Designing a MATSim environment for a one-way car sharing system as a transport mode

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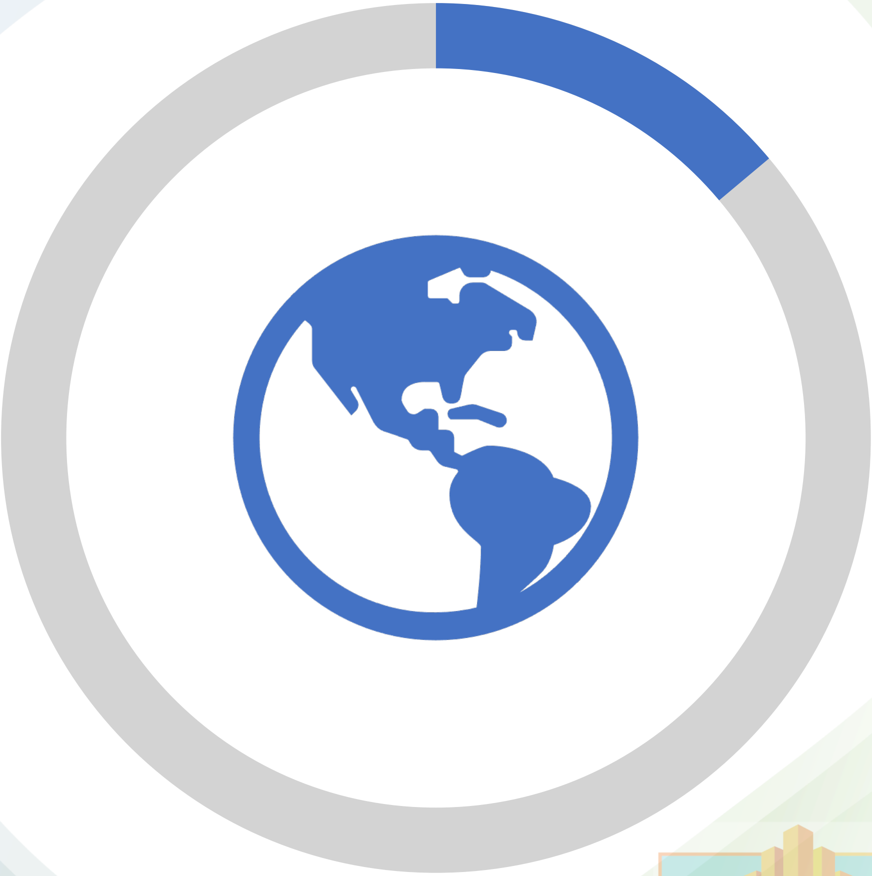
Outline

- Introduction
- Literature review
- Methodology
- Computational experiments
- Conclusion and future work

Introduction

- 14% of the global greenhouse gas emissions is due to transportation (Pachauri et al., 2014)
- More sustainable solutions
  - Carbon neutral fuel and electric cars
  - Ride-sharing and vehicle sharing (car, bike, e-scooter, etc.)
- Car sharing systems (CSSs)
  - Higher vehicle utilization
  - Less parking utilization
  - Examples: Mobility, car2go, DriveNow



Introduction

- Different configurations of CSSs
  - Round-trip or one-way trips
  - Fixed and dynamic pricing
  - Station-based or free-floating
  - Static or dynamic rebalancing
- This study considers
  - A one-way station-based CSS which adopts static rebalancing and fixed pricing

Research question

- It is costly to collect data.
- The data collected is not complete.
  - Ciari et al. (2013)
    - Modeling CSS with the Multi-Agent Transport Simulation (MATSim)
  - Balac et al. (2016)
    - Examining supply and demand relationship by looking at different values of fleet size and trip configuration
    - Parking reservation system
  - Balac et al. (2019)
    - Rebalancing operations for a free-floating CSS
- What is the effect of rebalancing operations in one-way CSSs?
  - Examine the effect of the number of cars, number of parking spaces, and willingness to walk values on the system

Multi-Agent Transport Simulation (MATSim)

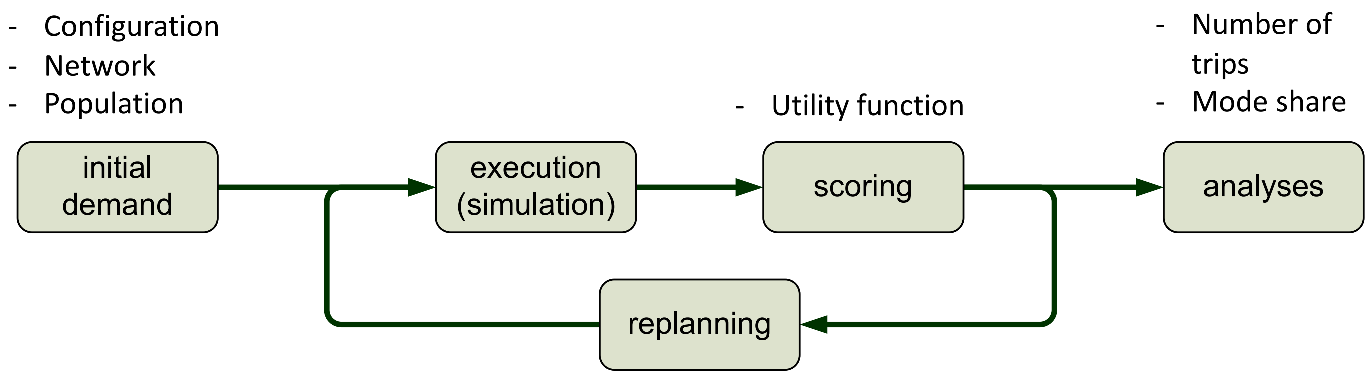


Figure: MATSim loop (Horni, Nagel, and Axhausen, 2016)

- Agent-based simulation
  - Each person corresponds to an agent.
  - Each person has an individual plan for the day.
- Simulates one day, several times
- The utility function defines the scores
- Availability of the car sharing API
  - Additional files: CSS stations and memberships

Assumptions

- Transport modes are walking and CSS.
  - The mode share is not analyzed.
- Only one CSS operator is available.
  - We do not consider competition.
- Every agent has a CSS membership.
- A sample of 10% of the population is considered.
- The parameters are set to default.

Case study / Sioux Falls

- A small network
- 24 CSS stations
- Data processing
  - Visualization with Via
  - Numerical analysis with MATLAB

NC

NFPS **P**

WTW

Case study / Sioux Falls
Experimental design

- Number of cars (NC)
  - 100, 250, 500, 1500
- Number of free parking spots per station (NFPS)
  - 200, 500, 1000, 3000 (1st set of scenarios)
  - 100, 200, 300, 400, 500 (2nd and 3rd set of scenarios)
- Willingness to walk (WTW)
  - 1 km, 1.5 km, 2 kms

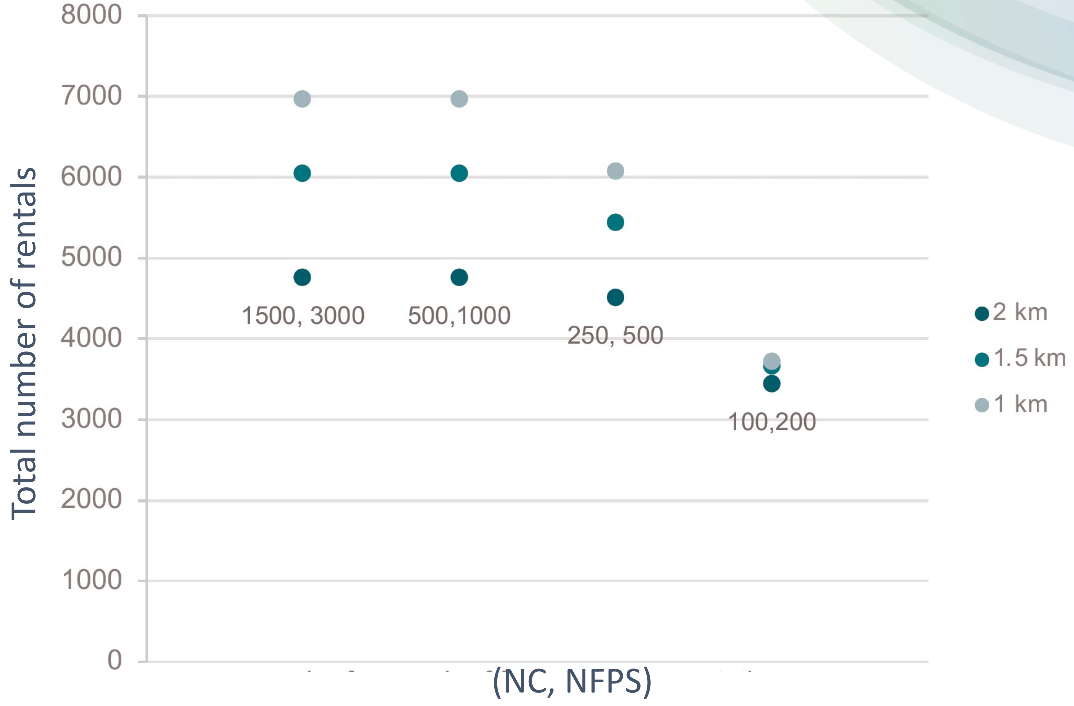
	1st set of scenarios	2nd set of scenarios	3rd set of scenarios
NC	Varied	Fixed	Fixed
NFPS	Varied	Varied	Varied
WTW	Varied	Varied	Fixed

System wide analysis (1st and 2nd set of scenarios)

Hourly/station analysis (3rd set of scenarios)

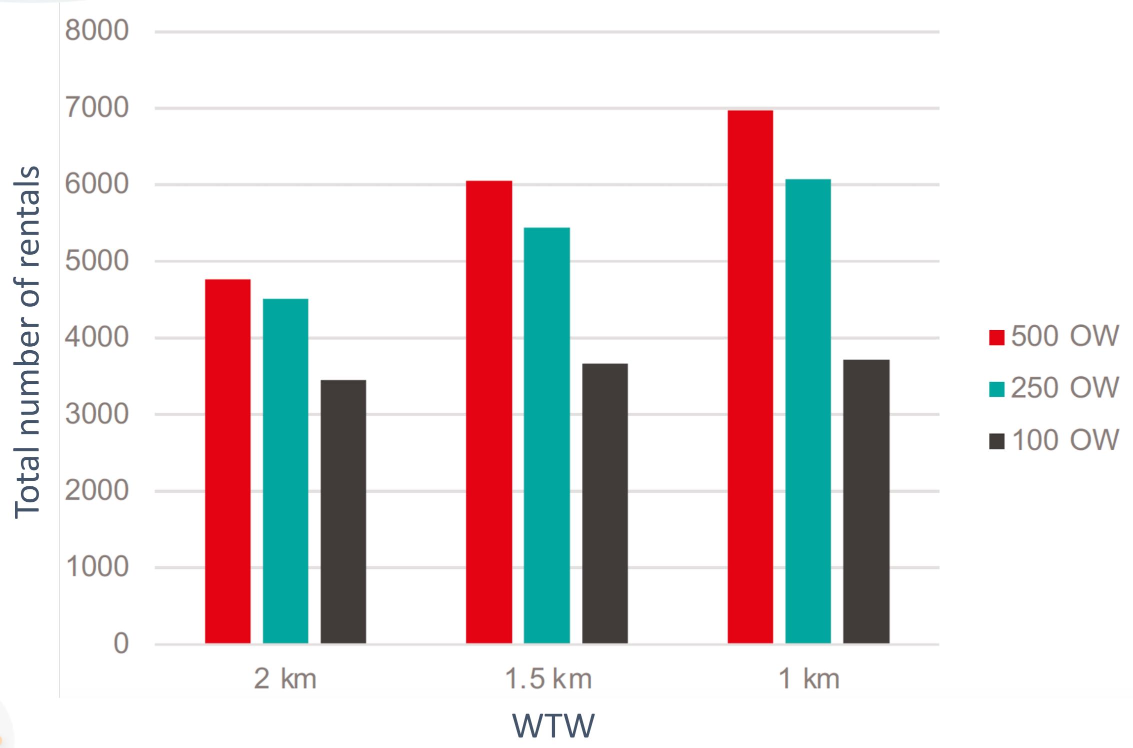
Case study / Sioux Falls
Saturation of number of rentals

- 84’000 agents
  - 10% of the sample: ~8’000 agents
- Activity chains of agents
  - home-work-home --> 2 legs
- Mode shares
  - 75% CSS and 25% walking
- There should be 12’000 trips $(0.75 \cdot 8000 \cdot 2)$
  - However, we observe 6’000 trips.
  - Why?



Varied
Twice P
Varied

Case study / Sioux Falls
Effect of limiting available cars per station



- Higher NC increases number of rentals
- Consistent for all WTW values
- With 250 cars we already achieve 90% of maximum number of rentals
    - Therefore, we continue with this value in the following scenarios.

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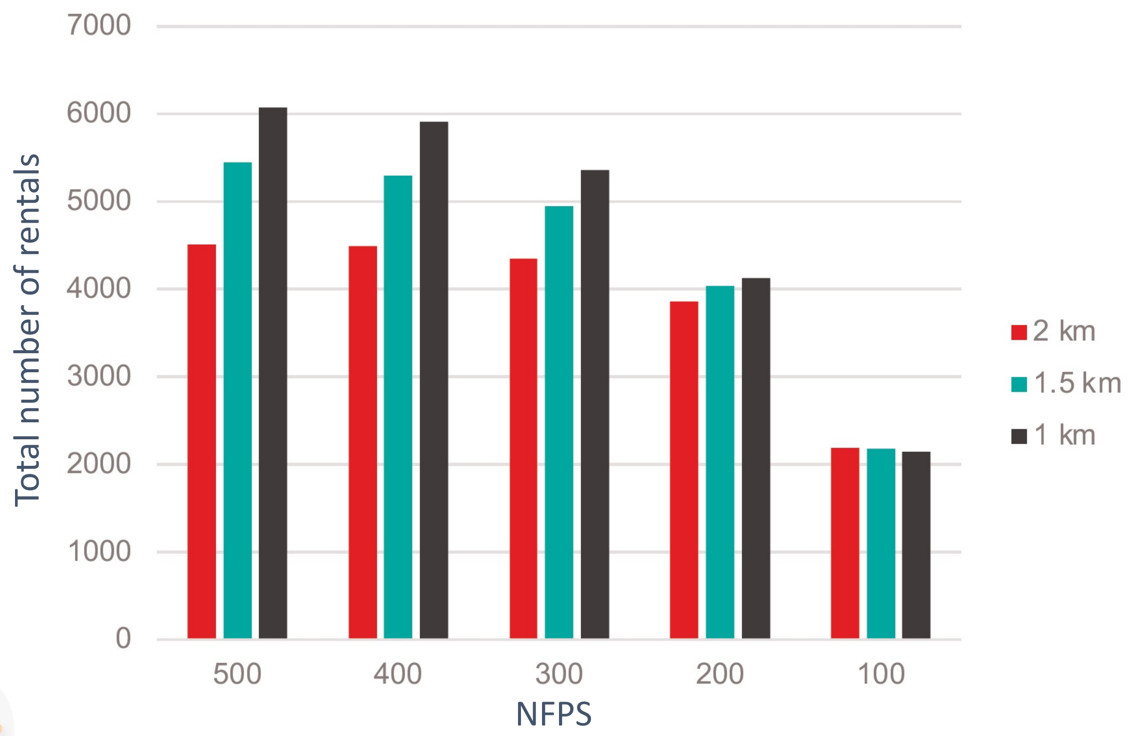
Effect of limiting available parking spaces

250

Varied

Varied



- Higher NFPS increases number of rentals
- Consistent for all WTW values
- Expected performance
  - We set the WTW to 1.5 km in the following scenarios.

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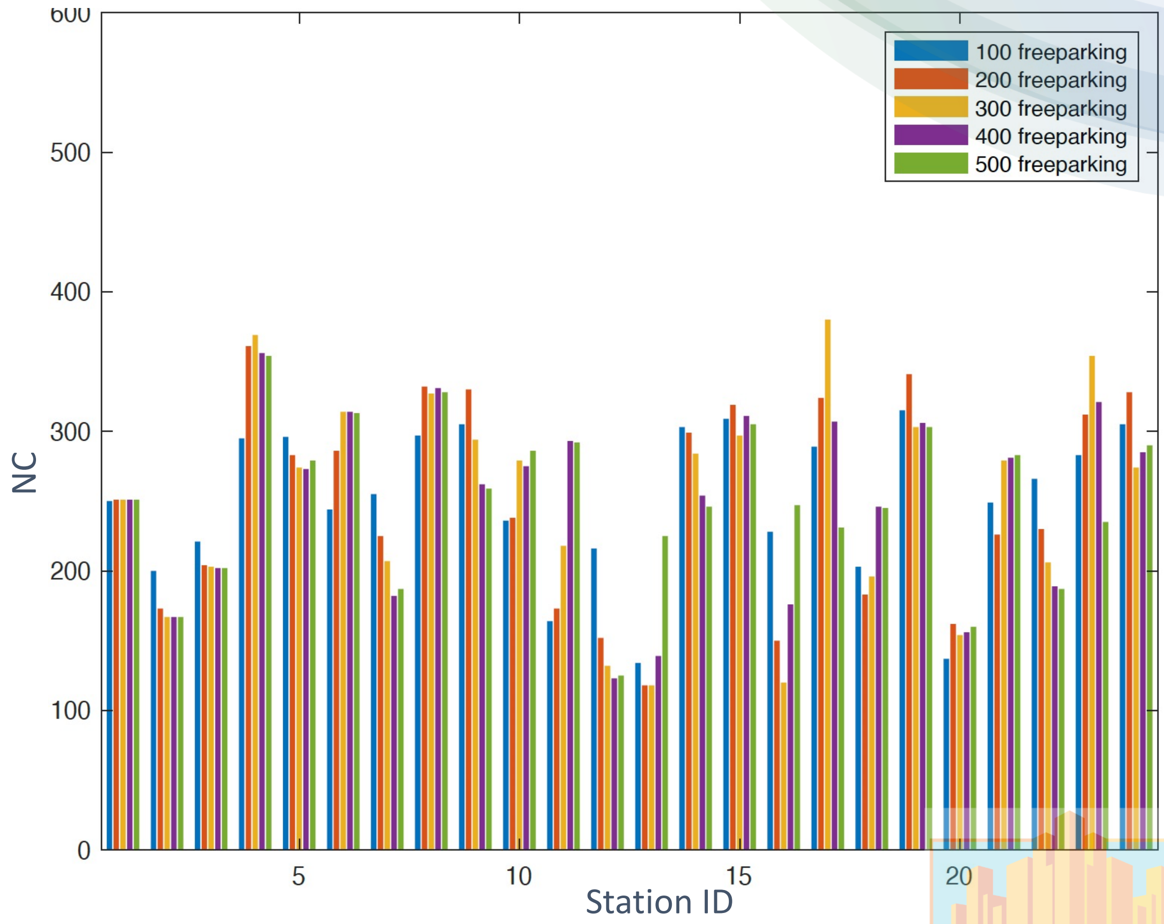
Final configuration

250

Varied P

1.5 km

- More than 100 cars at all station at the end of the day
- Rebalancing
  - What happens during the day?



Case study / Sioux Falls

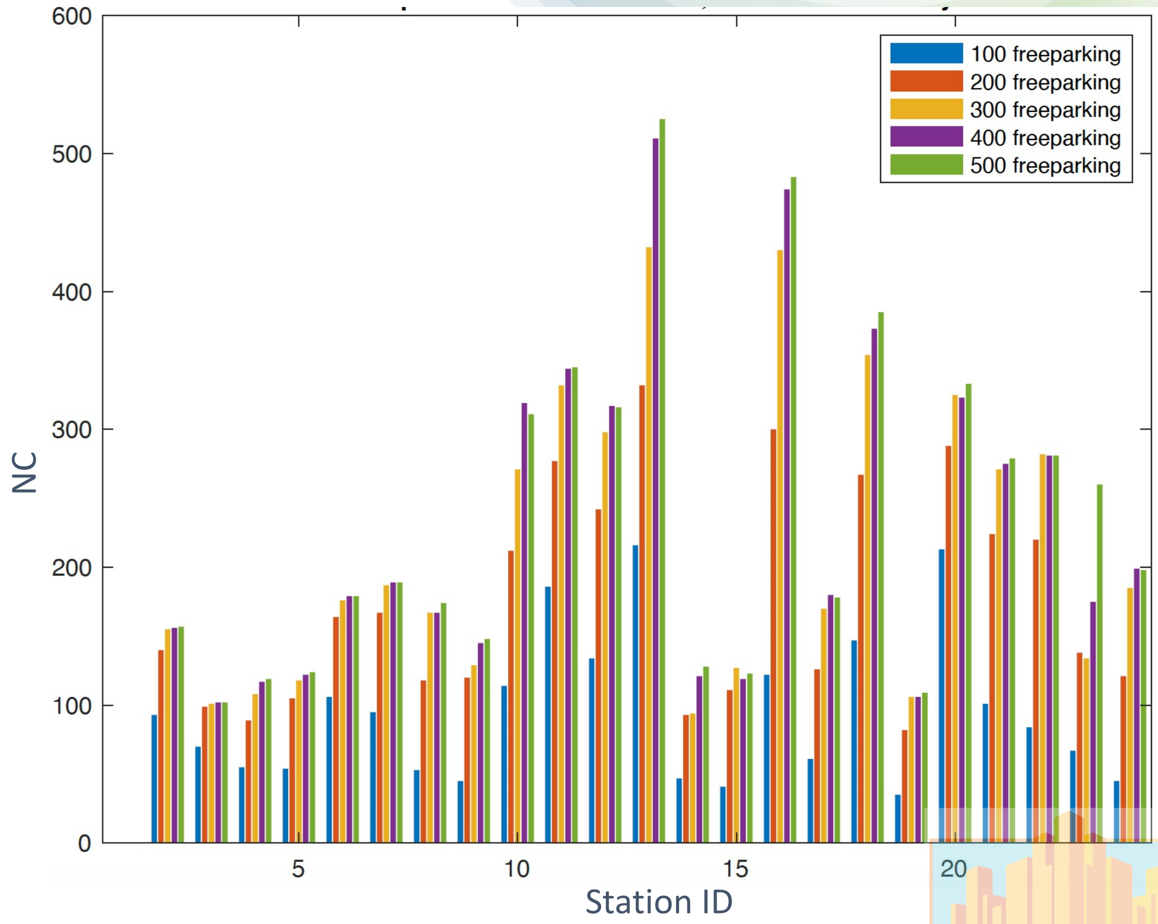
Departures

250

Varied P

1.5 km

- Number of departures increase with higher NFPS
- Significant change for stations 13 and 16
  - Station 13: 250 cars at the beginning of the day, yet around 500 departures



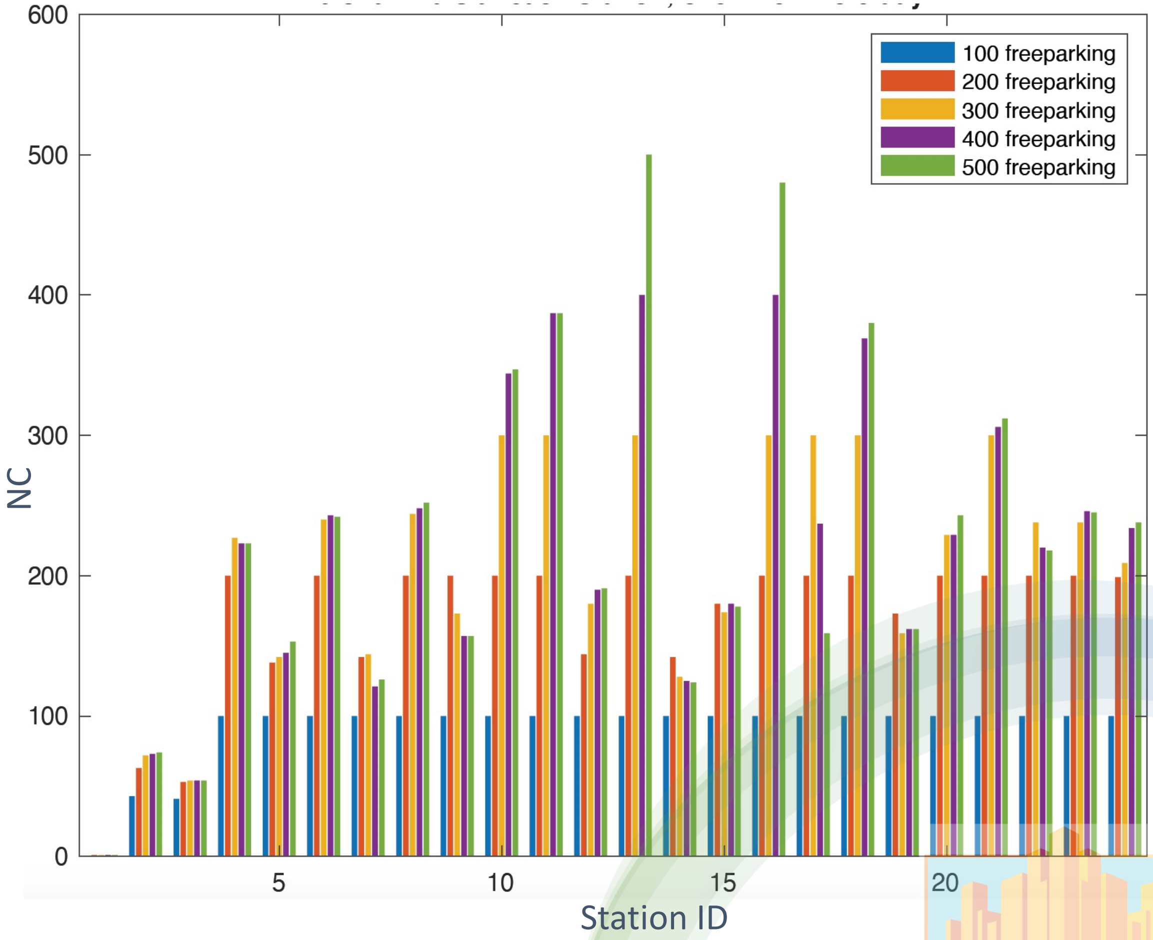
Case study / Sioux Falls
Arrivals

250

Varied **P**

1.5 km

- Number of arrivals is significantly less than number of initially free parking spots
- A bug in MATSim source code
  - The parking spot is not declared "free" when a car leaves a station



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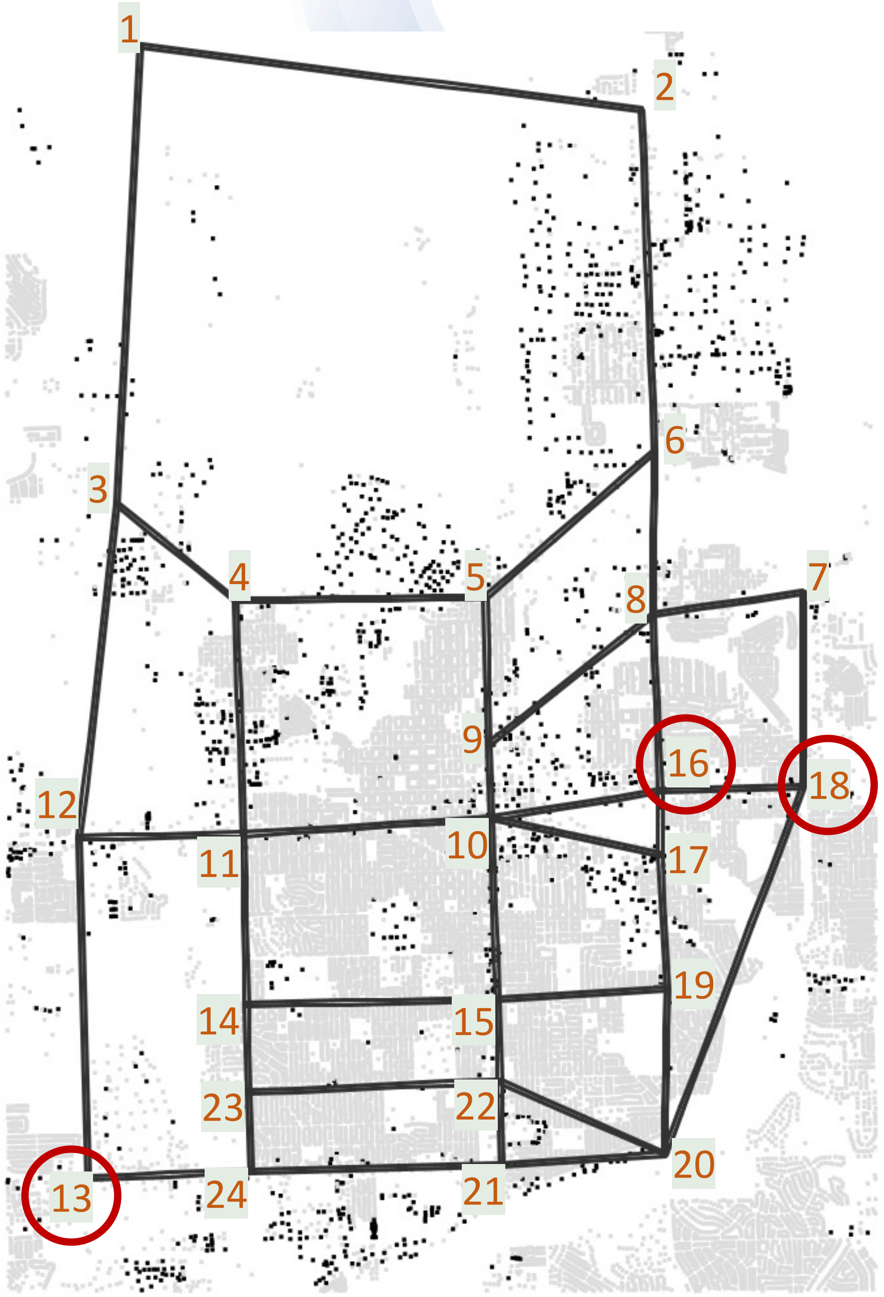
Hourly analysis

- Three stations that have the highest number of departure are chosen.



250

100, 500 P

1.5 km

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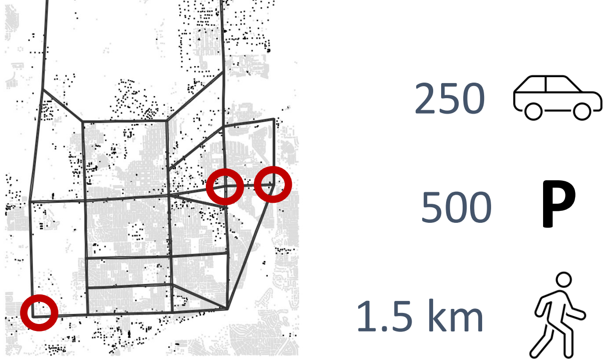
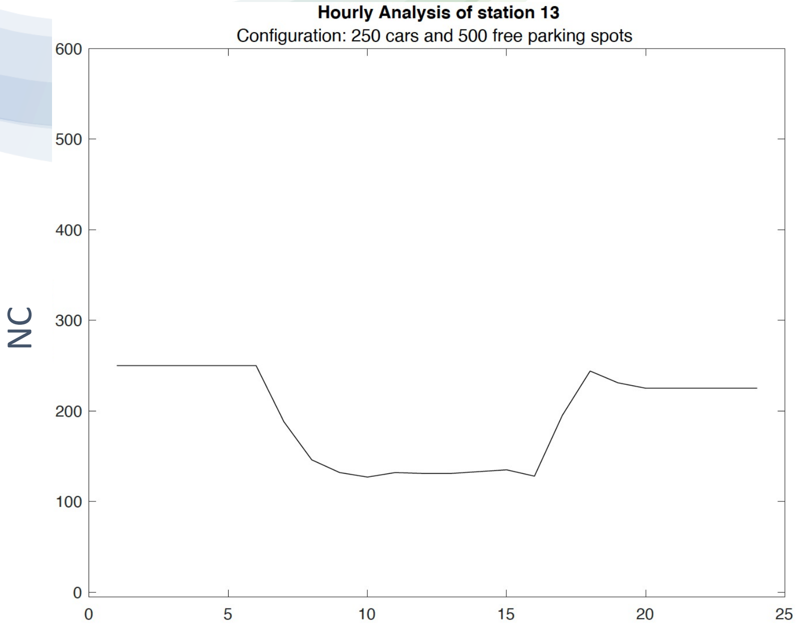
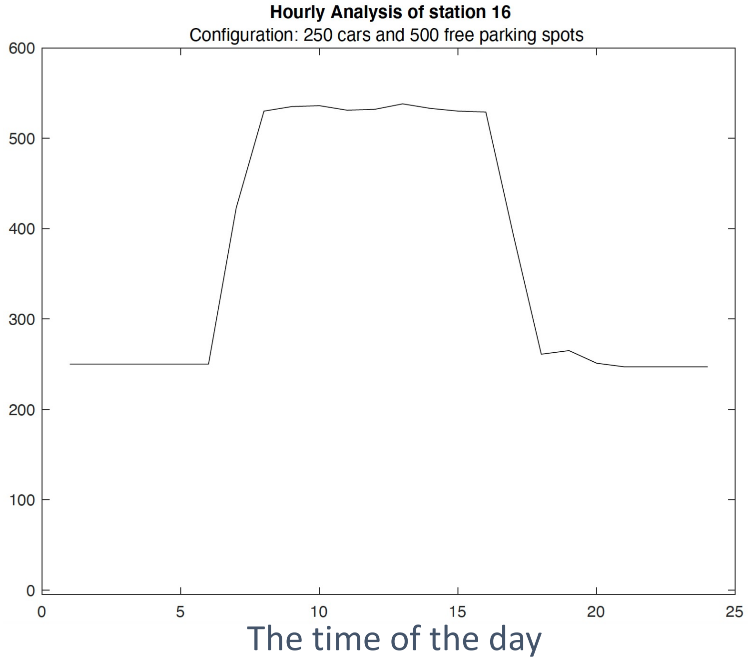
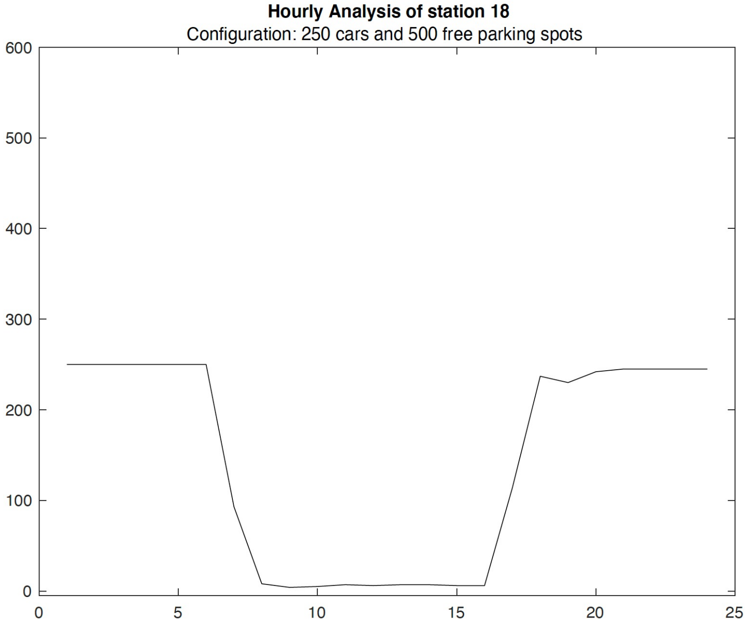
Hourly analysis / Station 13









- People leave between 7 AM and 8 AM
- People arrive between 5 PM and 6 PM

- People arrive between 7 AM and 8 AM
- People leave between 5 PM and 6 PM

- People leave between 7 AM and 8 AM
- People arrive between 5 PM and 6 PM
- NC is close to zero during the day

Case study / Sioux Falls

Heterogeneous configuration

0-300 (cars)
0-500 P
1.5 km (walking)

Station ID	NC	NFPS
…	…	…
13	150	500
14	150	150
15	150	200
16	250	200
17	150	300
18	300	400
…	…	…
Total	4050	5900

- Formation of an initial station configuration, where the number of cars and free parking spots are not the same at every station
  - Choice in function of the number of departures and arrivals

Configuration NC/NFPS	Heterogeneous	250/100	250/500
Total number of rentals	4944	2184	5446
% of maximum number of rentals	82%	36%	90%
Fleet size (total number of cars)	4050	6000	6000
Total number NFPS	5900	2400	12000

- Evaluation
  - Performance: 82% of maximum number of rentals
  - Lower fleet size
  - Lower investment costs

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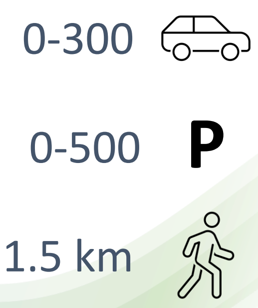
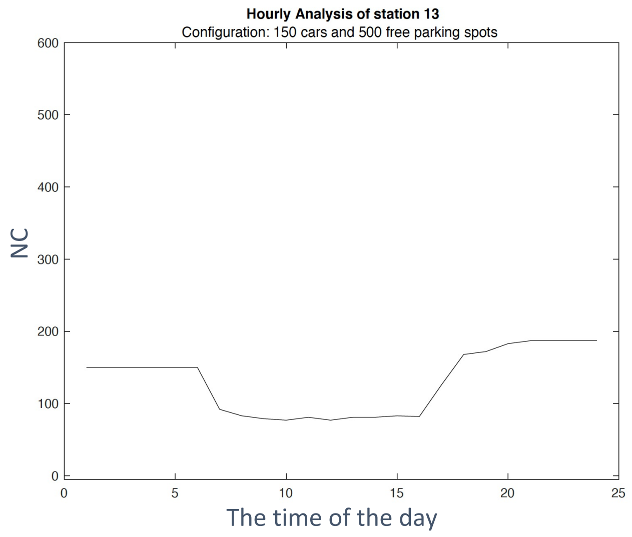
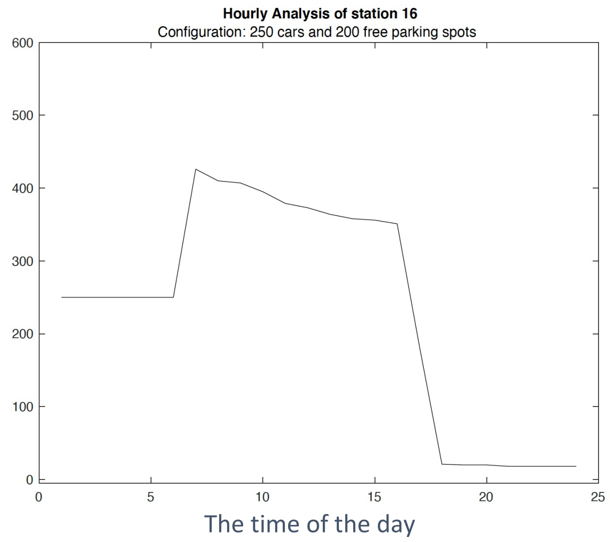
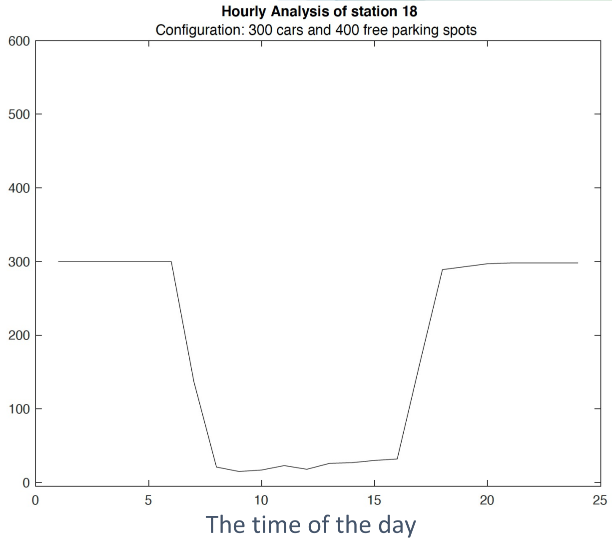
Heterogeneous configuration / Stations 13, 16, and 18









- More cars at the end of the day
- Station 13 shows high number of departures and arrivals throughout the day

- High difference between the morning time and the evening time
  - It might be due to limited arrivals
  - Rebalancing necessary

- Same number of cars in the morning and in the evening
- Almost zero cars available during the day
- Ideal performance
  - No need for rebalancing

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Summary of the results

- Some bugs in the implementation are found and reported.
- The number of arrivals at stations is strictly limited to the initial NFPS.
- Configuration at the end of the day is an indicator for rebalancing.
- Different scenarios allow us to determine a well-performing station configuration.
- Ideal performance is that the stations perform at capacity (cars and parking)
  - Not realistic since the people change schedules from one day to the other
  - Yet, MATSim helps us to get an idea about the general dynamics of the system and plan rebalancing operations accordingly.

Conclusion and future work

- MATSim
  - Shows realistic behavior of agents
  - Gives an idea on system performance
  - Simulates one day only
- Future work includes
  - Developing rebalancing operations module for a one-way station-based CSS
  - Examining the effect of static rebalancing

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