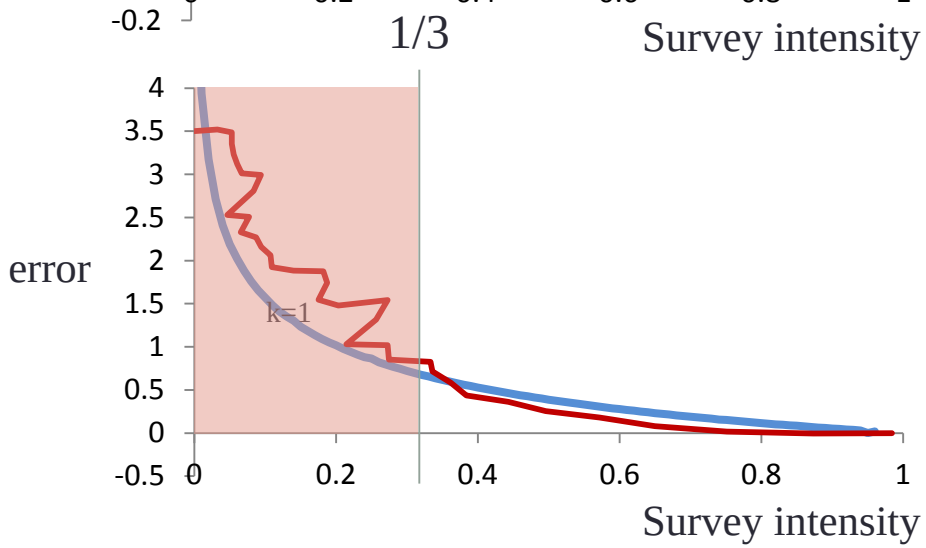
Survey Intensity, X

Validation

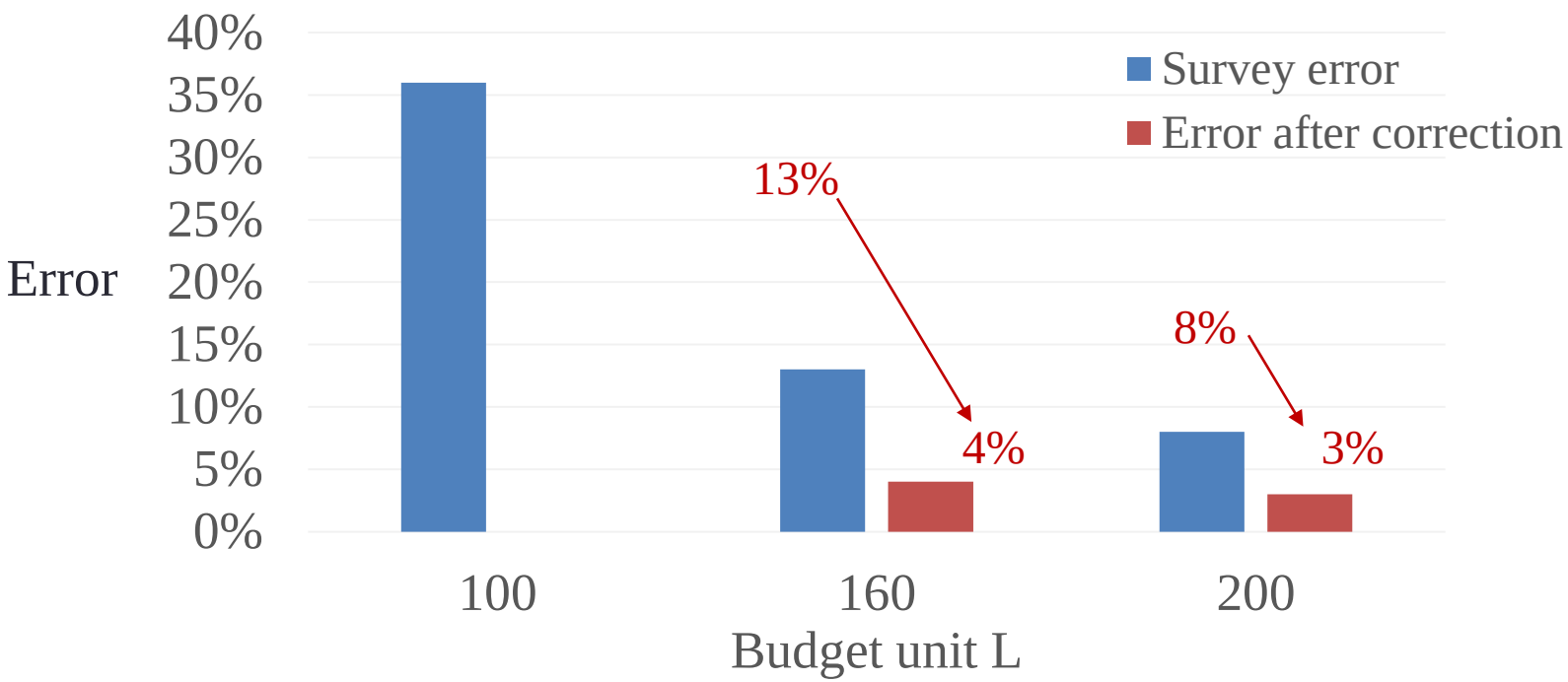
Ballston garage (2800 stalls)
Washington. D.C., US



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



Survey correction method



Budget is too low
Result not usable

Part III/2: Parking guidance system

PGIs

- Parking information
- Reduce searching

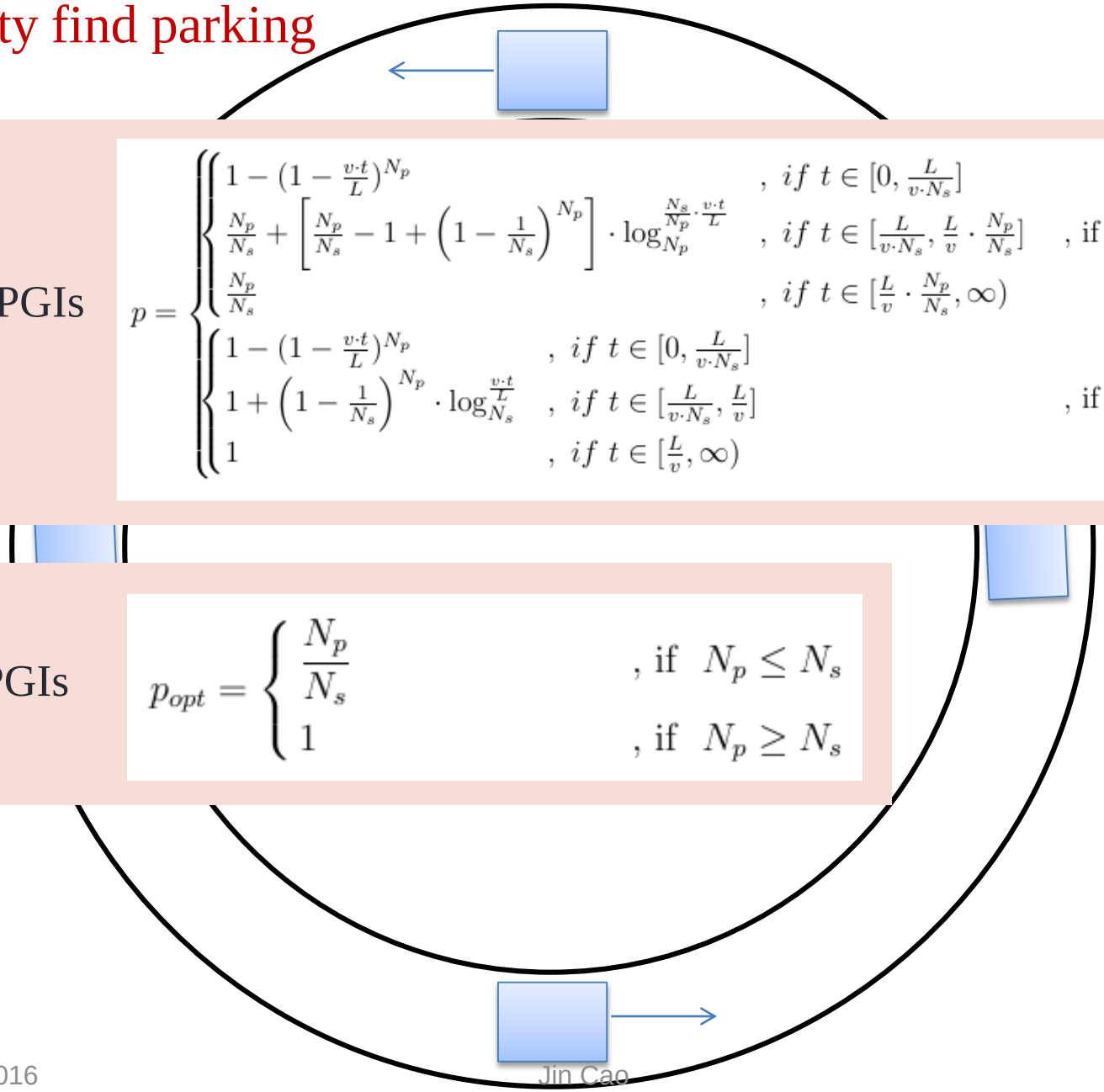
Guidance

Research Questions

PGIs useful?

When? How much reduction?

Probability find parking



without PGIs

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

with PGIs

$$p_{opt} = \begin{cases} \dfrac{N_p}{N_s} & , \text{if} \;\; N_p \leq N_s \\ 1 & , \text{if} \;\; N_p \geq N_s \end{cases}$$

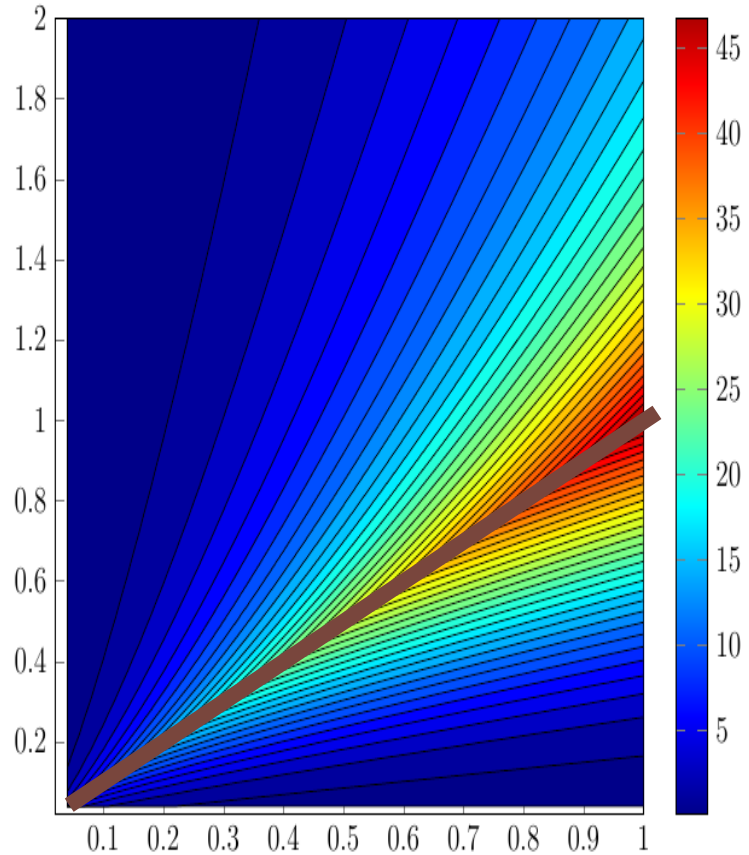
PGIs effectiveness under *static* conditions

PGIs Effectiveness Indicator

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

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.

$$occ^i_{opt} = occ^{i-1}_{opt} + \frac{1}{A} \cdot (p^{i-1}_{opt} \cdot N^{i-1}_{s\ opt} - N^i_d)$$

$$N^i_{p_{opt}} = (1 - occ^i_{opt}) \cdot A$$

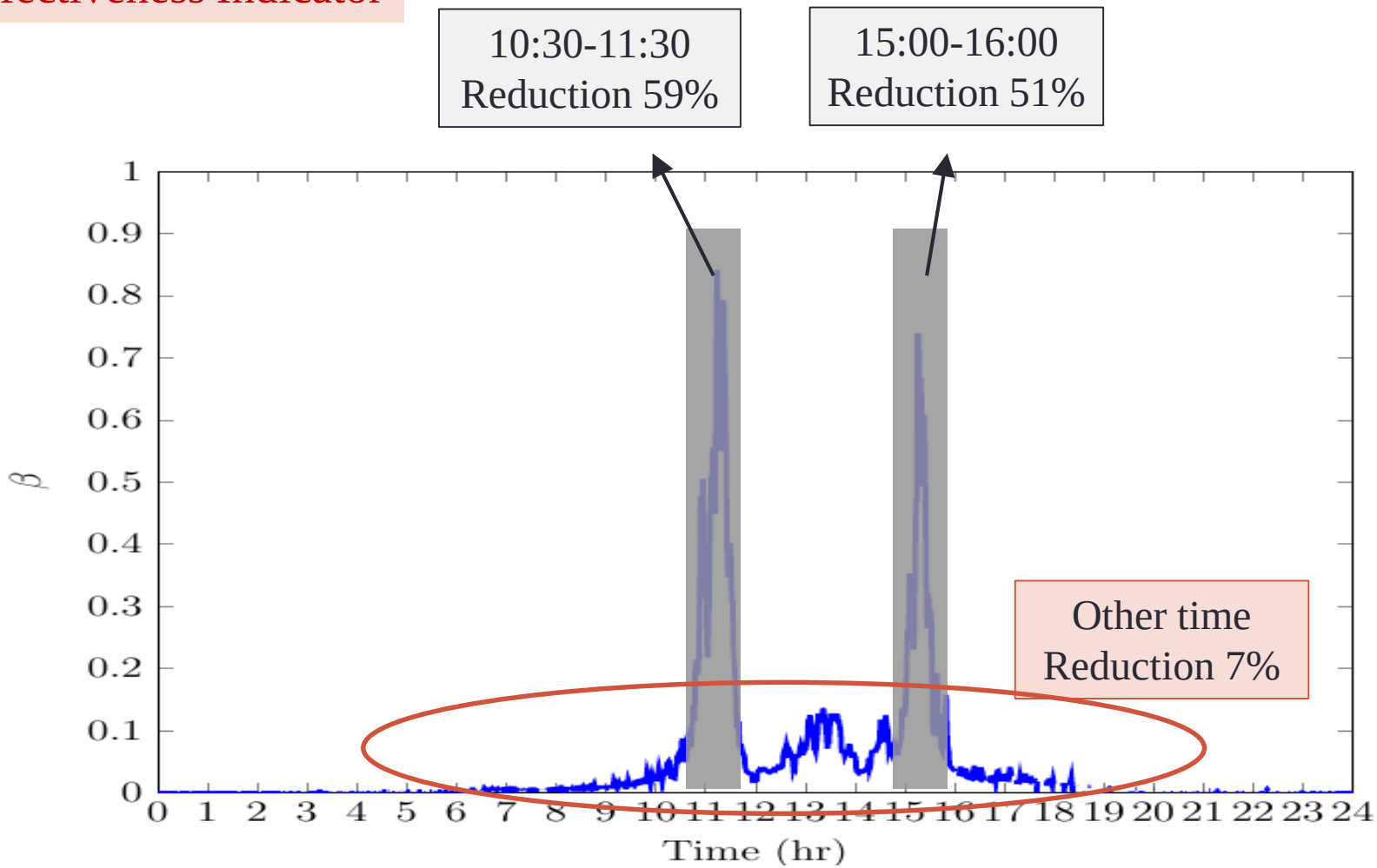
$$N^i_{s\,opt} = N^{i-1}_{s\ opt} \cdot (1 - p^{i-1}_{opt}) + N^i$$

Potential searching time reduction

$$T - T_{opt} = \sum_{i=1}^{I} (N^i_s - N^i_{s\,opt}) \cdot t$$

Real example → City of Zurich (Jelmoli area)

Effectiveness Indicator



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	Pragmatic
	Macroscopic model	Generalized findings
	Generalized conclusions	Diretly usable tools

Method

- Analytical
- Simulation
- Field measurements

Validation

- Mostly real data

Future work

- Heterogeneous networks
- Real time parking estimation
- Parking policy/pricing

Publications

1. Cao, J., M. Menendez (2015) System dynamics of urban traffic based on its parking-related-states, Transportation Research Part B: Methodological, 81(2015): 718-736.

2. Cao, J., M. Menendez and V. Nikias (2015) The effects of on-street parking on the service rate of nearby intersections. *Journal of Advanced Transportation*.

3. Cao, J., M. Menendez (2015) Generalized effects of on-street parking maneuvers on the performance of nearby signalized intersections. *Transportation Research Record: Journal of the Transportation Research Board*, 2483: 30-38.

4. Cao, J., M. Menendez (2013) Methodology to evaluate cost and accuracy of parking patrol surveys. *Transportation Research Record: Journal of the Transportation Research Board*, 2359: 1-9.

5. Cao, J., M. Menendez (2016) The effectiveness of parking guidance and information systems (PGIs) in reducing cruising-for-parking: a macroscopic probabilistic analysis, *submitted to Transportation Research Part B: Methodological*.