A Parking-State-Based Transition Matrix of Traffic on Urban Networks

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IVT Seminar 10.07.2014

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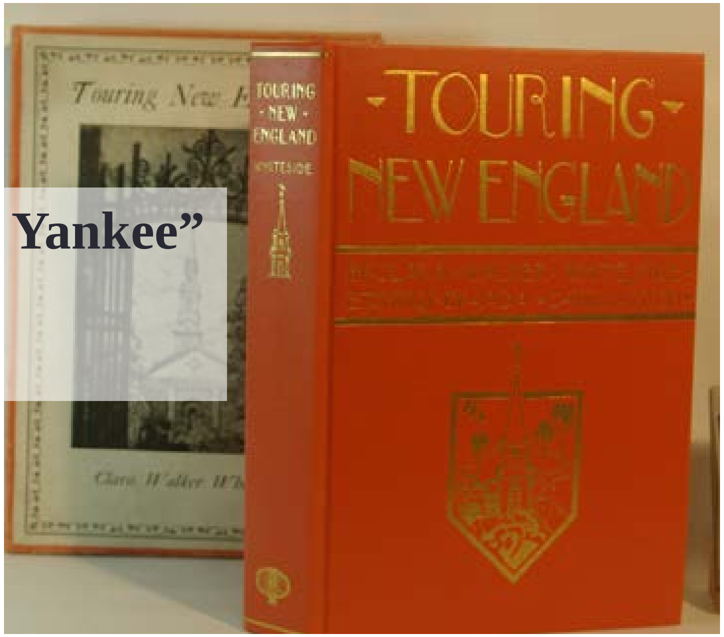
"We started out to view the town … Round and round the blocks we drove trying to find a place to park… Every curb was black with backed-in cars… "There's a place!" Alas! It was the wrong side of the street. So on we would go to the next corner hoping to be able to turn but invariably the traffic officer would firmly signal us, till time after time, we would find ourselves… in the very center of things, entangled in the traffic. "

"Touring New England on the Trail of the Yankee"

Clara Whiteside, in Connecticut, 1926



Quoted in "The high cost of free parking", Shoup, 2005.

Data on parking

Year	City	Share of cruising traffic	Average cruising time (min)
1927	Detroit (1)	19%	
1927	Detroit (2)	34%	
1933	Washington		8.0
1960	New Haven	17%	
1965	London (1)		6.1
1965	London (2)		3.5
1965	London (3)		3.6
1977	Freiburg	74%	6.0
1984	Jerusalem		9.0
1985	Cambridge	30%	11.5
1993	Cape Town		12.2
1993	New York (1)	8%	7.9
1993	New York (2)		10.2
1993	New York (3)		13.9
1997	San Francisco		6.5
2001	Sydney		6.5
Average			
Average		*30%*	*8.1 min*

Source: Shoup (2005)

Data on parking

20 international cities

Top 1: New Delhi

Top 2: Bangalore

Top 3: Beijing

- Globally, drivers have spent an average of nearly **20 minutes** searching.
- African drivers averaged both the shortest and longest times searching for parking in the last year when compared to the other 18 cities -- Johannesburg averaged 12.7 minutes and Nairobi averaged 31.7 minutes.

IBM Global Parking Survey (2011)

Data on parking

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Beijing's parking problem

Updated: 2011-04-02 07:51

(China Daily)

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The problem of parking Beijing's nearly 5 million cars is no less upsetting than traffic jams.

The Beijing government increased parking fee and launched a 100-day action plan from April 1 to regulate parking of cars. These are welcome moves because cars parked randomly on pavements and in bicycle lane and even some motor lanes have been disrupting the movement of motor vehicles, cyclists and pedestrians alike.

Yet it is doubtful whether the 100-day action plan will help solve the parking problem once and for all, because the primary contradiction between lack of parking space and rapid increase in the number of vehicles can hardly be resolved in such a short time.

Related readings:
- To reduce city traffic, parking fees raised
- Beijing hikes parking fees to ease traffic congestion
- Beijing gives roadside parking meters another try
- Revamp for parking lots aimed at easing drivers' frustrations

Beijing had parking space for 650,000 cars in 2003 when the city ad about 1.57 million vehicles. Though the expanded parking space ca ow accommodate 1.3 million vehicles, the number of cars has ached nearly 5 million (according to December 2010 figures).

This gap is the price urban planners have to pay for their lack of vision most of the buildings built in the 1990s have no provisions for underground parking lots and even today very few housing units have well-designed and efficient parking facilities.

Another problem is that even if there were enough parking lots, many drivers would still prefer parking their ca in places where parking fee is not charged. Such blatant violation of traffic rules has contributed considerably to the parking chaos in the city.

2003: Beijing had
0.65 million parking
1.57 million vehicles

Dec 2010:
1.3 million vs. 5 million

This gap is the price urban planners have to pay for their lack of vision - most of the buildings built in the 1990s have no provisions for underground parking lots and even today very few housing units have well-designed and efficient parking facilities.

Source: http://europe.chinadaily.com.cn/opinion/2011-04/02/content_12270087.htm

Data on parking

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Data on parking

In some other cities?

Source: http://transportblog.co.nz/2014/02/25/unitary-plan-and-minimum-parking-requirements/

Parking

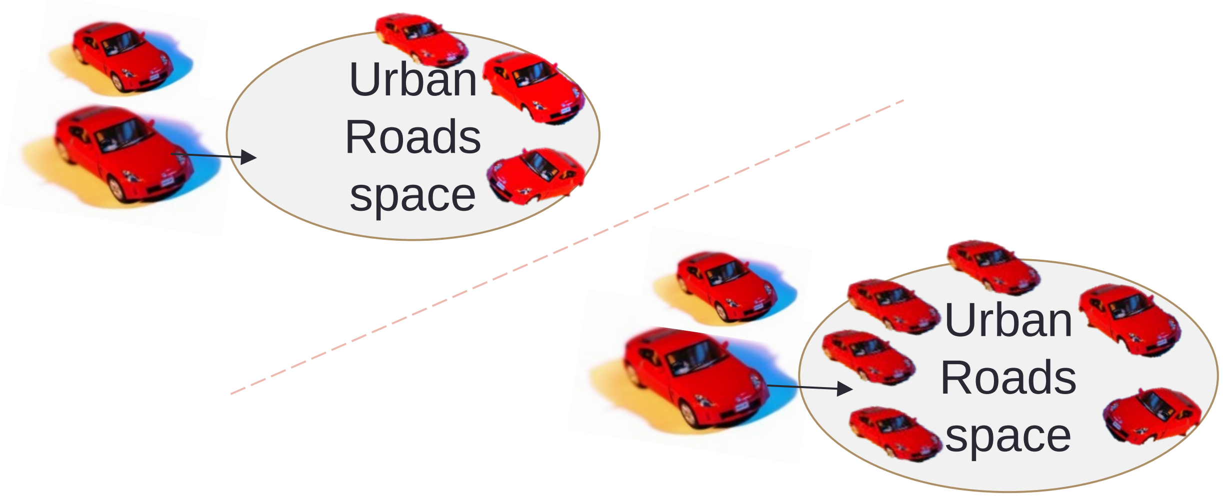
Individual impact ⟷ Collective consequences

- How many of the cars on congested streets are simply searching for curb parking rather than going somewhere?
- How much fuel does this cruising waste, and how much air pollution does it create?
- How much congestion it causes on the urban transportation system?
- How much time is wasted on such a part of the trips?

Urban Parking & Traffic Performance

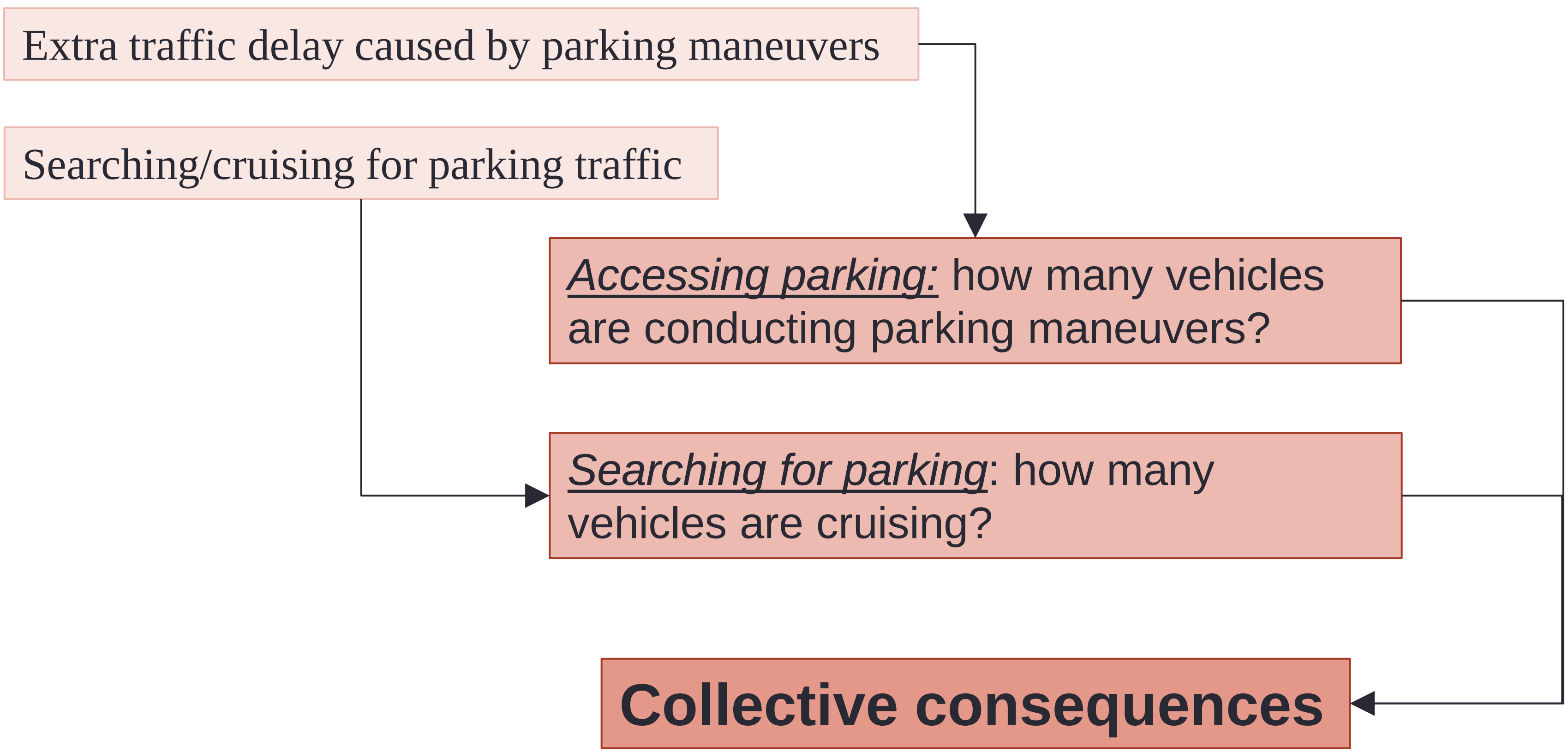
Extra traffic delay caused by parking maneuvers

Searching/cruising for parking traffic



It is harder for traffic to enter the city if the road space is continuously kept by cruising traffic or parking vehicles.

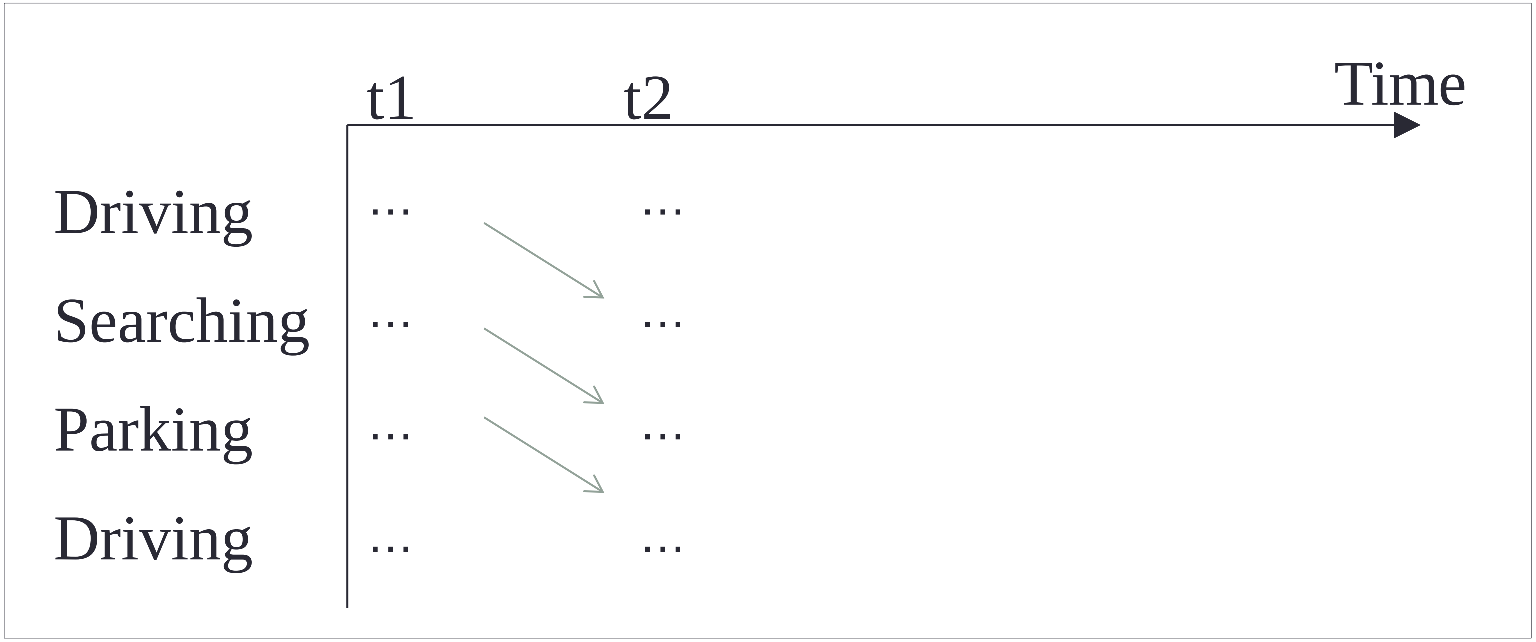
Model the impact of *parking* on urban traffic



Macroscopic approaches ?

Parking-state-based Transition Matrix

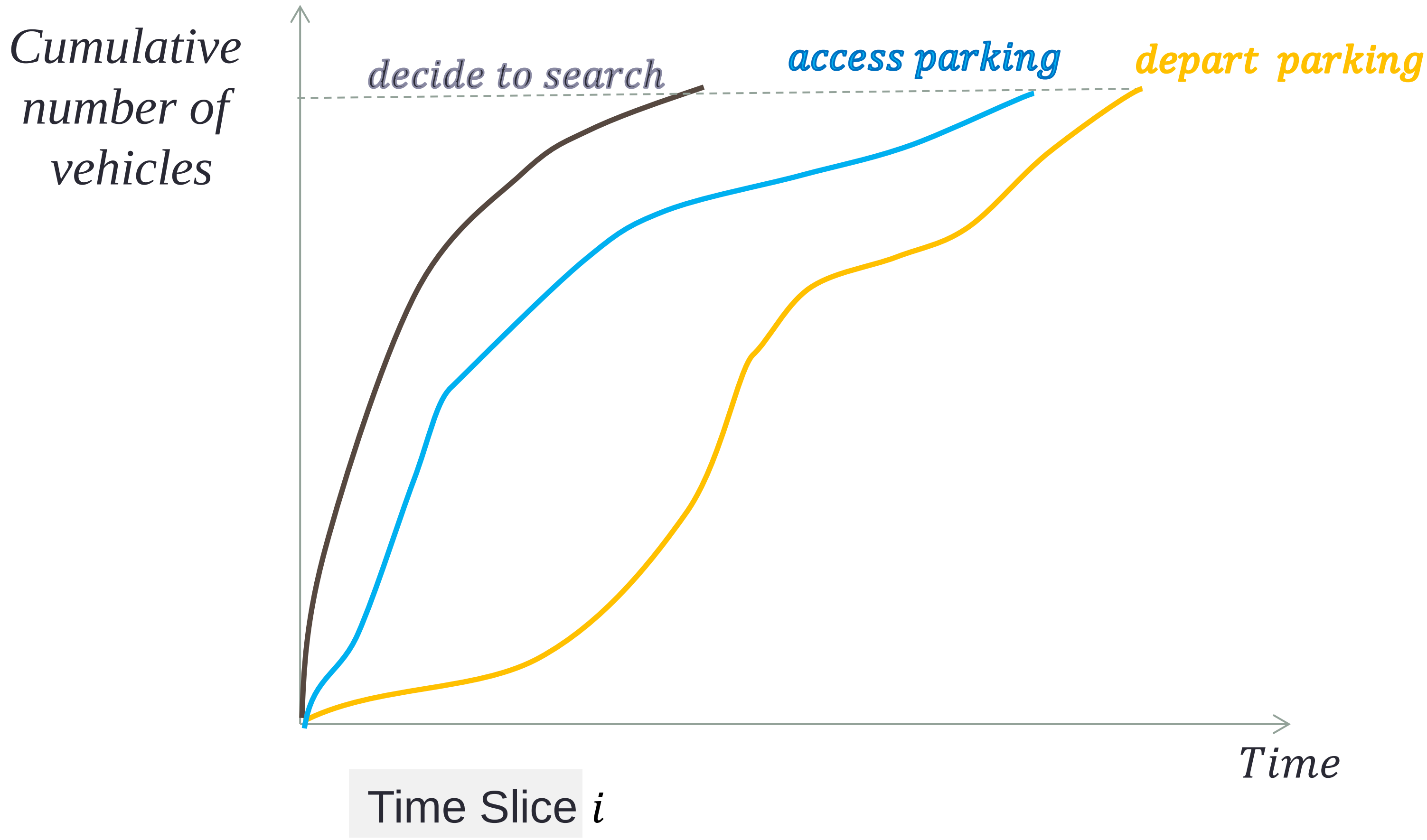
The parking-state-based transition matrix of vehicles on network



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

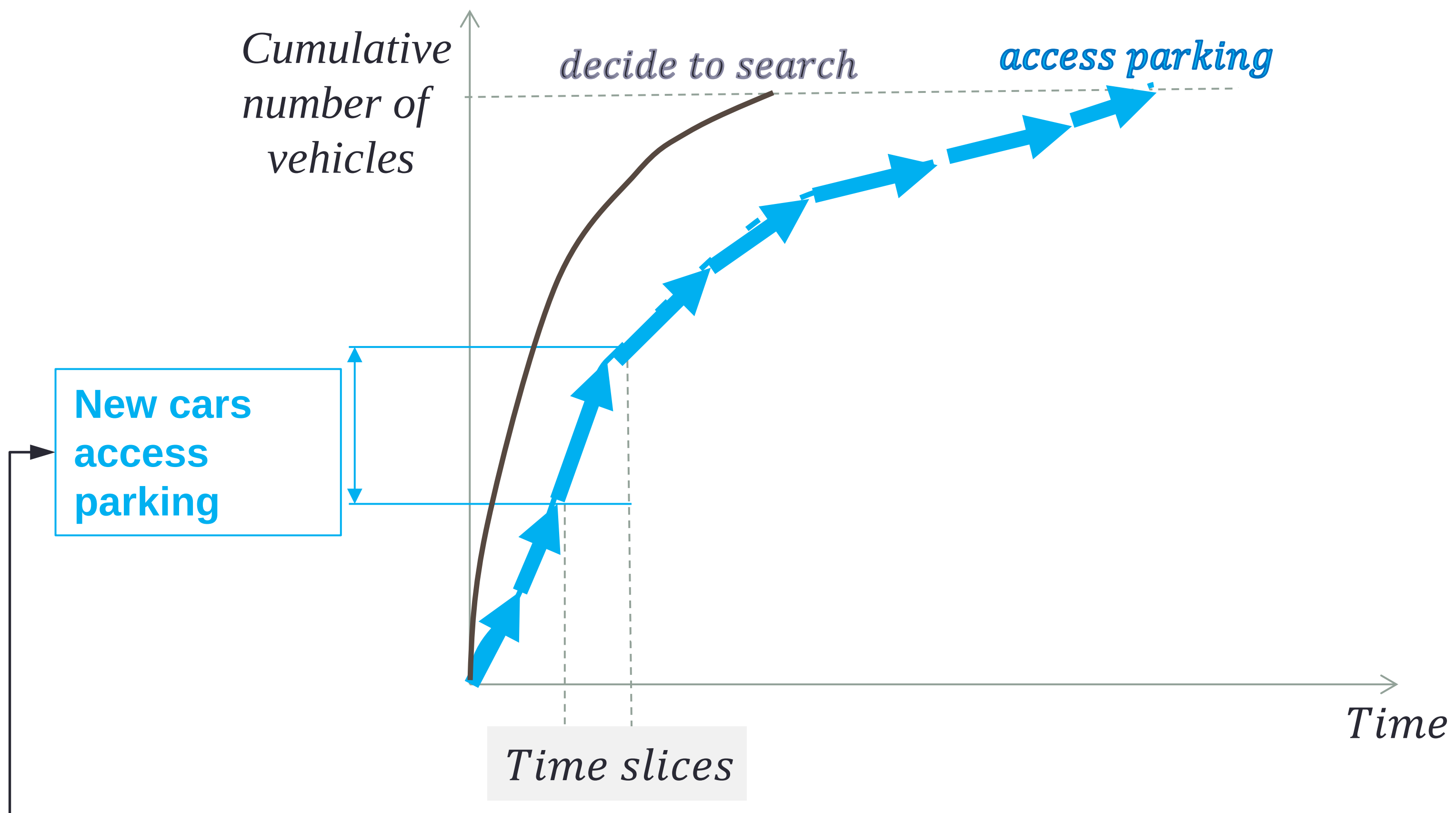
See similar ideas used in Arnott (2008): Modelling parking; and Geroliminis (2007, Dissertation 4.2)

Parking-state-based Transition Matrix



"Queuing diagram" of vehicles on urban networks

Construct the Matrix

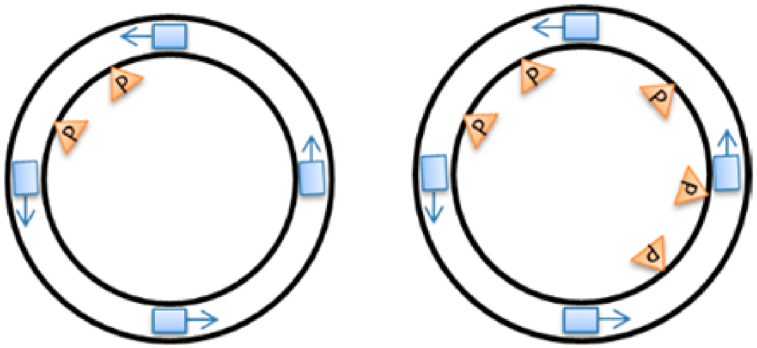


Incrementally **construct the curves/matrix**

Construct the Matrix

Basic assumption.

Number of cars access parking in a given time slices



Variables for each time slice:

- *Number of searchers,* ***N.***
- *Number of available parking spots,* ***A.***
- *A maximum distance a car can drive in each time slice,* ***d.***
- *The length of the road network,* ***L.***

See similar use of the ring road network in parking at Arnott (2008), Geroliminis (2014).

Construct the Matrix (results)

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

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

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

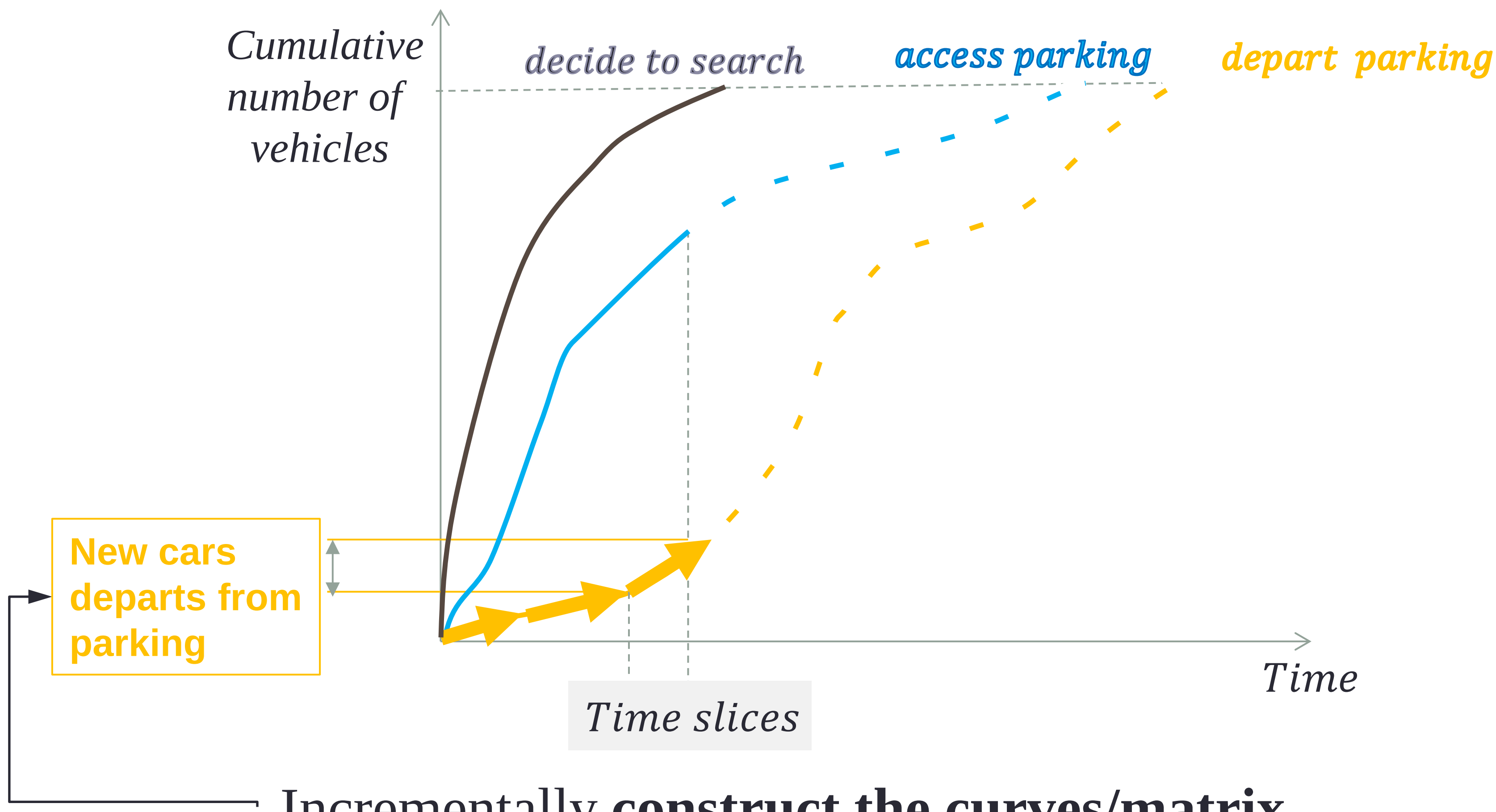
Advantages

- *Minimum data requirements.*
- *The sequence of the car arrivals to each parking stall is considered, it is close to real situation.*
- *The instantaneous change of the parking supply are consider (within each time slice).*

Although, the model can only provide a average number of cars that can access parking, the real situation could be with more randomness.

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

Construct the Matrix



Incrementally **construct the curves/matrix**

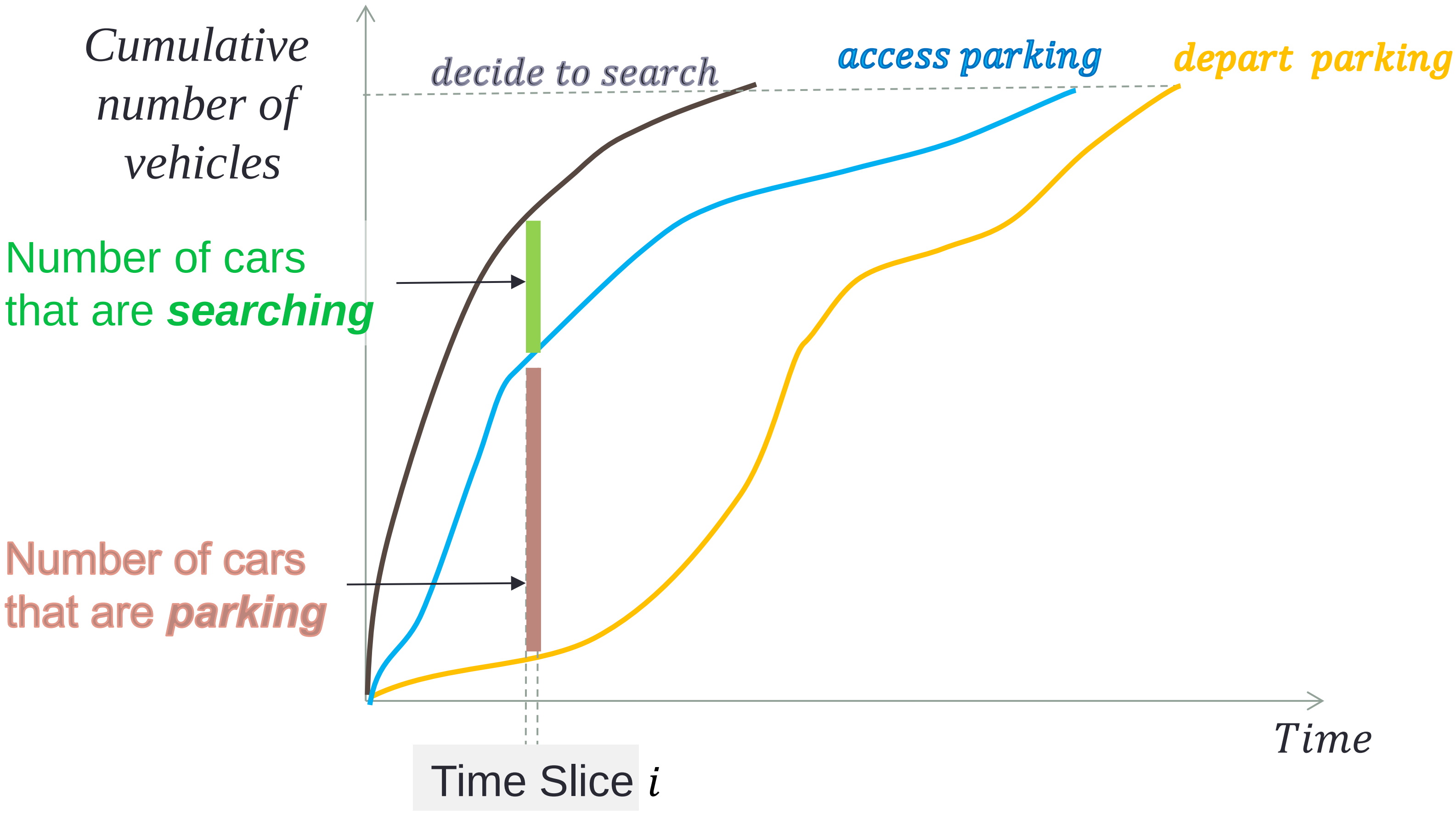
Construct the Matrix

Basic assumption.

Number of cars depart parking in a given time slices

Assume the parking duration obeys a known distribution, then the number of departure can be found based on the arrival and parking duration.

Results from the Matrix



"Queuing diagram" of vehicles on urban networks

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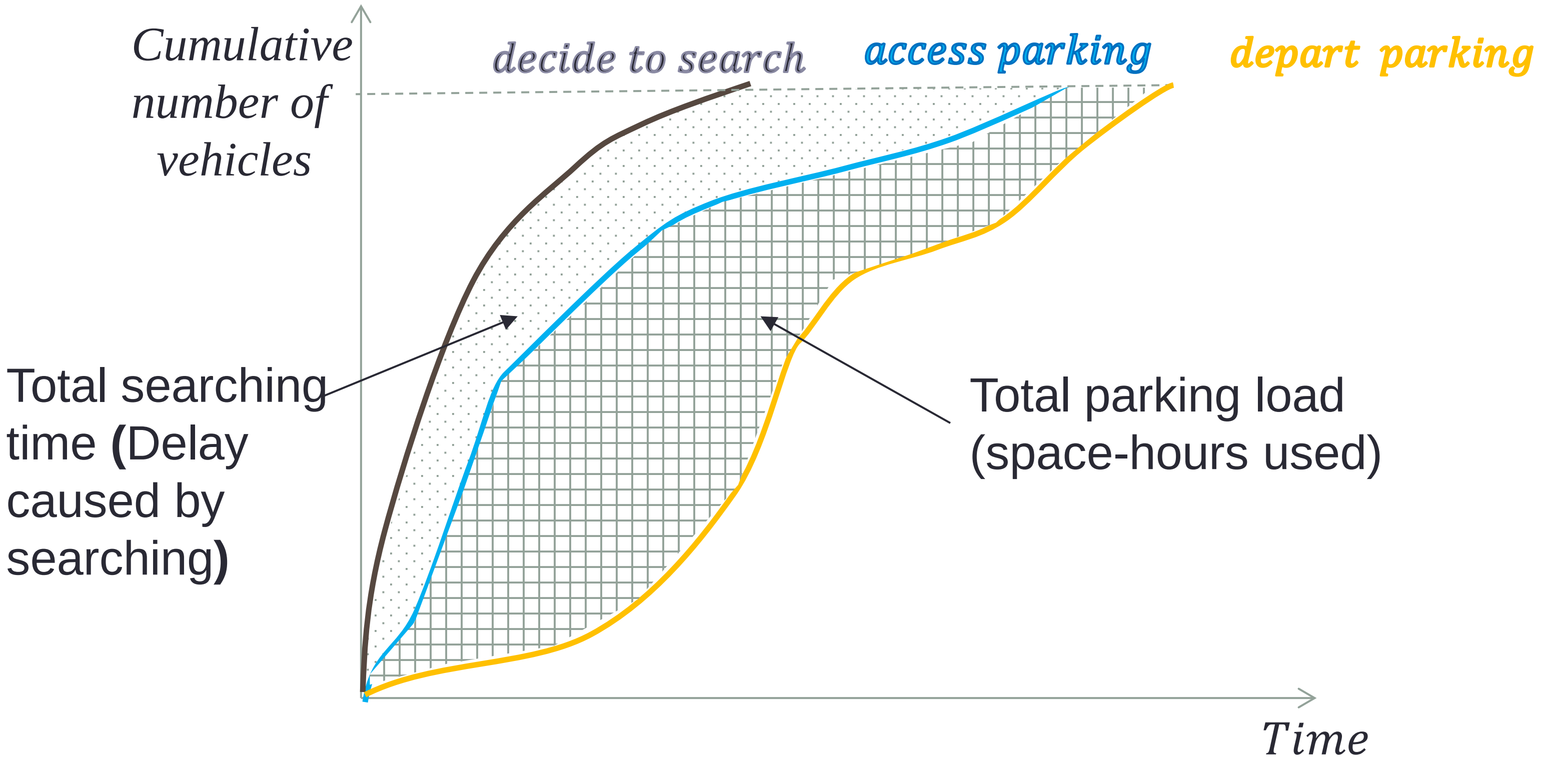

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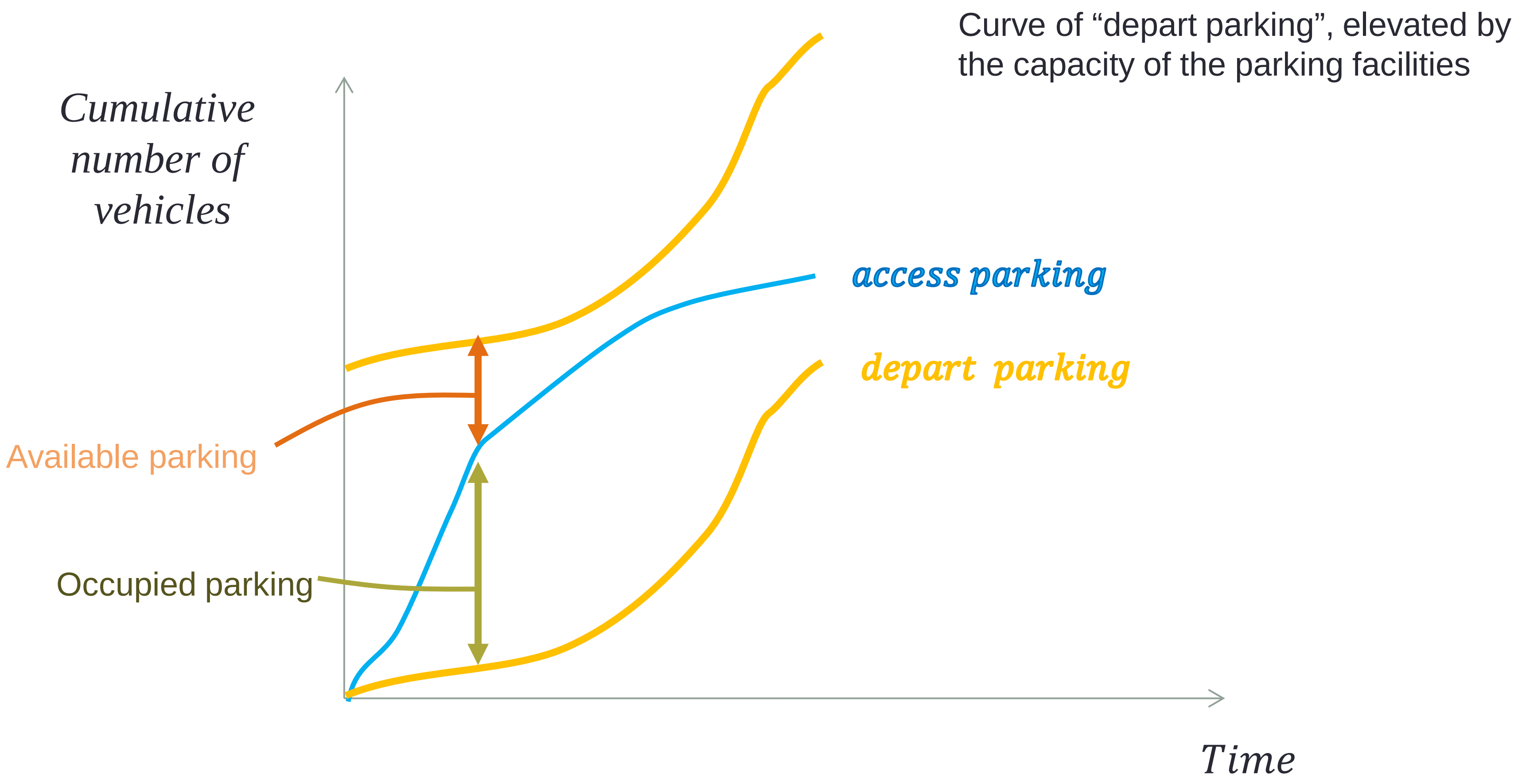
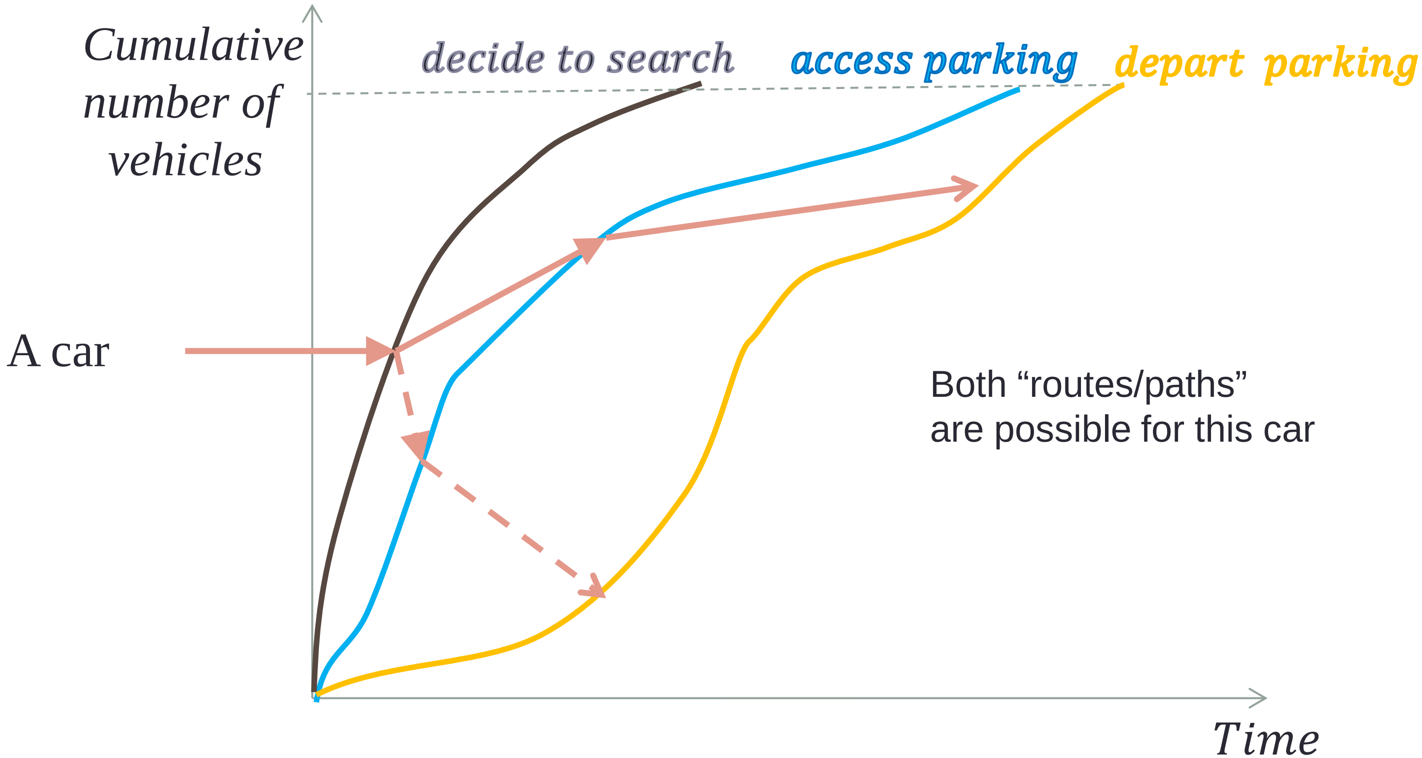


"Queuing diagram" of vehicles on urban networks

Unavailable results from the Matrix

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



“Queuing diagram” of vehicles on urban networks

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.

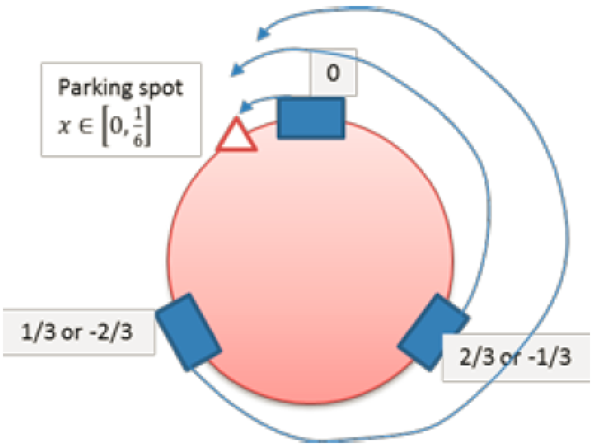
- Next step, to find the value of n_{depart} , number of cars departs from the parking facilities. Then build the matrix under the current framework and assumptions.

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

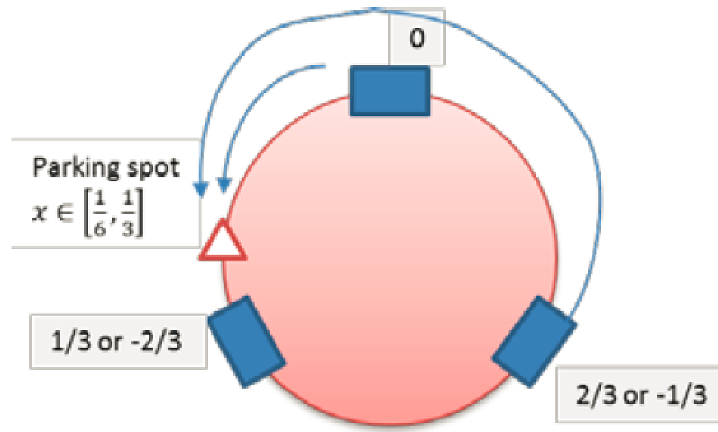
THANK YOU

Model (results)

Examples



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



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

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