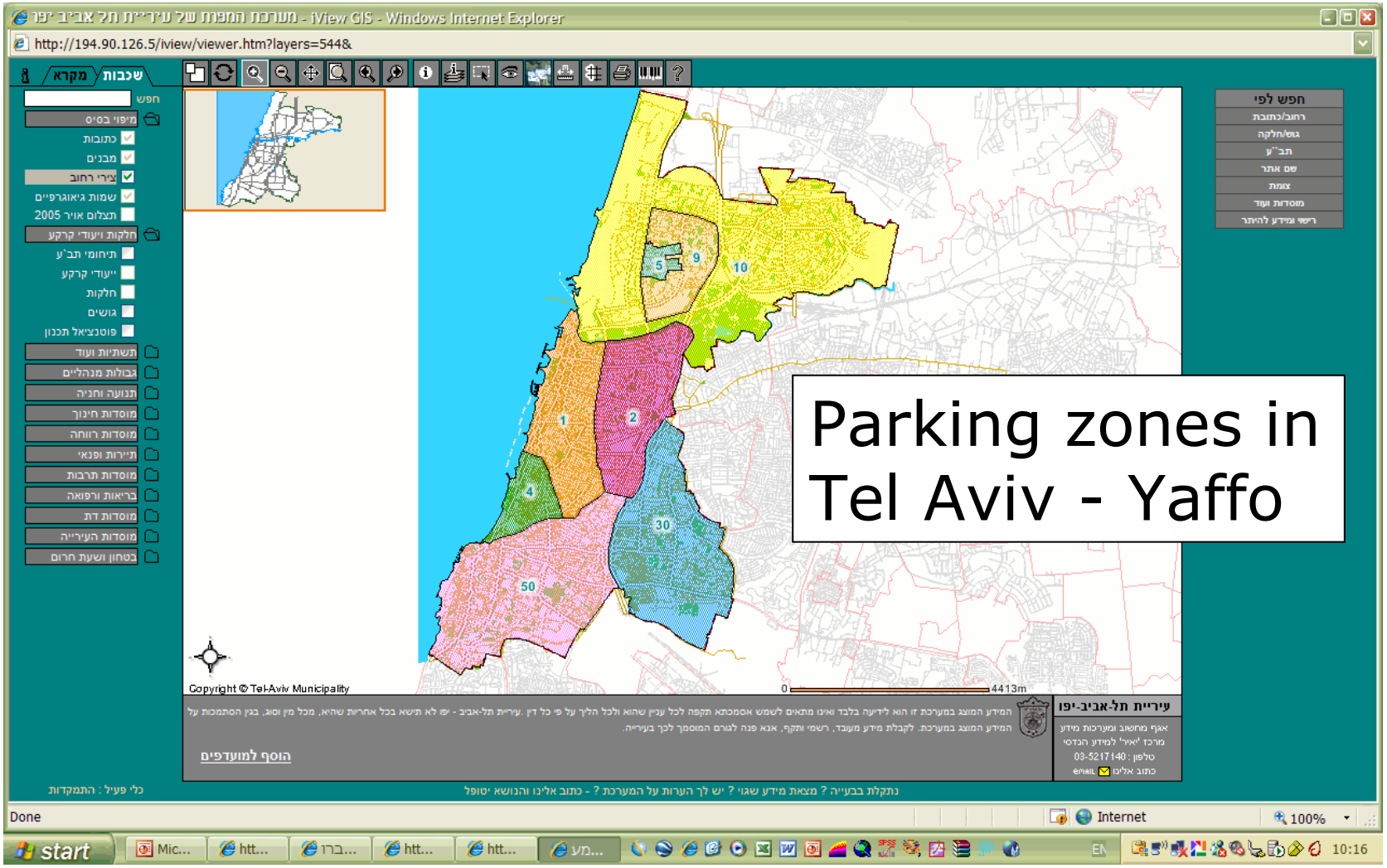
Agent-based model of driver parking behavior as a tool for urban parking policy evaluation

Itzhak Benenson[1,2], Slava Birfir[2], Karel Martens[3]

[1]Deptartment of Geography and Human Environment,
[2]Environment Simulation Laboratory, Porter School of Environmental Studies,
University Tel Aviv
[3]Department of Geography, Planning and Environment,
Radboud University Nijmegen, the Netherlands

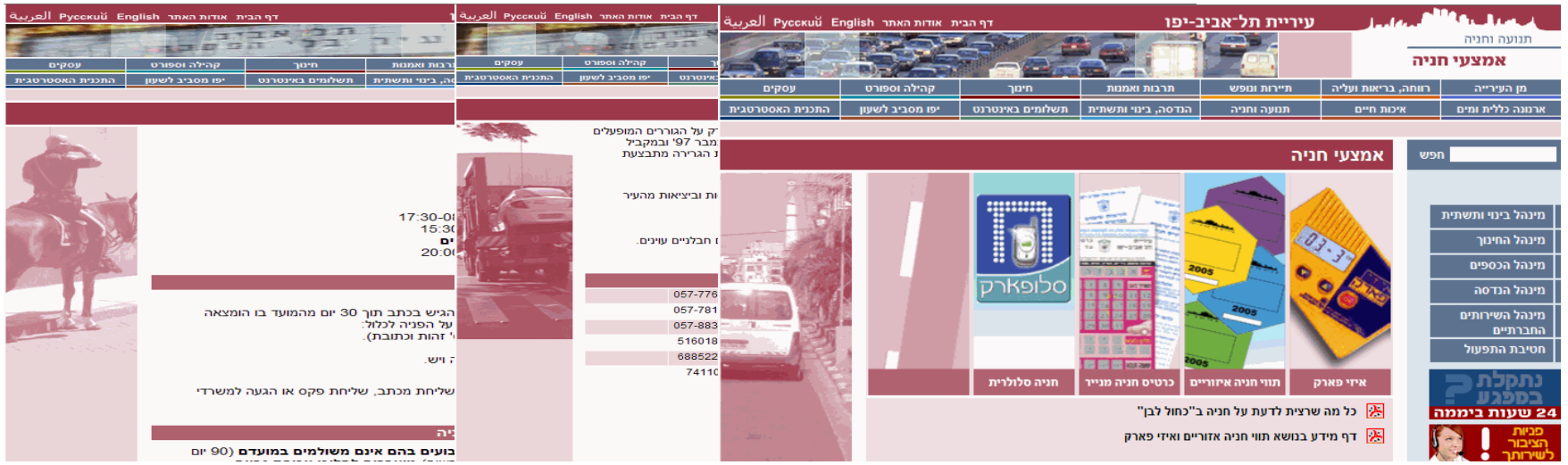
bennya@post.tau.ac.il

Start of project:
Tel Aviv in search of new parking policy



Many unanswered questions

- Whether to stick to the existing system of parking zones?
- What should be the height of the parking fees?
- What should be parking permissions/restrictions for various categories of drivers (local citizens, workers, shop/business customers, visitors)?
- What should be the level of control and enforcement?
- Is current/proposed policy economically justified?
- What might be political consequences of the current/proposed policy?
- ...



Limited knowledge base

No quantitative answers to many basic questions, especially at level of parking zones and areas:

- What is the demand?
- What is the supply, including privately-owned parking?
- What is the economically justified parking fee?
- What is the parking fee citizens or visitors are willing to pay?
- What level of control is necessary to avoid illegal parking?

In a metropolitan center like Tel Aviv, demand for parking will always exceed demand, unless appropriate parking policies are designed, implemented and enforced.

The policy challenge is to find the appropriate design. Geosimulation can help find that design.

Starting points

Meta-goals of parking model

- Dreams for the driver:

  To find parking quickly and close to the destination, if necessary against a small, fair, fee.

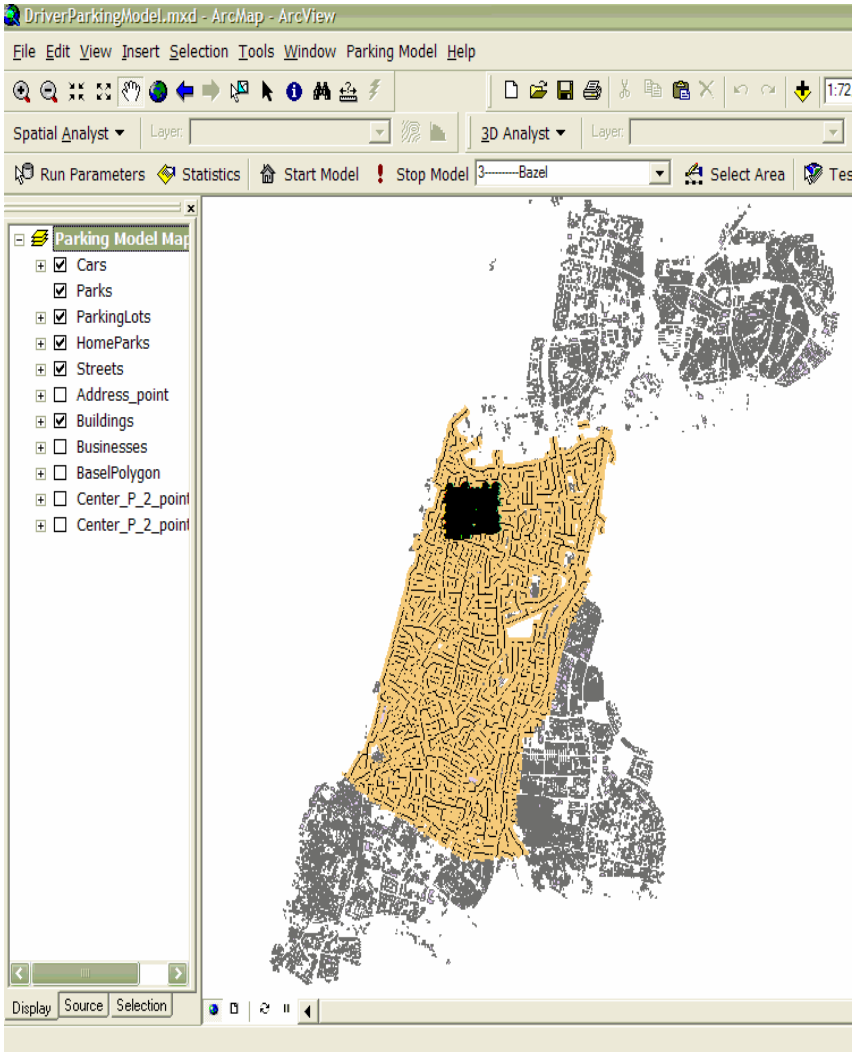
- Dreams for the municipality:

  To guarantee car drivers a safe and convenient access to the city.
  To guarantee citizens and visitors an overall pleasant urban environment.
  To book high overall revenues from parking fees.

  Meta-goal: To increase the chances of re-election for current major and city council.

Information basis: Tel Aviv municipal GIS

- Street network that includes traffic directions and turns, *thus enabling estimation of the process of driving to the destination*
- Parking permissions along the streets, off-street parking places and lots, *thus enabling estimation of the parking space supply*
- Residential buildings, public buildings, offices and businesses, *thus enabling estimating of the numbers of the drivers that want to park*



Additional info on parking *demand*

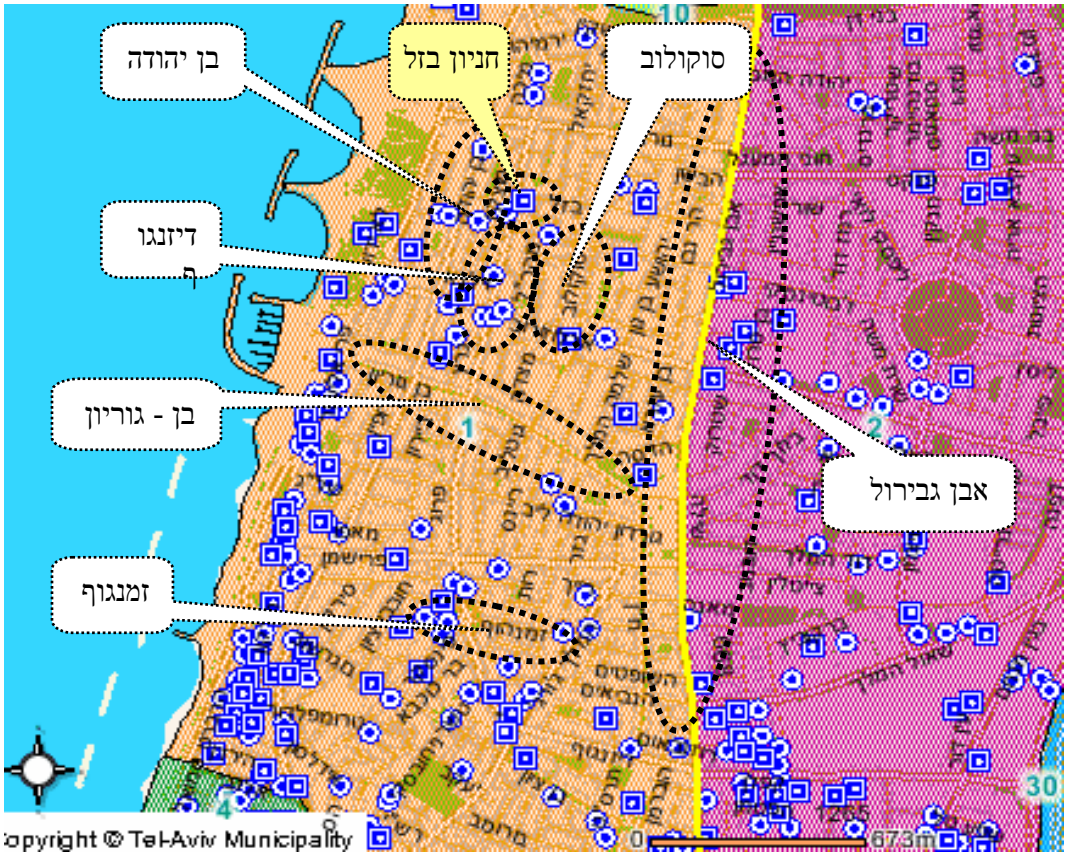
- Key indicators:
  - Parking duration
  - Willingness-to-pay
  - Possession of parking zone tag

- The way of estimating:

  Surveys at various locations throughout the city

For how long people park?

During the daytime, in the center of the city, majority of free-parking drivers search for short-term parking



Short-term parking (< 30 mins) along the main streets ~ 70% of the drivers, along the secondary streets ~ 50%.

Cars that do not have zone tags comprise ~ 30% of all parking cars

How much are the drivers ready to pay?

Majority of drivers are ready to pay 5 NIS for short-term parking (<20 mins) and 10-12 NIS for long-term parking (~ 1 hour)

Ben Yehuda no 152 - 190
07/09/2005 09:00 – 10:30

Wolfson no 1 - 37
11/09/2005 08:00 – 09:00

Dizengof 199-229
21/09/2005 09:00 – 11:00

Sokolov no 29-105
12/09/2005 12:00 – 13:30

Even Gvirol 8-114
15/09/2005 10:00 – 12:00

Building the model

Starting point: driver/agent perspective

"**Where**" and "**when**" is critical for driver → we have to characterize the parking situation for **a specific area and a specific time interval**

Given the area and time:

- Driver wants to find parking place close to my destination → **the distribution of distance between my parking place and destination** should have mean and STD as close to zero as possible
- Driver wants to find parking place quickly → **the distribution of my search time** should have mean and STD as close to zero as possible
- Driver wants to pay as less as possible → **the distribution of my payment** should have mean and STD as close to zero as possible

In order to estimate and model this we need:

- **high-resolution,**
- **spatially explicit**
- **agent-based,**

i.e.

Geosimulation model of parking in the city

Surprisingly (and luckily) -

nobody did that before!

The model is developed as an ArcGIS application, and can work with practically unlimited number of drivers

Geosimulation of parking in the city – *Objects*

- **Street segments**

Attributes: traffic directions, parking permissions

- **Destinations: Houses and Public places**

Attributes: capacity, working hours

- **Parking places – intervals of 4 m length - along the street**

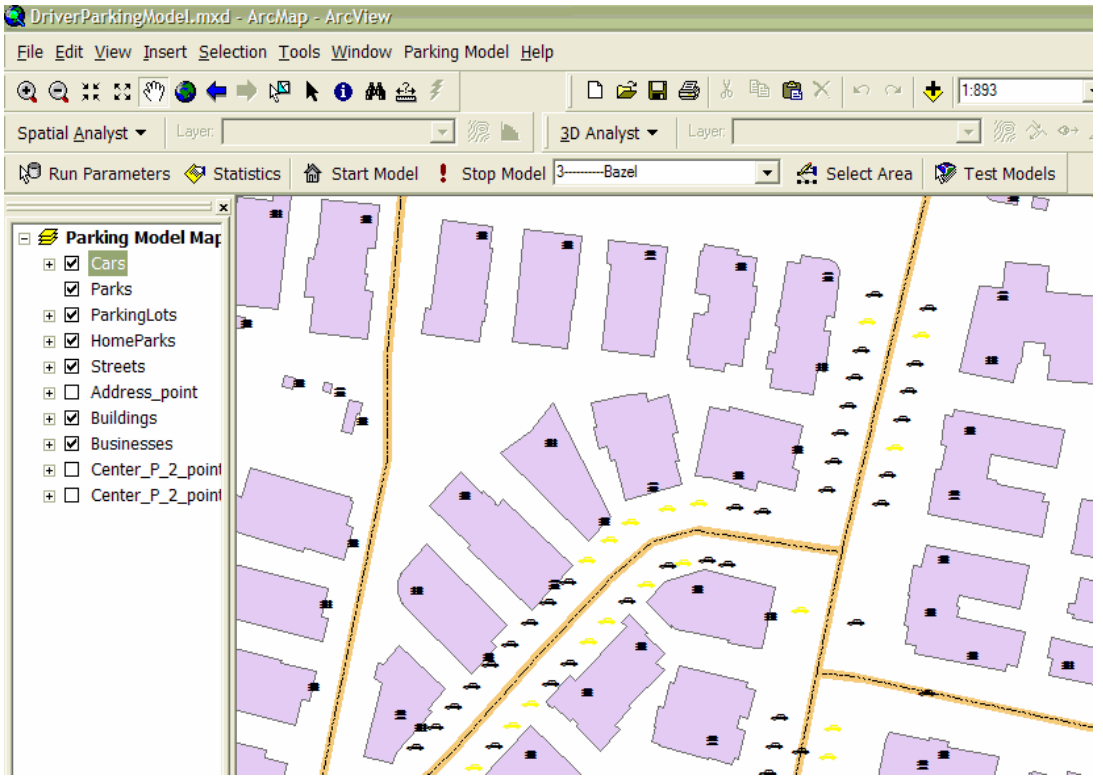
Attributes: permissions, fees

- **Dedicated parking places**

Attributes: permissions

- **Parking lots**

Attributes: capacity, fees



Geosimulation of parking in the city - *Agents*

Drivers belonging to one of four categories:

- **Residents** 
- **Guests**

with residential buildings as their destination, and

- **Employees** 
- **Customers** 

with public places as their destination.

Agents' states:

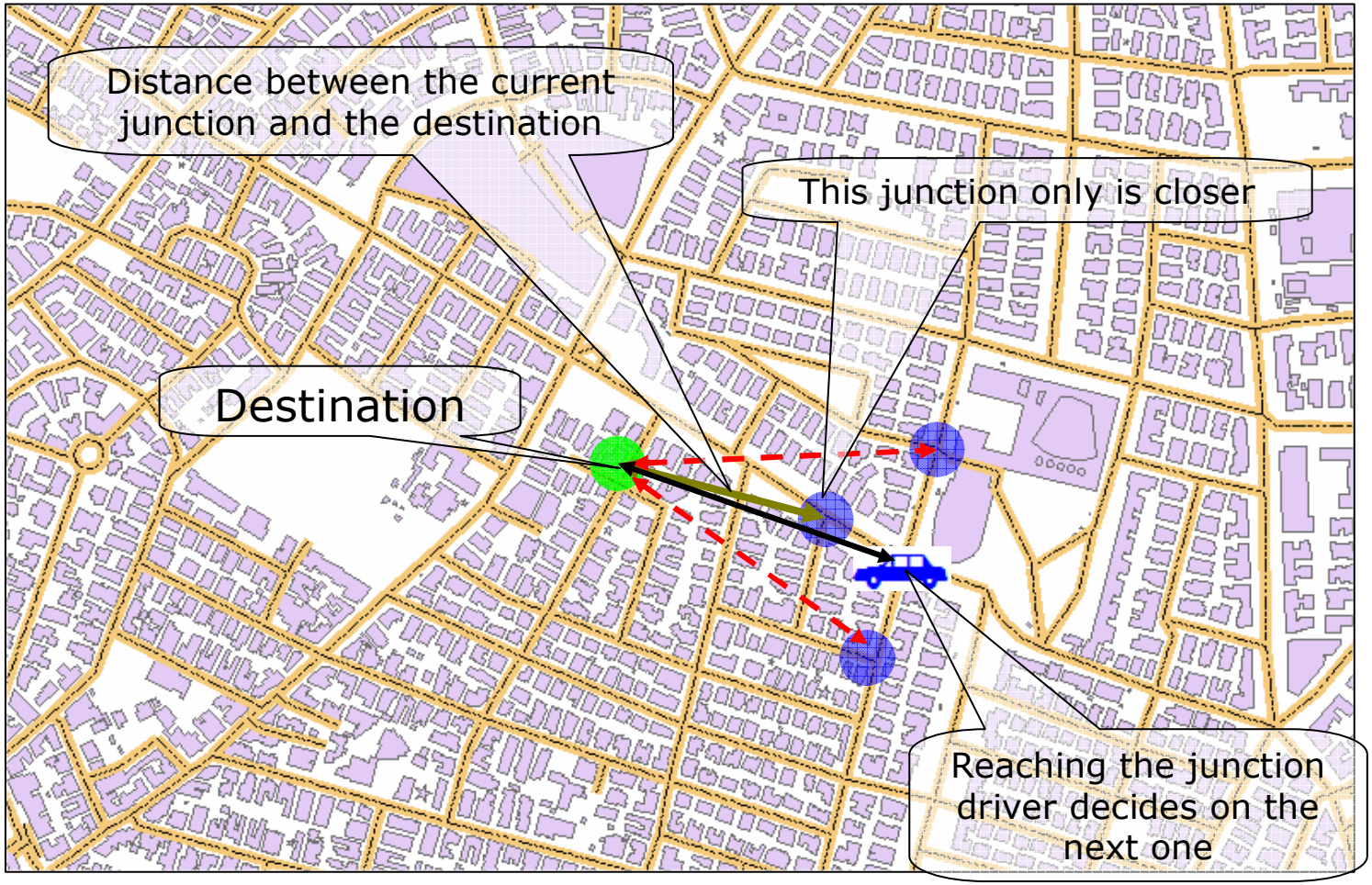
Driving to destination, search for parking, parking, driving out of the system.

Agents characteristics:

Destination, willingness-to-pay, arrival time, duration of stay.

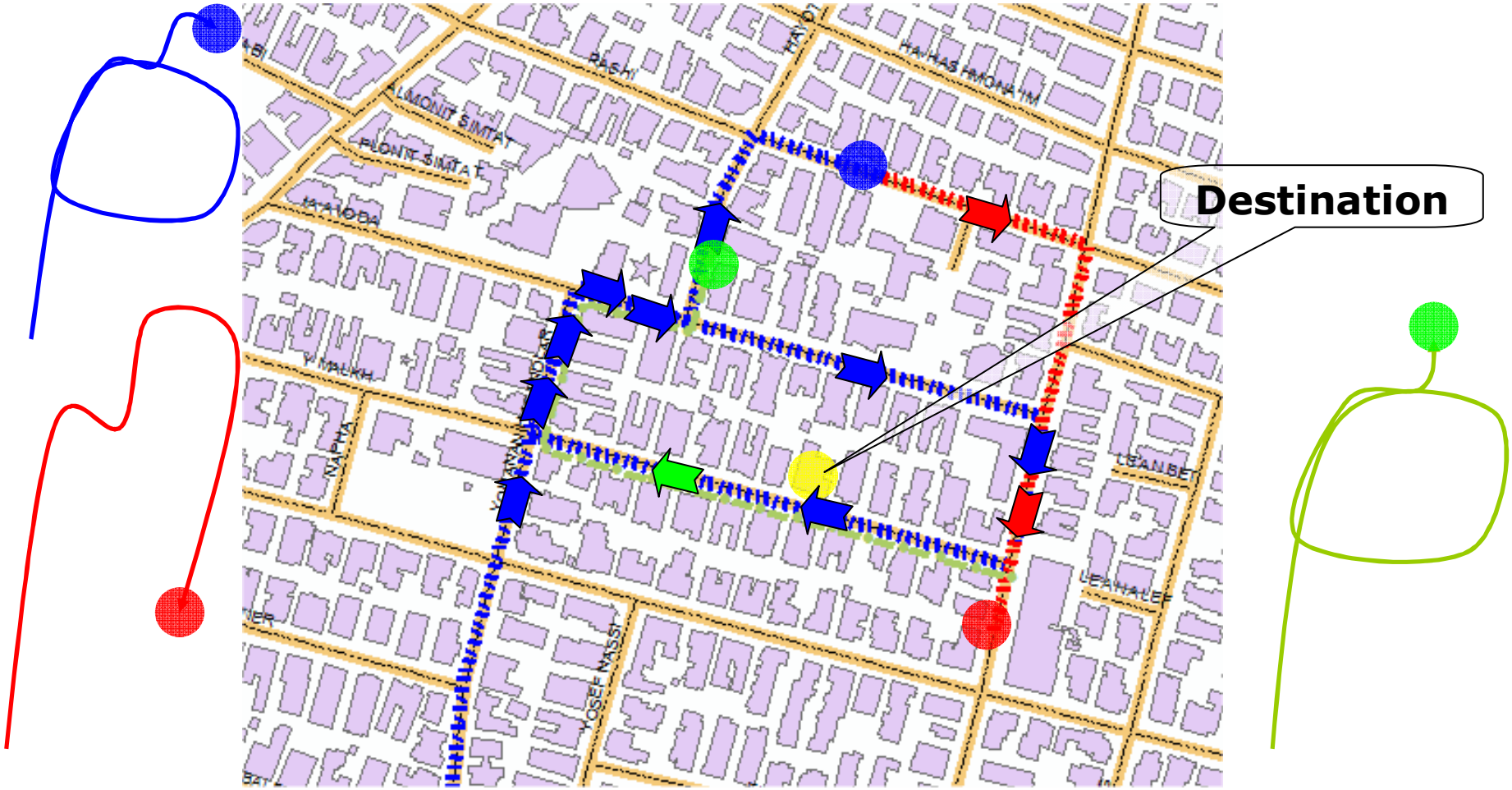
Agents search behavior:

Driving Behavioral Heuristic



Our view of parking behavior:

First try to park close to the destination; if failed try to park at some reasonable distance; if failed park for money

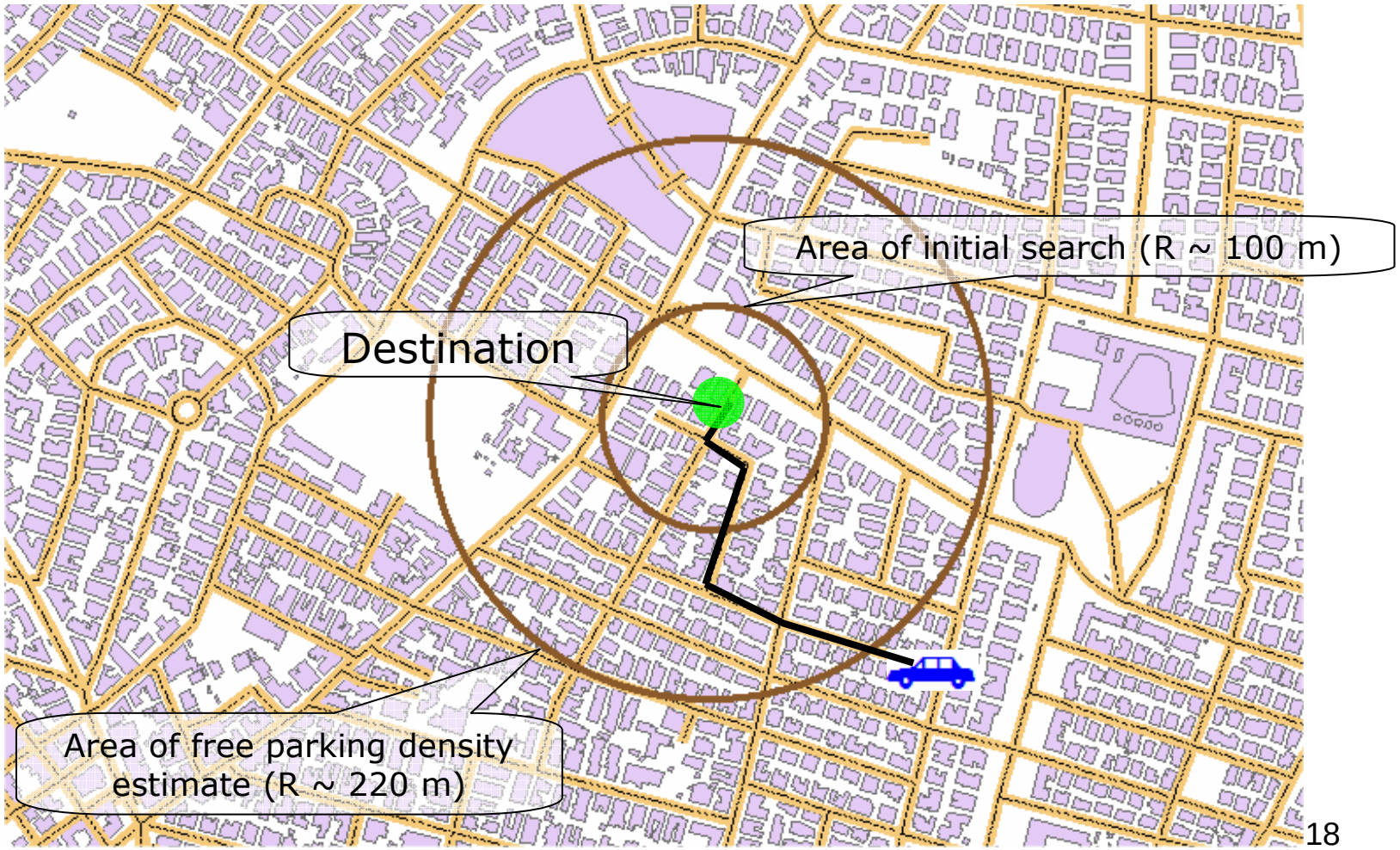


Three records of my parking search when visiting friends at Baaley Malacha str

Geosimulation of parking in the city –

Parking Behavior before Reaching Destination:

- The car "enters" the system at a distance of 250-240 m from its destination
- Stage 1: Estimate fraction of free parks (between 220 m and 100 m)
- Stage 2: Initial parking search (between 100 m and destination)



Geosimulation of parking in the city –

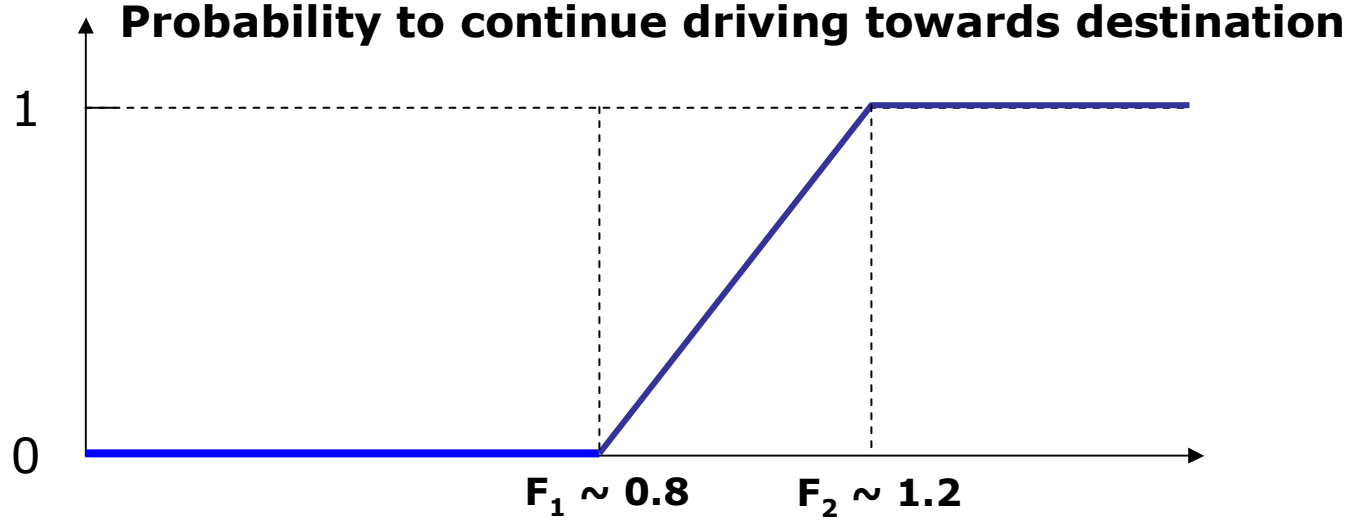
Parking Behavior before Reaching Destination:

- Stage 1: Let expected fraction of free parking places as

$$p_{free} = N_{free}/(N_{free} + N_{occ})$$

- Stage 2: Let the fly distance from the current position of the car to destination is **D**. Calculate expected number of free parking places till destination as

$$F_{exp} = p_{free*}D/4$$

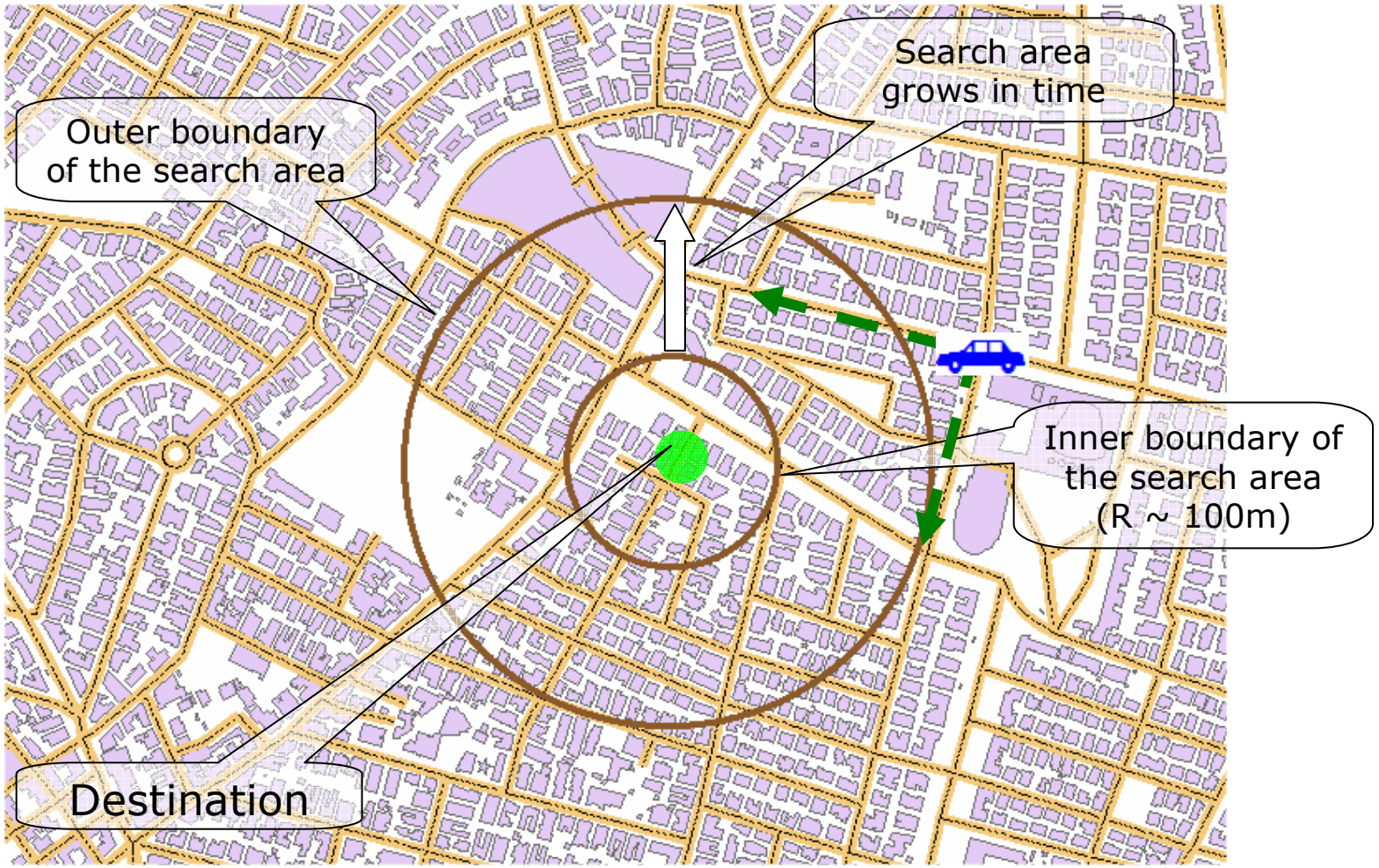


Geosimulation of parking in the city –

Parking Behavior after Missing Destination:

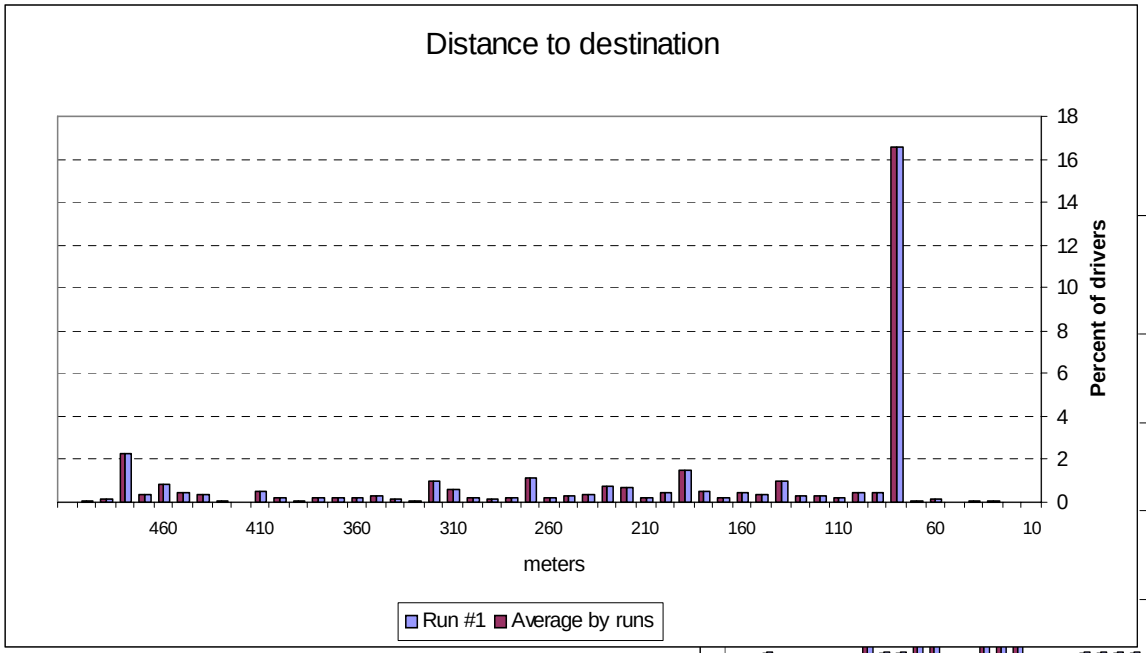
• Stage 3: Search for free parking within some distance from the destination, acceptable distance slowly grows. Take arbitrarily direction within search area, if getting too far away – choose the direction that takes you back to the search area

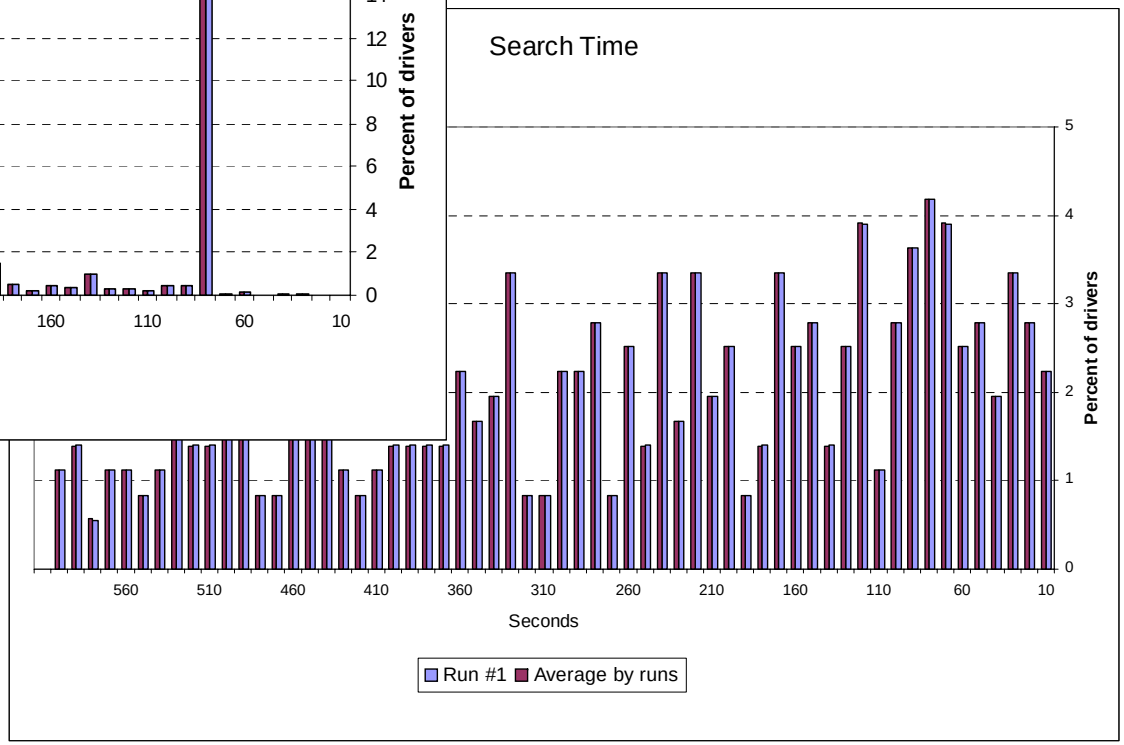
• Stage 4: Cancel search for free parking, park for money



Geosimulation of parking in the city – *Outputs*

Driver's view of the parking situation





Over the given *Area*, during given *Time Interval*

Geosimulation of parking in the city – *Outputs*

Municipality's view of the parking situation

Illegal parking

Type of illegal parking	**Number of cars**	**Overall places of a given type**	**Fraction occupied illegally**
Red-White	232	240	0.967
Blue-White, no region label	120	1400	0.086
Other illegal	25	28	0.893

Revenues from legal parking

Type of parking	**Revenue/hour**
On-street	1154
Parking Lot N 1353	2027
Parking Lot N 1401	632
Parking Lot N 1481	3014

Over a given *Area*, during a given *Time Interval*

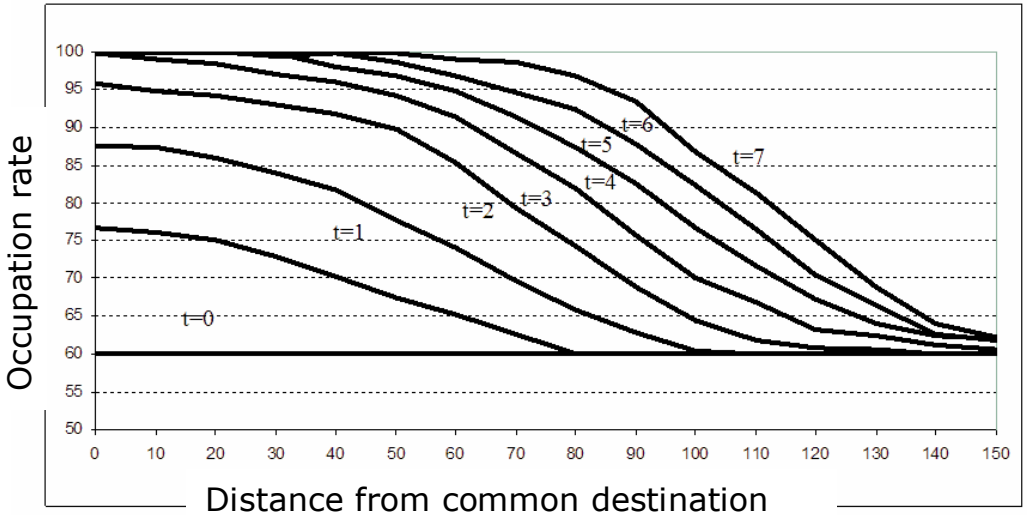
Some results

Few model screen shots

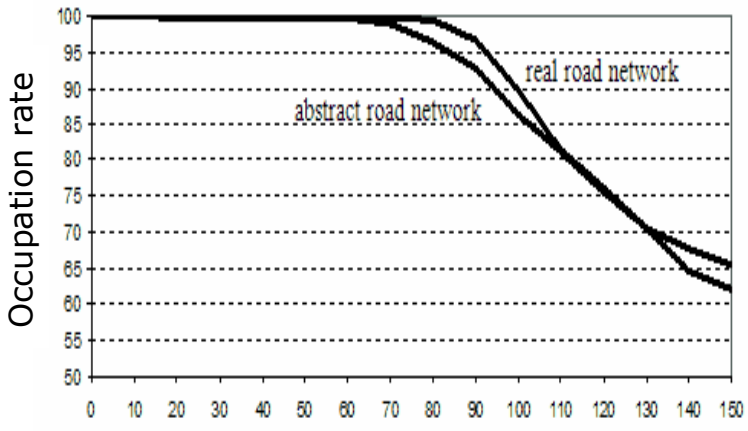
Testing the model – minimal cases

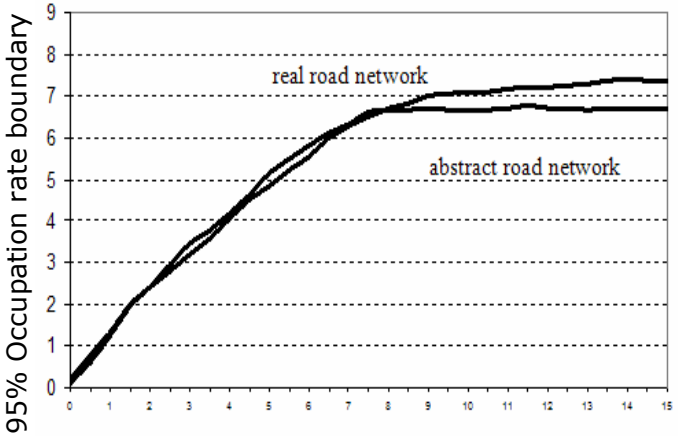
Cinema scenario – first arrival

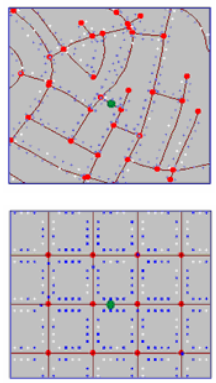
The model dynamics correspond to our expectations - properly simulate theoretical situations, and the outcomes of the abstract and real cases do not differ significantly



Abstract versus real-world road network – similar results

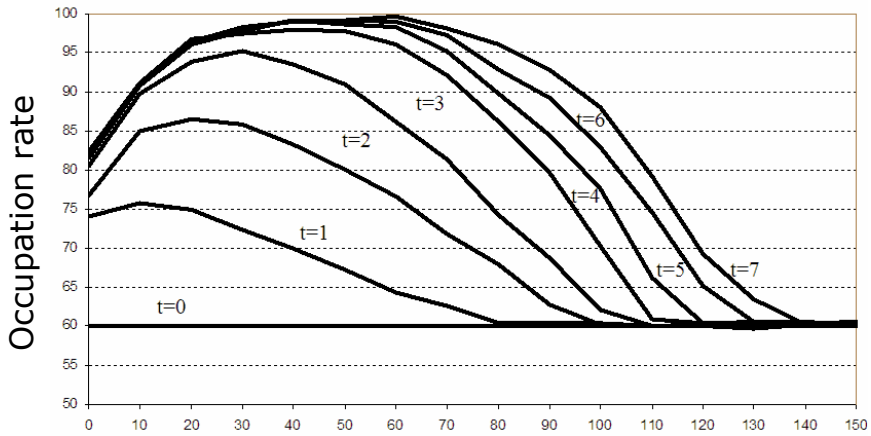






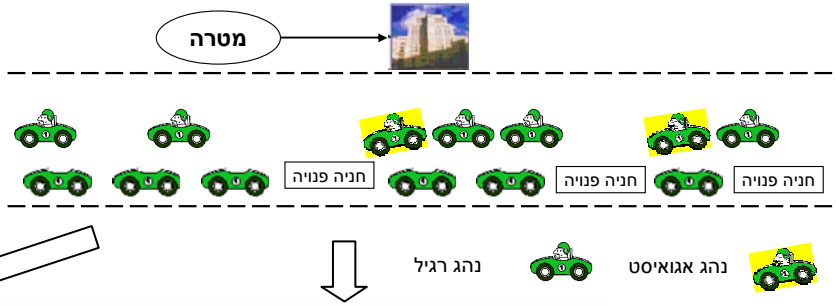
Testing the model – advanced cases

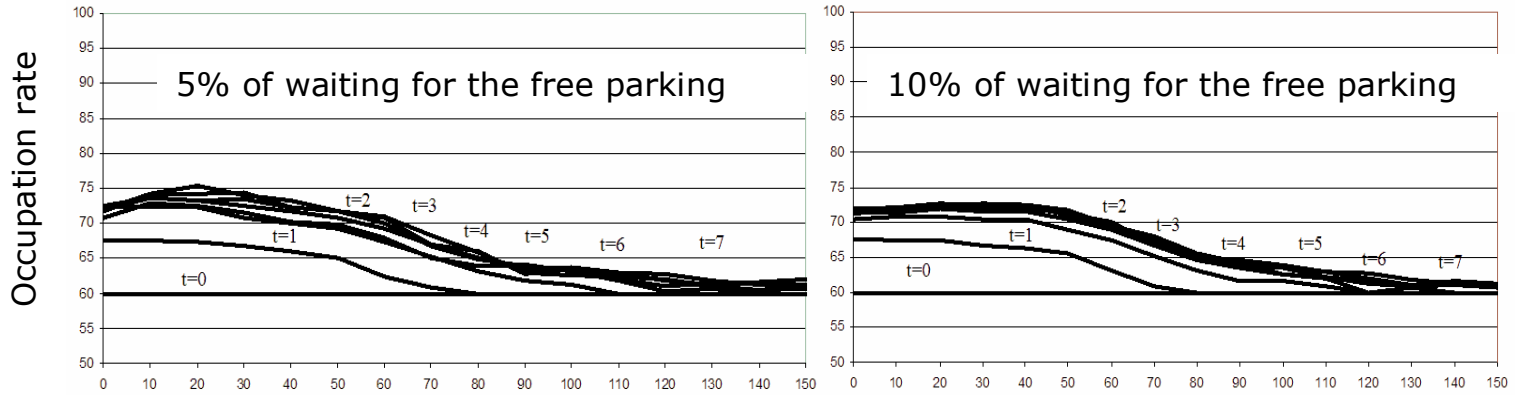
Cinema scenario – second arrival



Distance from common destination

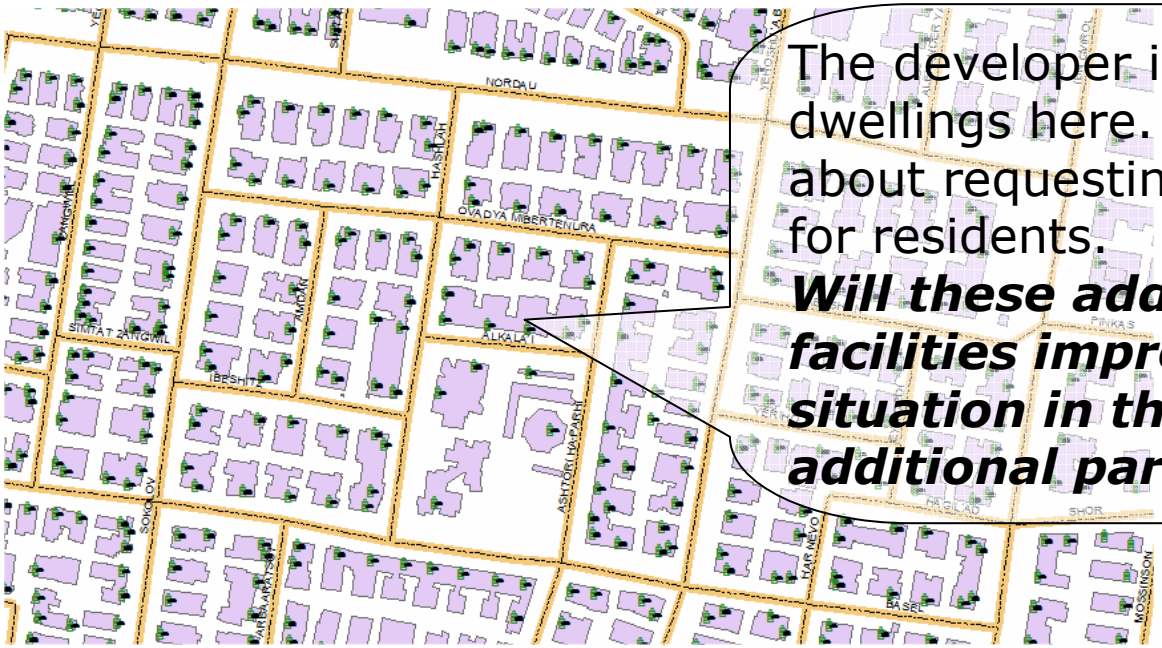
Some drivers wait for the parking place that will become free “in a moment”





Distance from destination, which is uniformly distributed along the street

Bazel street parking problem

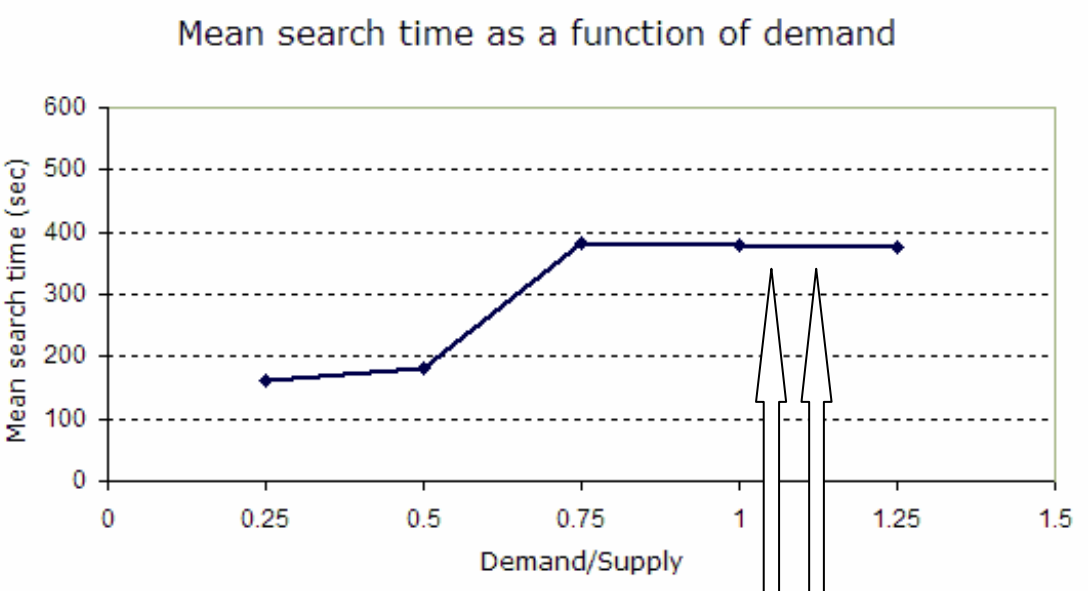


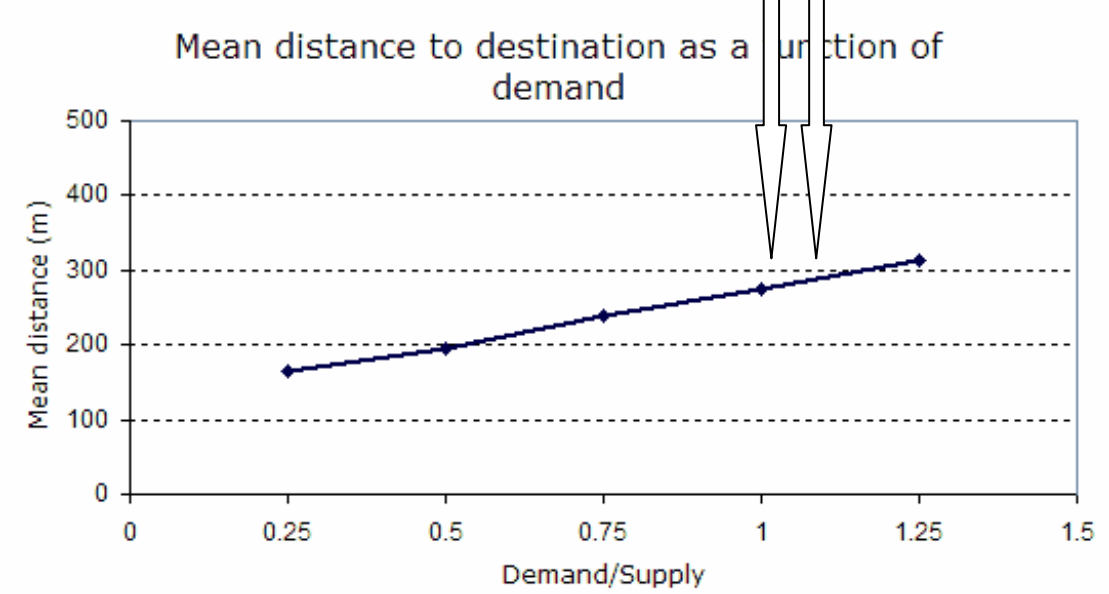
The developer is building a building for dwellings here. The municipality thinks about requesting 2-3 floors of parking for residents.

Will these additional parking facilities improving parking situation in the area? How many additional parking places will help?

Field survey:

- Average number of apartments in a building – 16
- Average **minimal** number of cars in a building (by zone labels) - 10
- Average number of parking places dedicated to householders per building – 2
- Average fraction of local citizens' cars parking in the area during daytime – 50%
- Average number of free parking places along the street per building – 10
- The distance between visitors' parking place and destination - < 200m
- Paid parking facilities in the neighborhood - unlimited
- Fraction of visitors/local citizens who skip the search for the free parking and park for money – 30%





Bazel street parking problem

During the time interval 17:00 – 19:00, 50% of the cars will continue parking, 50% will leave and their place will be occupied by the new arrivers. Scenarios differ in number of cars seeking for parking, from 500 (very low number, just for testing the model) to 2500, close to reality.

General conclusion: In the areas where all parks are occupied in the daytime, we need supply ~ 30% above the demand to feel real improvement

Thank you!