Macroscopic Modelling of Parking Dynamics in Urban Networks

Jin Cao, Monica Menendez
IVT, ETHZ, Switzerland

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Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

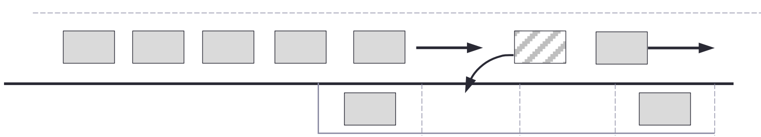
Institut für Verkehrsplanung und Transportsysteme
Institute for Transport Planning and Systems

Urban Parking & Traffic Performance

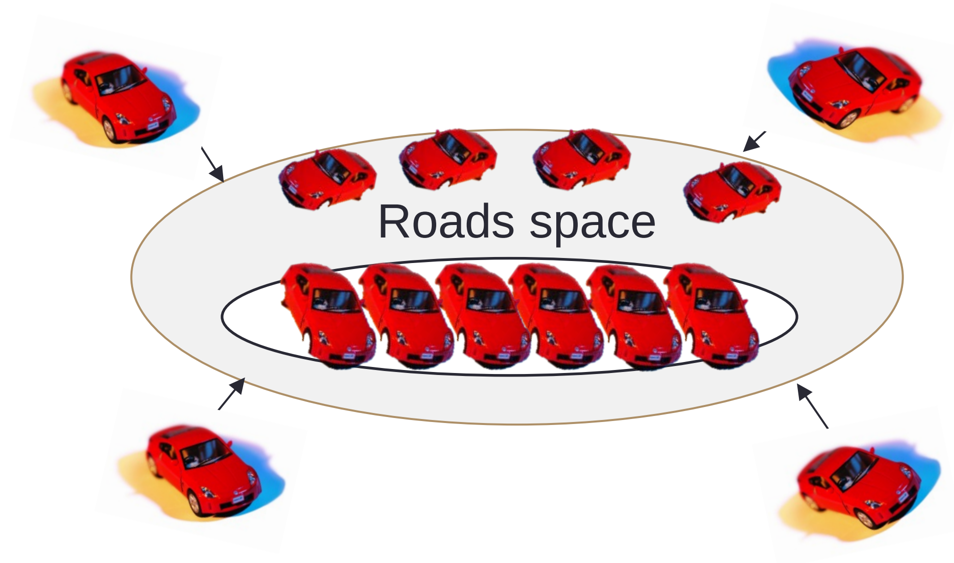
Parking affect traffic through:

1. "Searching/cruising for parking" traffic

2. Extra traffic delay caused by parking maneuvers



On-street parking spots



Data related: Shoup (2005); IBM Global Parking Survey (2011); Cao (2014)

Urban Parking & Traffic Performance

Collective impact

1. Longer searching time → Searching traffic (long time occupation of the road space)

2. Extra delay/ blockage → Delay for traffic

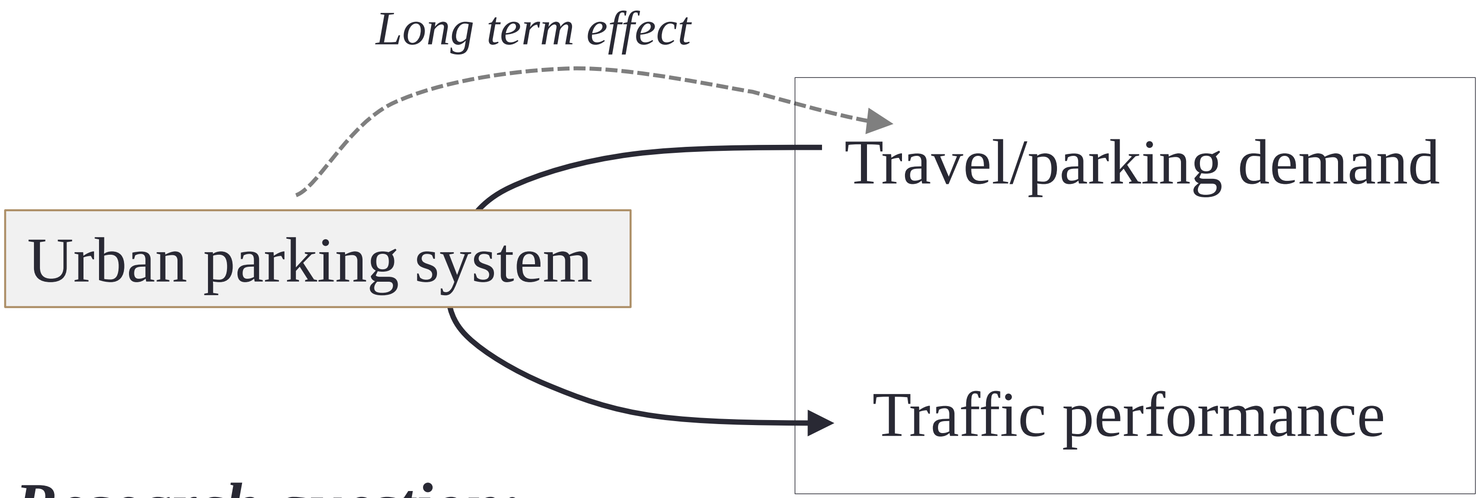
Effects for individual user → Effects for the urban traffic system

User utility ← System performance (traffic)

Parking policy → ?

Data related: Shoup (2005); IBM Global Parking Survey (2011); Cao (2014)

Urban Parking & Traffic Performance



Research question:

Under a given travel demand,

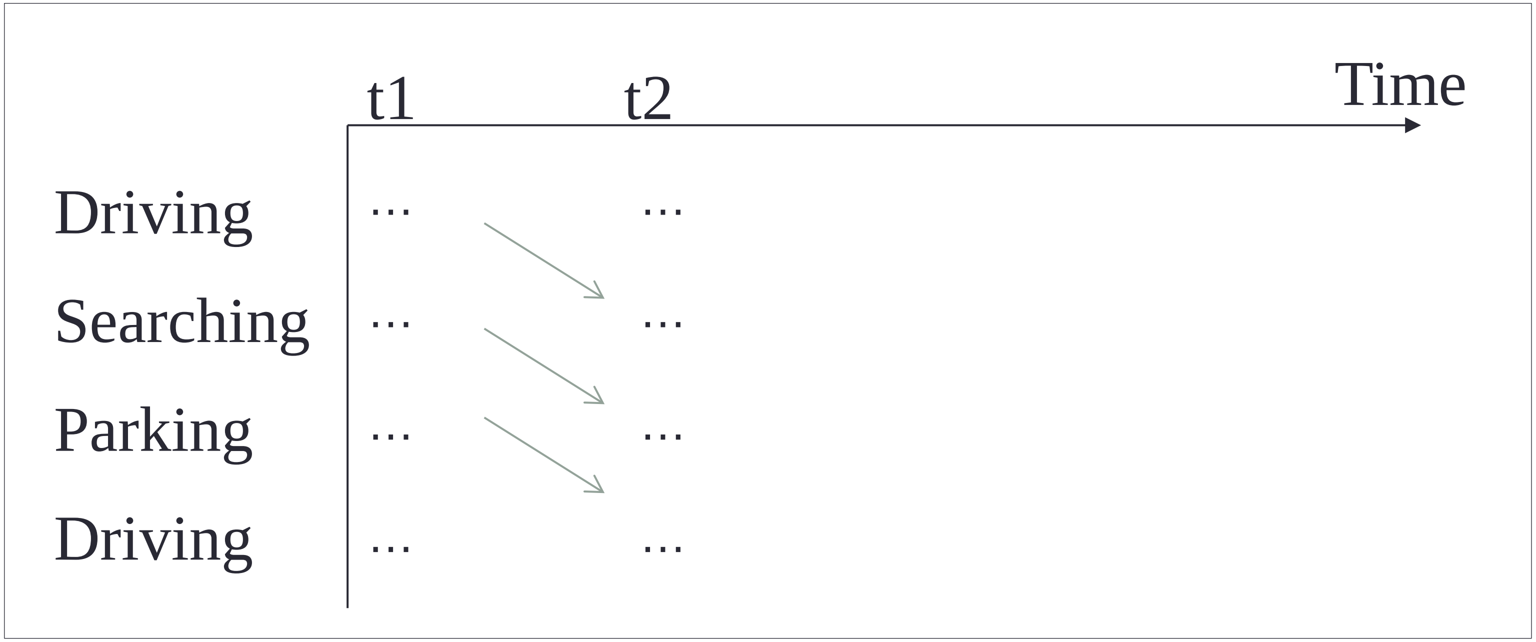
- How does parking system affect traffic performance?
- How does traffic affect parking system?

Microscopic

Macroscopic modelling of parking dynamics in urban networks

Parking-state-based Transition Matrix

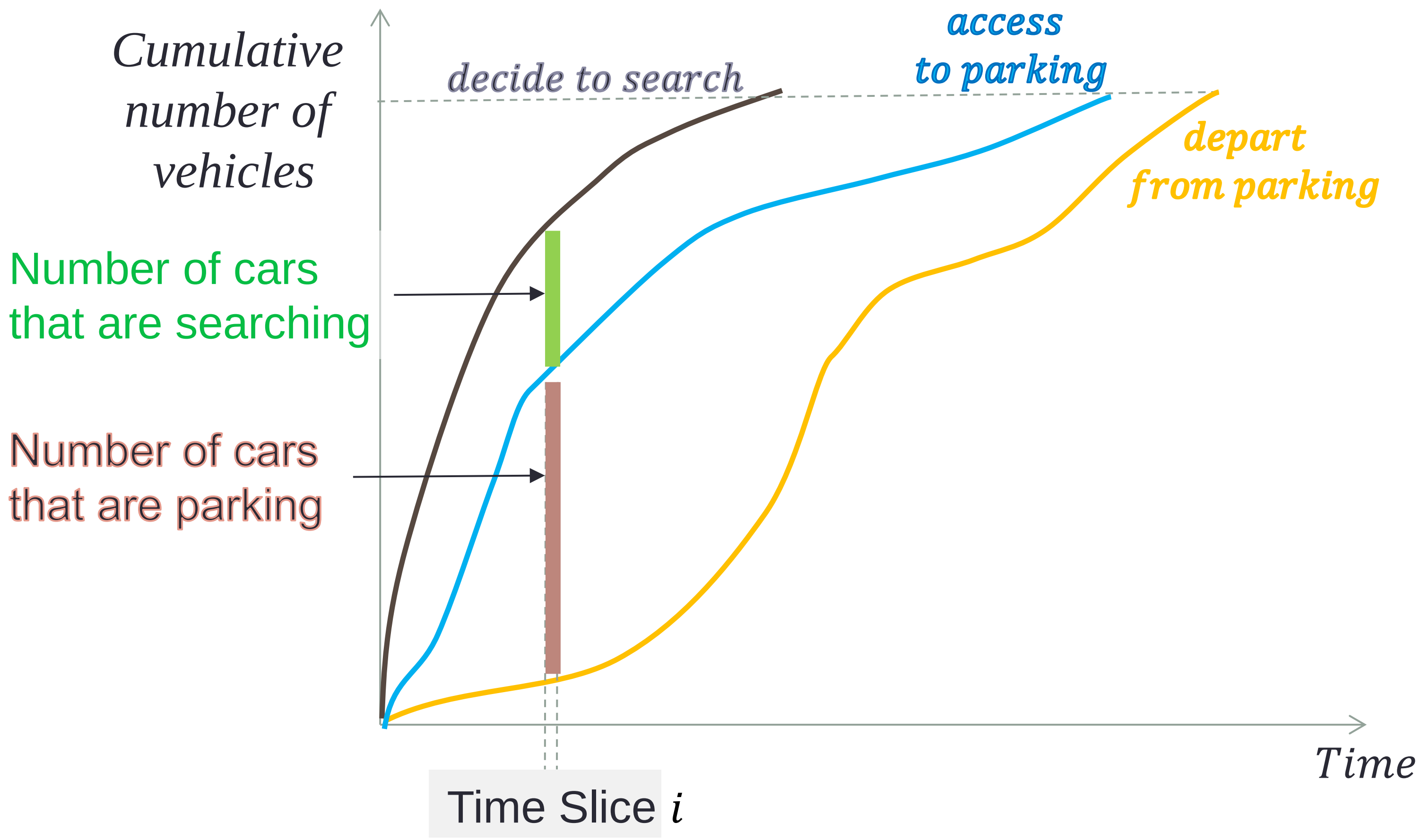
The parking-state-based transition matrix of vehicles on network



In the matrix, the number of cars in each parking-state is shown.

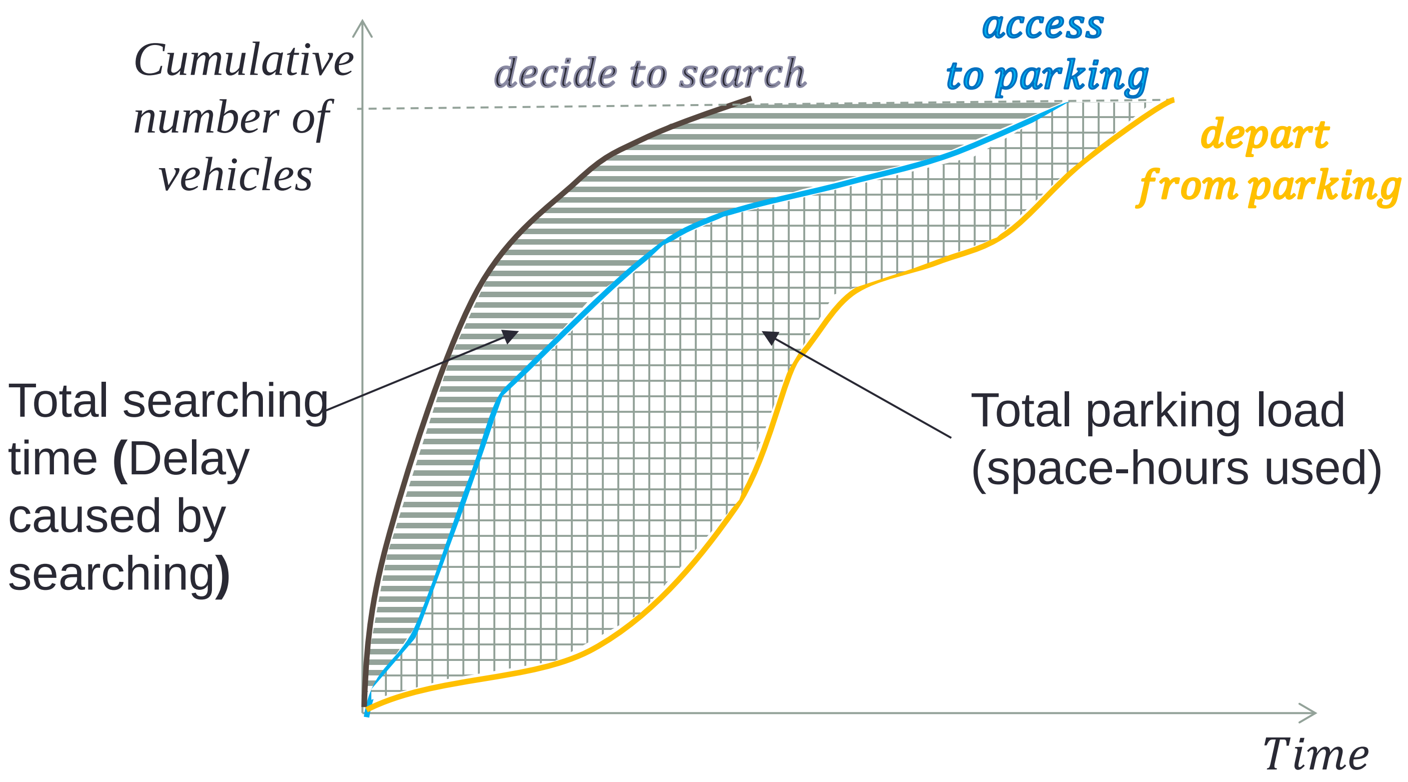
See similar ideas used in Arnott (2008): Modelling parking; and Geroliminis (2007, Dissertation 4.2)

Parking-state-based Transition Matrix



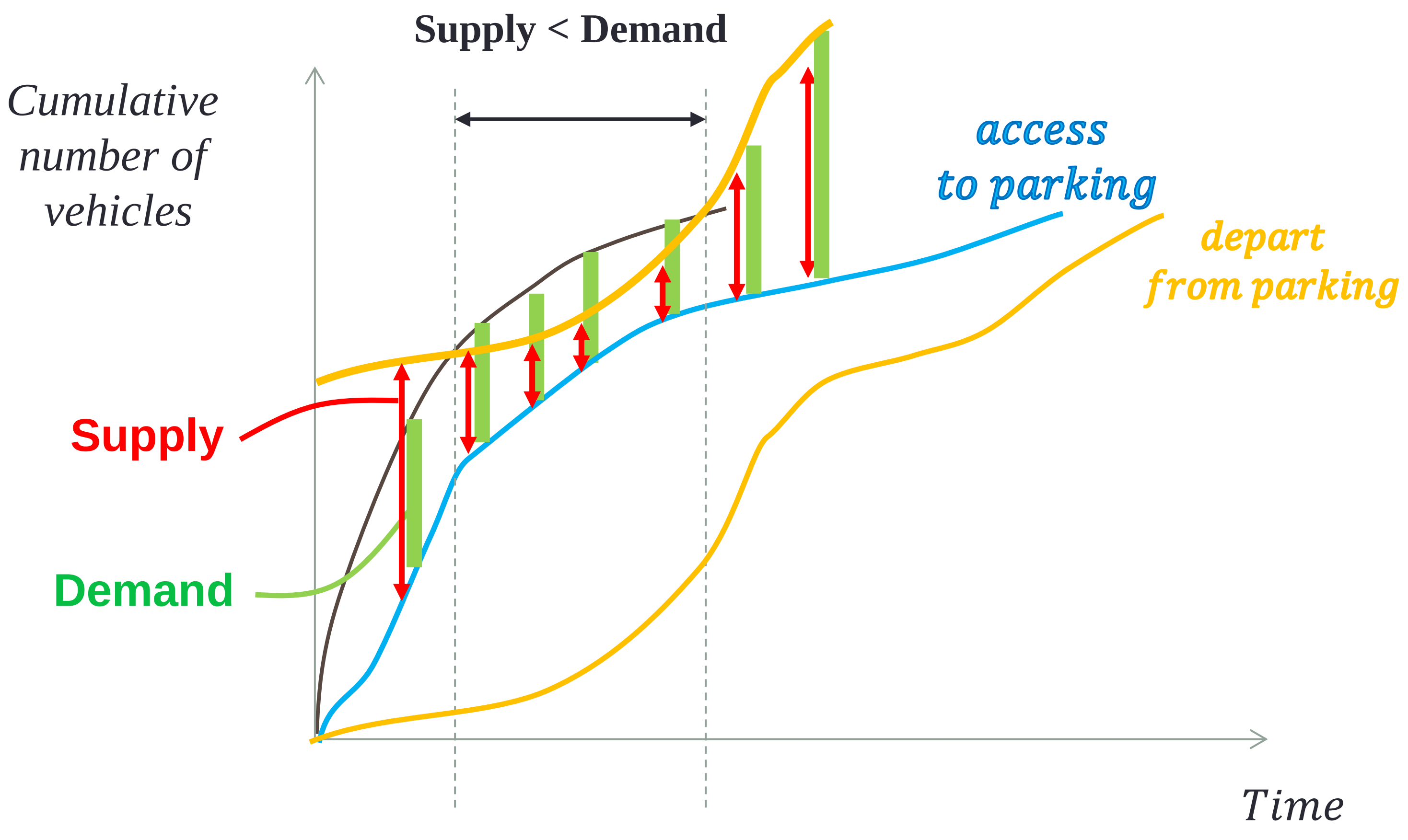
"Queuing diagram" of vehicles on urban networks

Parking-state-based Transition Matrix



"Queuing diagram" of vehicles on urban networks

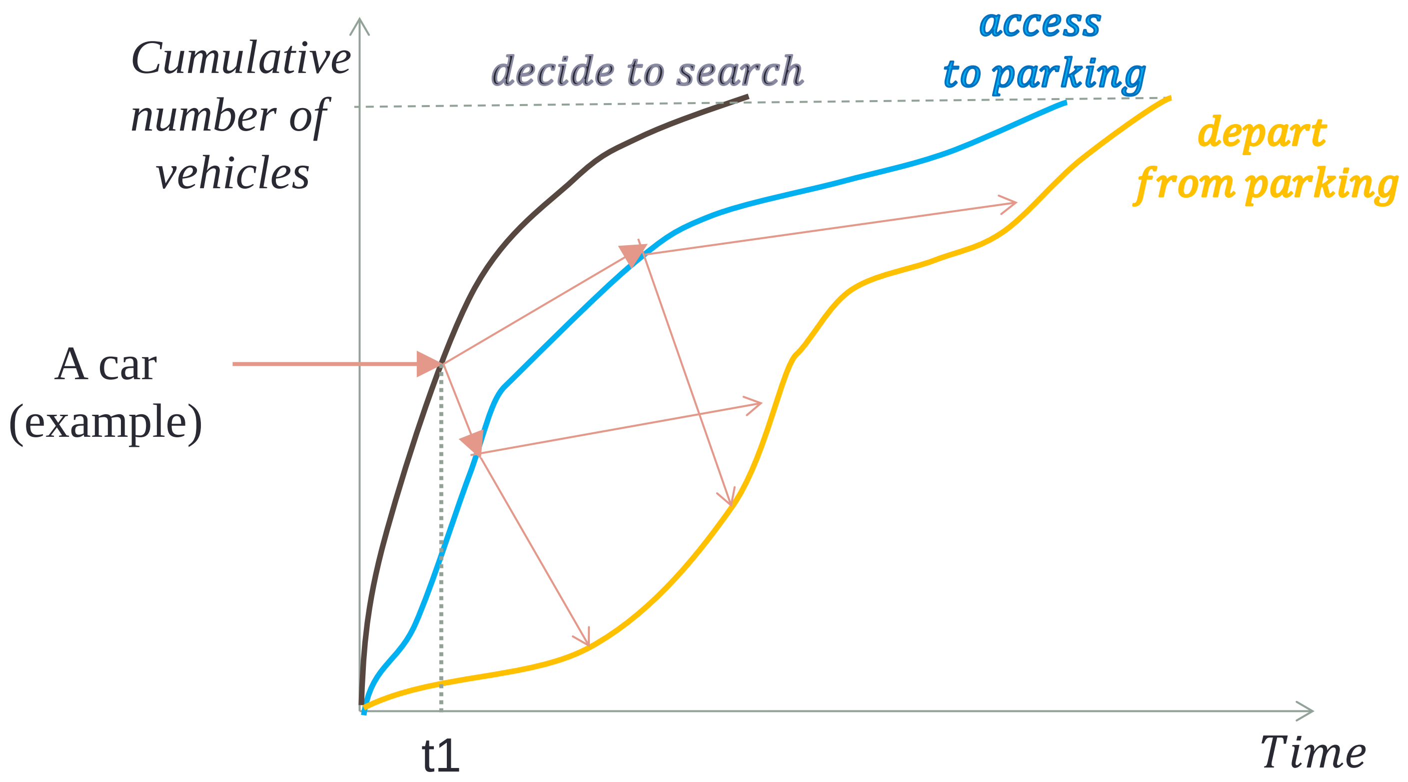
Parking-state-based Transition Matrix



“Queuing diagram” of vehicles on urban networks

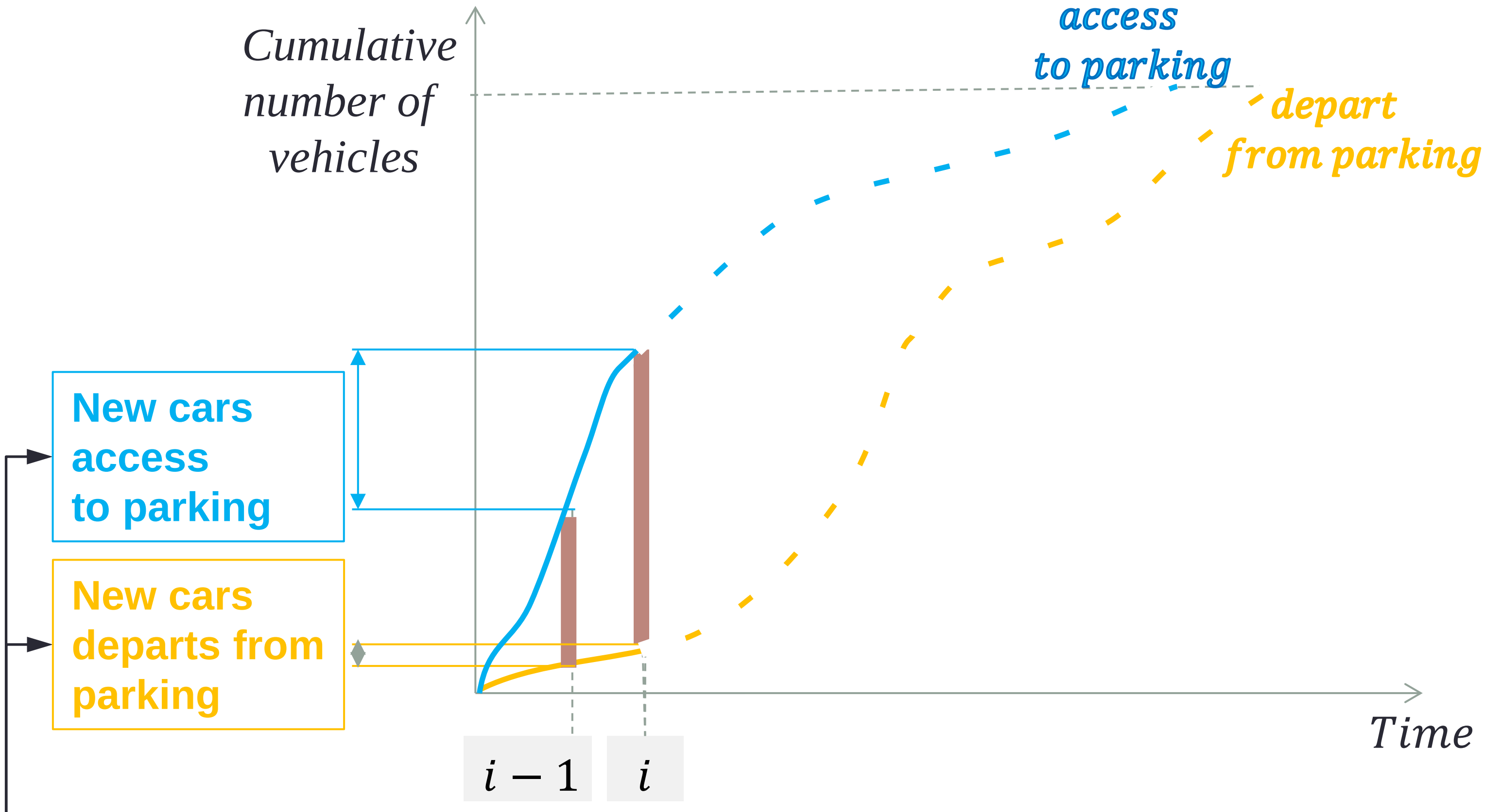
Parking-state-based Transition Matrix

Info shortage for any individual trip, as the system is not a FIFO.



"Queuing diagram" of vehicles on urban networks

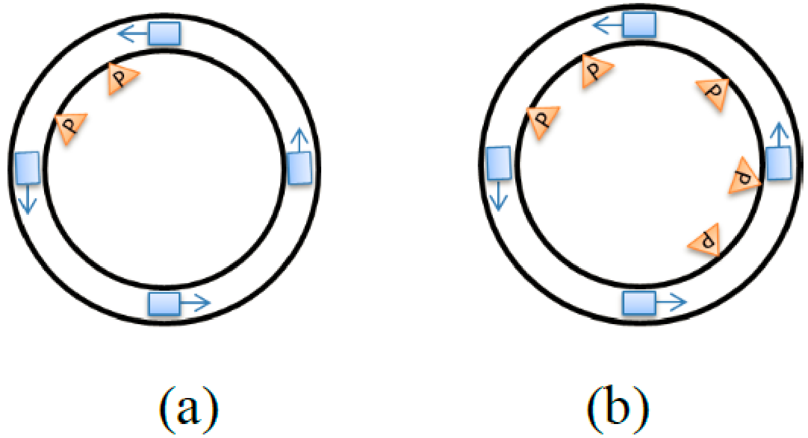
Construct the Matrix



Incrementally **construct the curves/matrix**

Model

New cars access to parking → n_{access}=?



Basic assumption.

Basic variables:

d the maximum driving distance of each car is $d = vt$.

L the size of the network is L (the total length of the ring road).

N at the beginning of the period, there are N cars searching for parking.

A at the beginning of the period, a number of A parking spots are available.

See similar use of the ring road network in parking at Arnott (2008).

Model (results)

SVT

$$when \;\; d \in [0, s], n = N \cdot \left[1 - \left(1 - \frac{d}{L}\right)^{A}\right].$$ Eq 1(a)

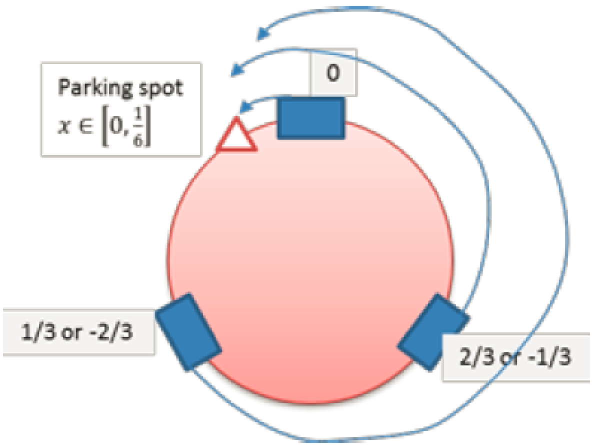
$$when \;\; d \in (s, L), n =$$ Eq 1(b)

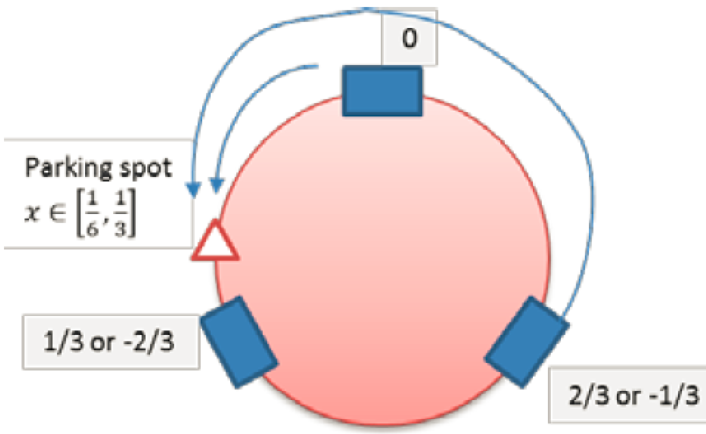
$$n_{access} = \begin{cases} A & if \; A < m \\ A \cdot \left\{1 - \frac{N}{L} \cdot \left\{\int_{d-(m-1)s}^{s} \left\{ \begin{array}{l} \sum_{i_{m-1}=m-1}^{A-1} C_{A-1}^{i_{m-1}} \left[\frac{(N-m+2)s-x}{L}\right]^{A-1-i_{m-1}} \cdot \\ \left\{\sum_{i_{m-2}=m-2}^{i_{m-1}} C_{i_{m-1}}^{i_{m-2}} \cdot \ldots \cdot \sum_{i_1=1}^{i_2} C_{i_2}^{i_1} \left[\left(\frac{x}{L}\right)^{i_1} \cdot s^{(i_{m-1}-i_1)}\right]\right\} \end{array} \right\} dx \right\}\right\} & if \; A = m \\ A \cdot \left\{1 - \frac{N}{L} \cdot \left\{ \begin{array}{l} \int_{0}^{d-(m-1)s} \left\{ \begin{array}{l} \sum_{i_m=m}^{A-1} C_{A-1}^{i_m} \left[\frac{(N-m+1)s-x}{L}\right]^{A-1-i_m} \cdot \\ \left\{\sum_{i_{m-1}=m-1}^{i_m} C_{i_m}^{i_{m-1}} \ldots \sum_{i_1=1}^{i_2} C_{i_2}^{i_1} \left[\left(\frac{x}{L}\right)^{i_1} \cdot s^{(i_m-i_1)}\right]\right\} \end{array} \right\} dx \\ + \int_{d-(m-1)s}^{s} \left\{ \begin{array}{l} \sum_{i_{m-1}=m-1}^{A-1} C_{A-1}^{i_{m-1}} \left[\frac{(N-m+2)s-x}{L}\right]^{A-1-i_{m-1}} \cdot \\ \left\{\sum_{i_{m-2}=m-2}^{i_{m-1}} C_{i_{m-1}}^{i_{m-2}} \cdot \ldots \cdot \sum_{i_1=1}^{i_2} C_{i_2}^{i_1} \left[\left(\frac{x}{L}\right)^{i_1} \cdot s^{(i_{m-1}-i_1)}\right]\right\} \end{array} \right\} dx \end{array} \right\}\right\} & if \; A > m \end{cases}$$

$$when \;\; d \in [L, \infty), n = min\{A, N\}.$$ Eq 1(c)

Model (results)

Examples





if $x \in \left[\frac{1}{6}, \frac{1}{3}\right]$, a number of m-1=2 cars can reach x.

(a) if $x \in \left[0, \frac{1}{6}\right]$, a number of m=3 cars can reach x.

For validation: the results (equation) is compared to the average value given by programmed experiments.

Summary

- The model for n_{access} allow us to imitate a practical situation with the imbalance between parking availability and demand, as well as the parking search phenomenon.
- But the model neglects the influence of the network shape (by assuming all streets have the same likelihood of being visited), and personal requirements for parking.

- Next step, to find the value of n_{depart} , number of cars departs from the parking facilities. Then build the matrix under the current framework and assumptions.

- Explore information from the transition matrix (or queuing diagram), relax the assumptions and improve the model to more generalized conditions.