Evaluating different strategies to solve rebalancing operations in car sharing systems: A generic optimization framework

Selin Ataç
Nikola Obrenović, Michel Bierlaire

Transport and Mobility Laboratory
School of Architecture, Civil and Environmental Engineering
École Polytechnique Fédérale de Lausanne

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Outline

1. Introduction

2. Evaluating different rebalancing operation strategies
   - Motivation
   - Literature

3. Methodology
   - Considered system and the framework
   - Preliminary experiments

4. Conclusion

Introduction

- 37.5% of the U.S. greenhouse gas emissions is due to transportation (EPA, 2021[1]).
  - Passenger cars contribute the most with 40.5%.

[1] EPA (2021) Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2019..

[2] Amatuni, L., Ottelin J., Steubing B. and Mogollón J. M. (2020) Does car sharing reduce greenhouse gas emissions? Assessing the modal shift and lifetime shift rebound effects from a life cycle perspective, Journal of Cleaner Production.

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  - Short rentals
  - Higher car and less parking utilization
  - Examples: Mobility, car2go, SHARENOW

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- Car sharing systems
  - Short rentals
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  - Examples: Mobility, car2go, SHARENOW
- Introducing a car sharing system results in between 3% and 18% reduction in CO2 emissions (Amatuni et al., 2020[2]).

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Motivation

- Is shared mobility as sustainable as we think?
  - Reck et al. (2022)[3] claim that personalized micro-mobility is more sustainable than the shared one.
  - One reason is costly rebalancing operations.

[3] Daniel J. Reck, Henry Martin, and Kay W. Axhausen. Mode choice, substitution patterns and environmental impacts of shared and personal micro-mobility. Transportation Research Part D: Transport and Environment, 102:103134, 2022.

[4] Jia Shu, Mabel Chou, Qizhang Liu, Chung Teo, and I-Lin Wang. Models for effective deployment and redistribution of bicycles within public bicycle-sharing systems. Operations Research, 61:1346–1359, 11 2013.

Motivation

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  - Reck et al. (2022)[3] claim that personalized micro-mobility is more sustainable than the shared one.
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- The added-value of bike rebalancing in bike sharing systems?
  - Shu et al. (2013)[4] find that the number of substituted trips change as a function of number of bicycles and number of redistributions per day.
  - Periodic and frequent rebalancing operations are not necessary for some configurations of the system.

[3] Daniel J. Reck, Henry Martin, and Kay W. Axhausen. Mode choice, substitution patterns and environmental impacts of shared and personal micro-mobility. Transportation Research Part D: Transport and Environment, 102:103134, 2022.

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- The added-value of rebalancing operations in car sharing systems
  - The effect of city characteristics
  - The effect of trip demand behavior
  - The effect of different rebalancing operations strategies
  - ...

Previously in the literature..

- Martinez et al. (2017)[5]
  - Agent-based model and supply side, i.e., operations by the staff such as maintenance, rebalancing, and refueling

[5] Martínez, L. M., G. H. de Almeida Correia, F. Moura and M. M. Lopes (2017) Insights into carsharing demand dynamics: Outputs of an agent-based model application to Lisbon, Portugal, International Journal of Sustainable Transportation, 11 (2) 148-159.

[6] Vasconcelos, A. S., L. M. Martinez, G. H. Correia, D. C. Guimarães and T. L. Farias (2017) Environmental and financial impacts of adopting alternative vehicle technologies and relocation strategies in station-based one-way carsharing: An application in the city of Lisbon, Portugal, Transportation Research Part D: Transport and Environment, 57, 350-362.

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- Vasconcelos et al. (2017)[6]
  - The same agent-based model as in Martinez et al. (2017)
  - Comparison between with and without rebalancing
  - Evaluating three different policies that investigates the effect of electric vehicle adoption

[5] Martínez, L. M., G. H. de Almeida Correia, F. Moura and M. M. Lopes (2017) Insights into carsharing demand dynamics: Outputs of an agent-based model application to Lisbon, Portugal, International Journal of Sustainable Transportation, 11 (2) 148-159.

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- Considers both supply and demand side of car sharing.
- Uses a transport simulation toolkit, i.e., MATSim, and its car sharing API.
- Incorporates rebalancing operations optimization.

The framework

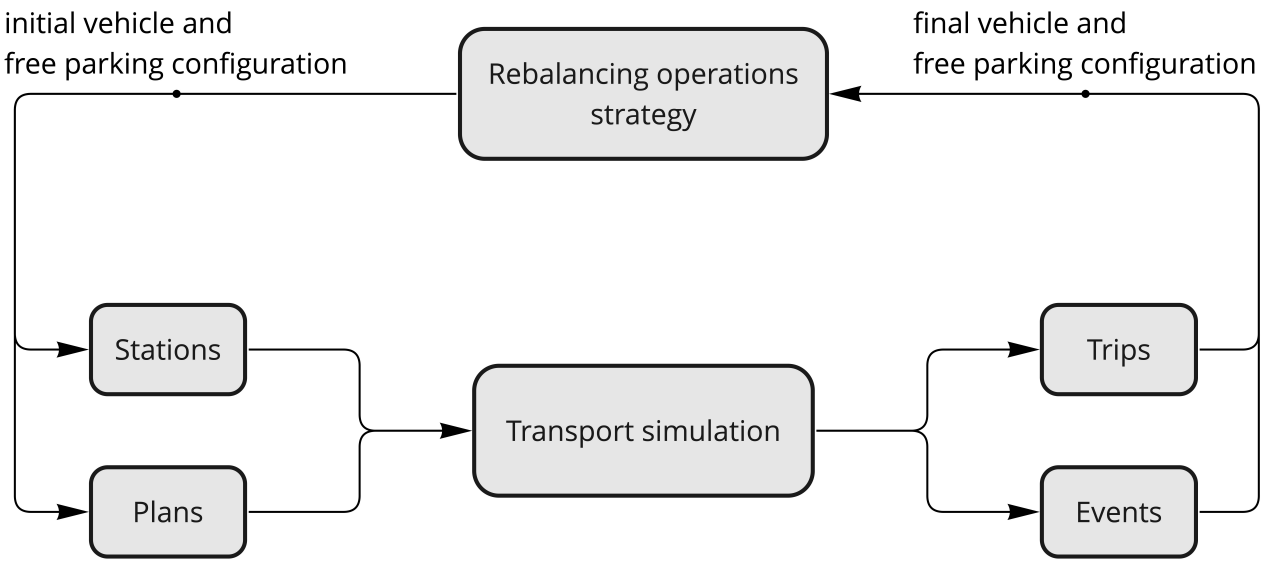

Figure: The framework

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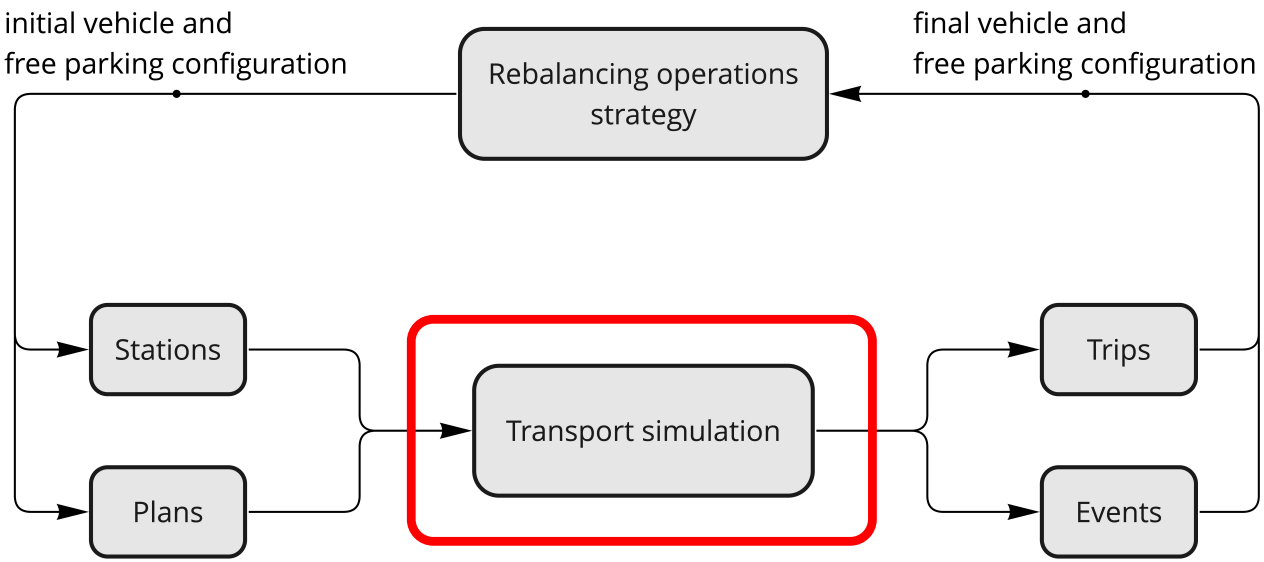

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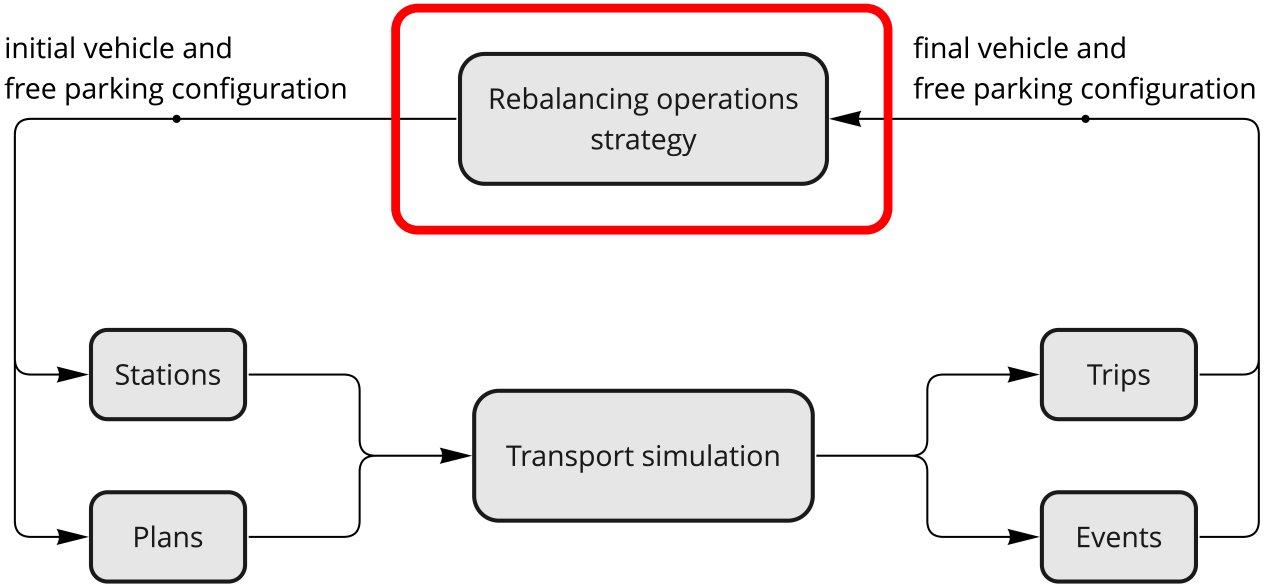

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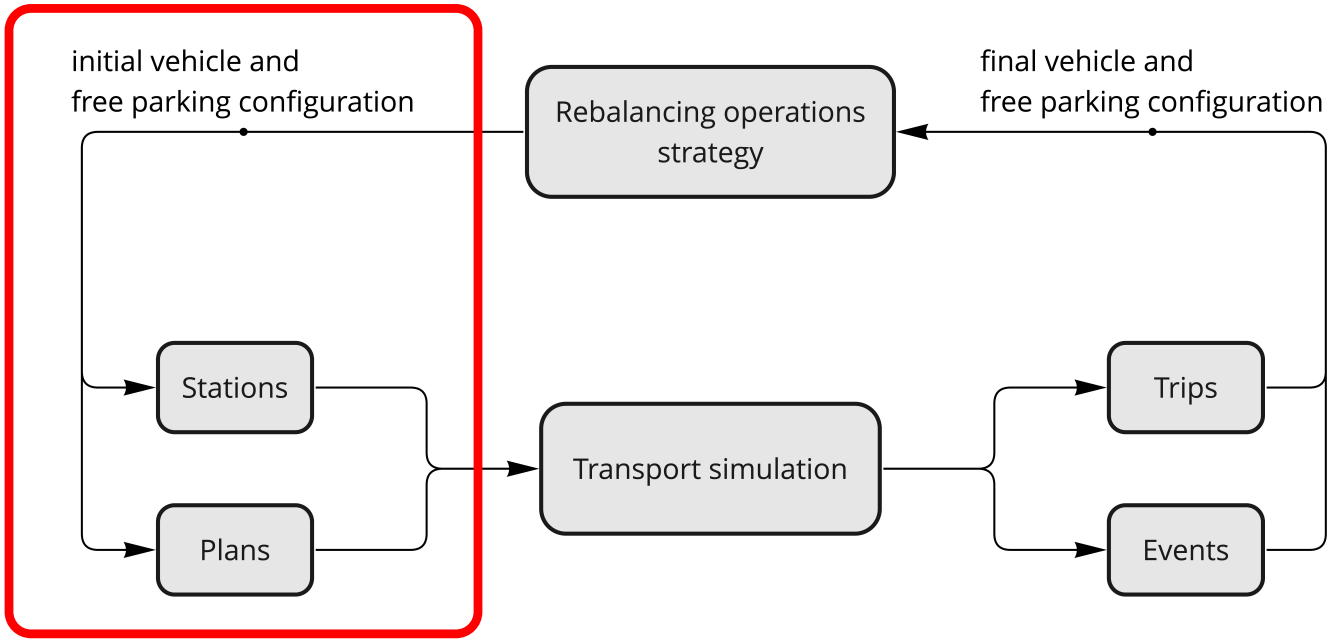

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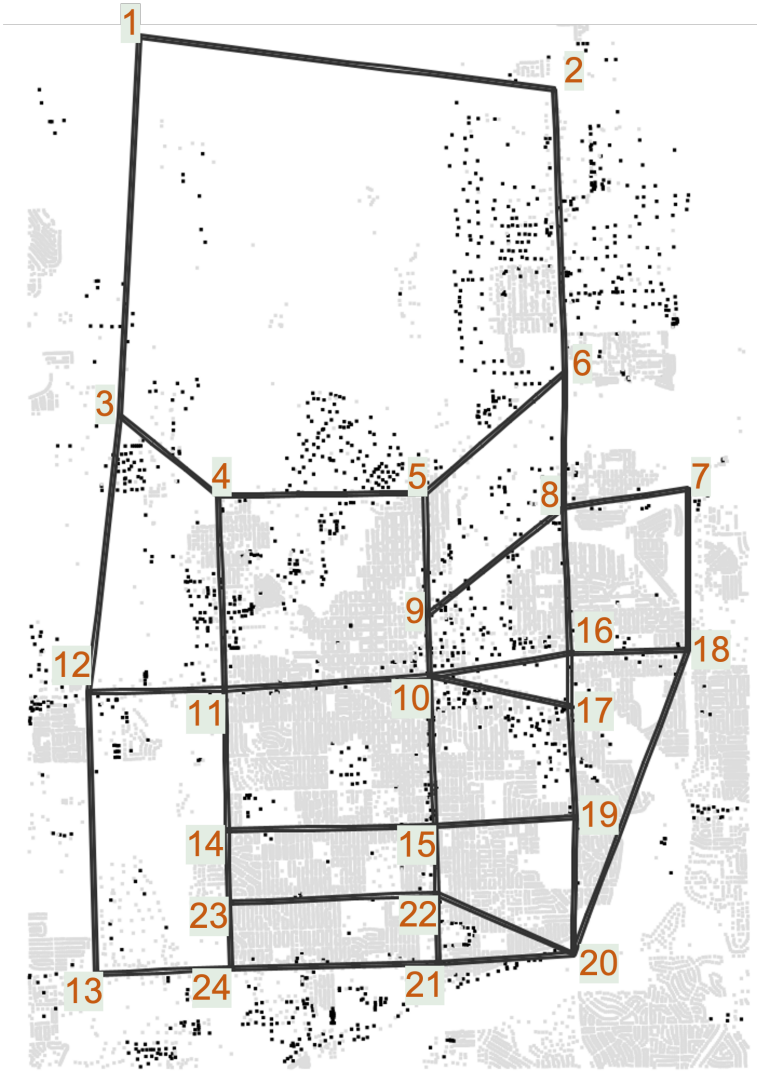
Illustrative case study

- Sioux Falls, US scenario
  - 84110 agents
  - 24 stations (5 vehicles and 5 free parking spots per station)



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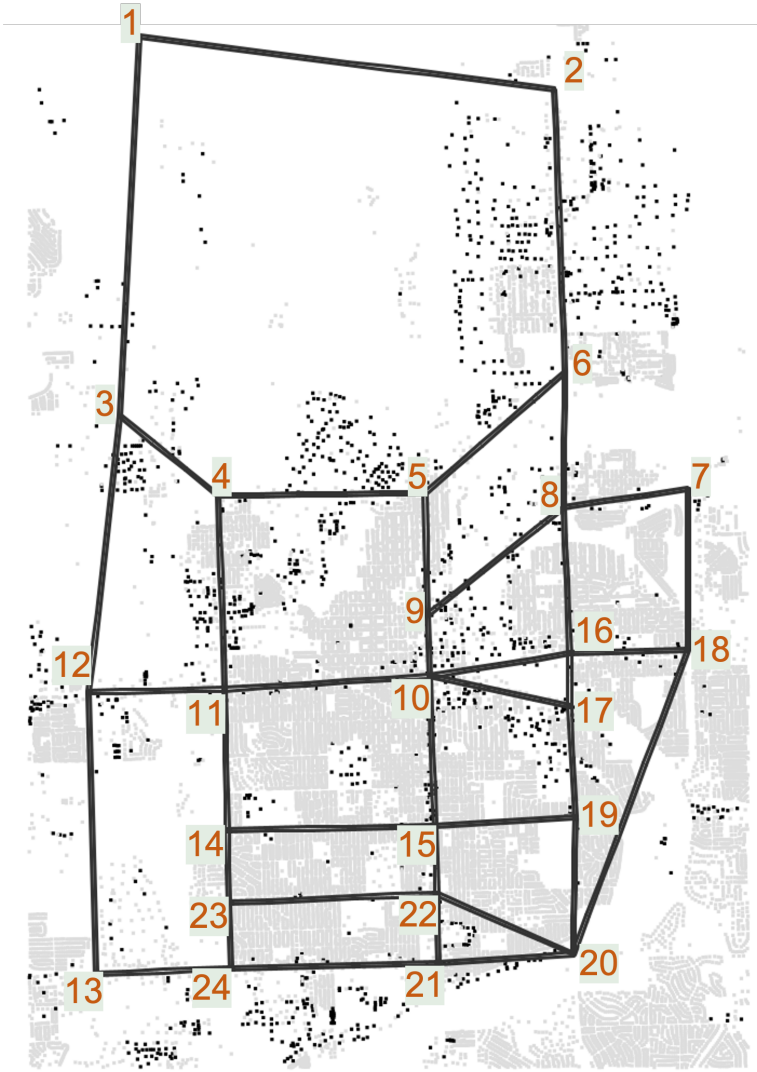

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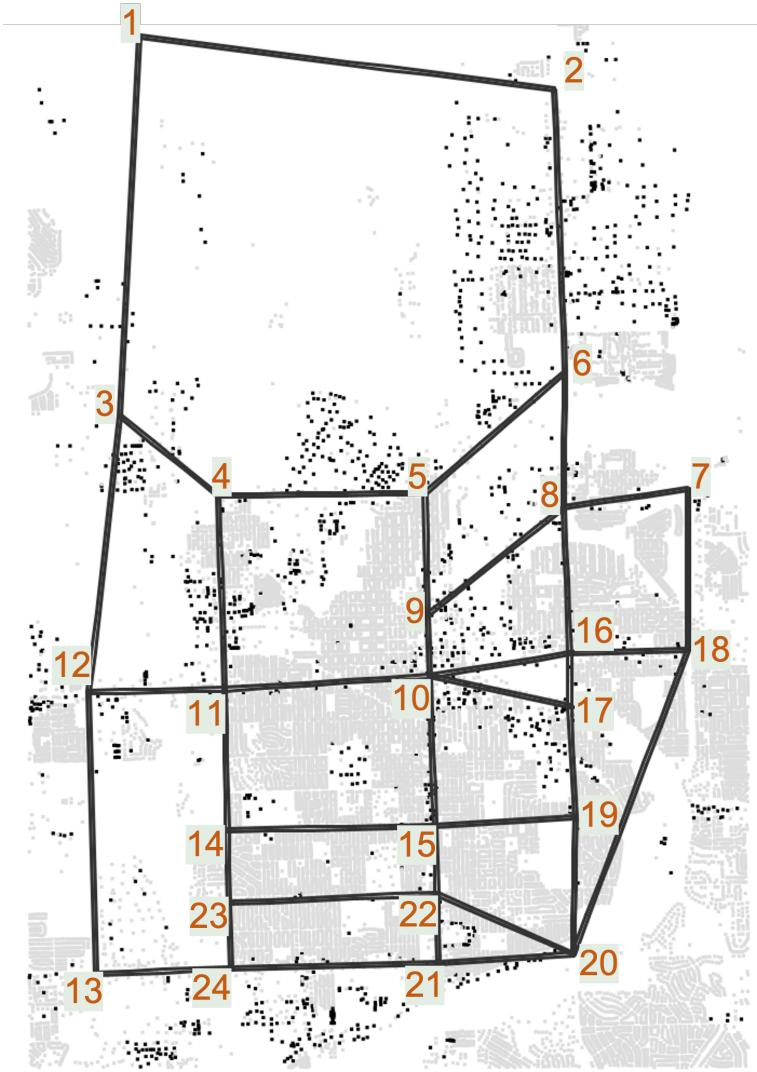

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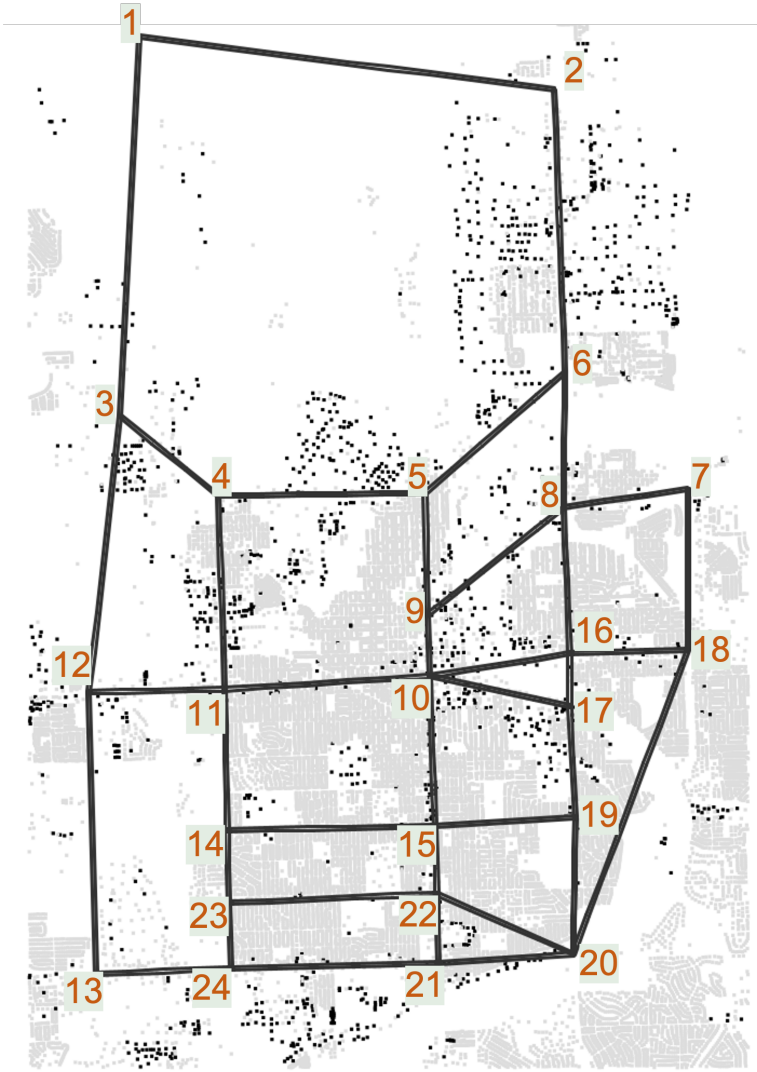

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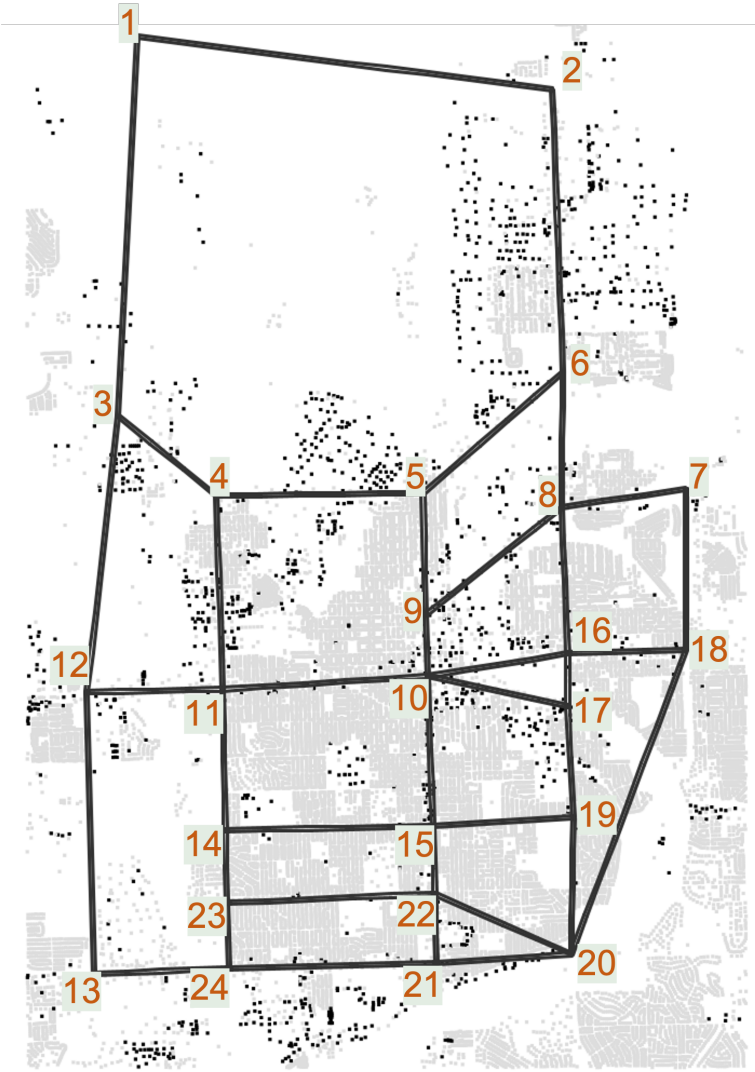
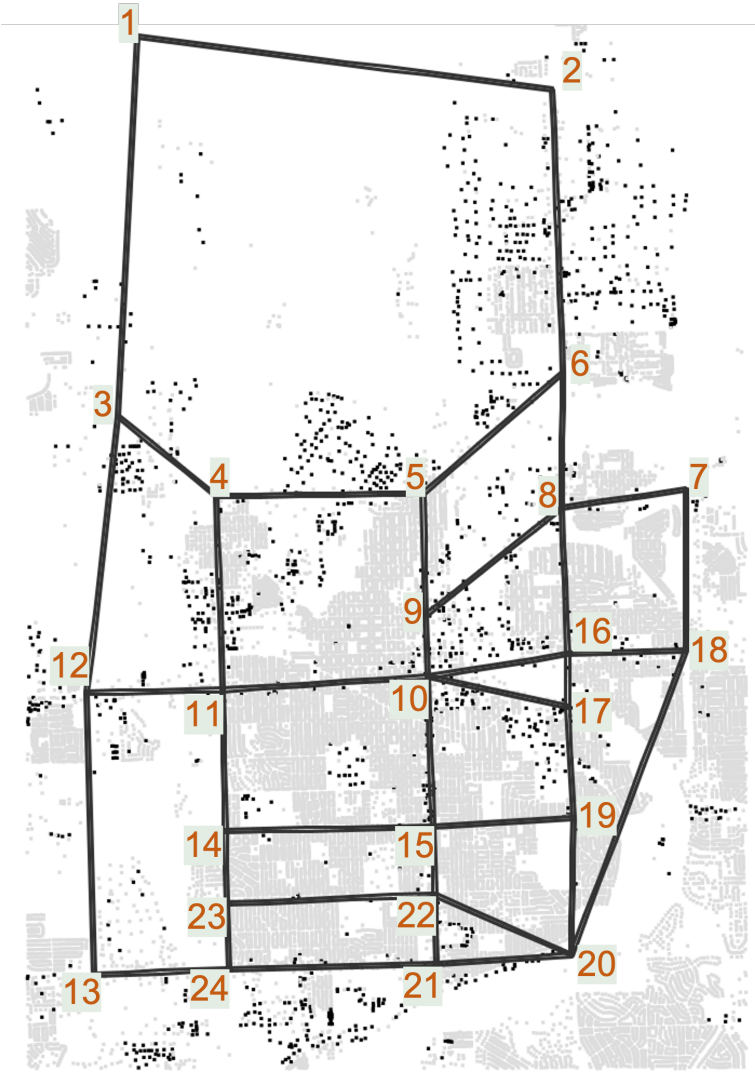


Scenarios

- "do nothing" scenario
  - The final configuration of the vehicles for one iteration is fed back to MATSim as an initial configuration for the next iteration.



Scenarios

- "do nothing" scenario
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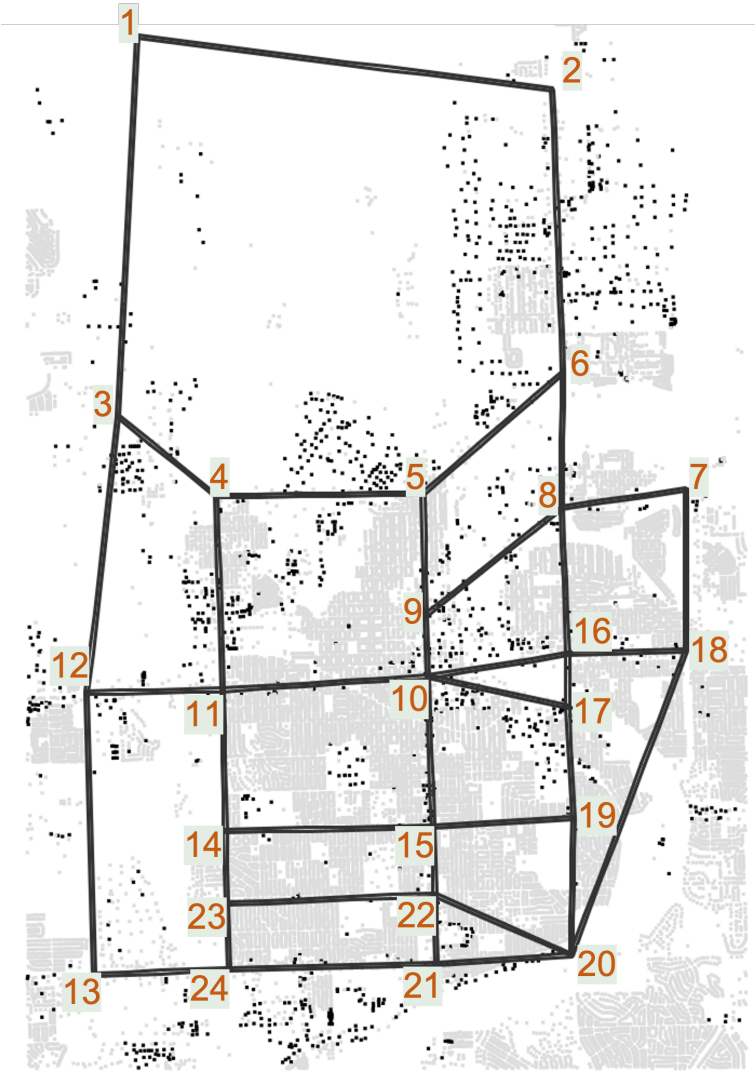
- "rebalance" scenario
  - The minimum required number of vehicles per station is computed and the free parking is determined where each station has 10 total parking spots.



Results

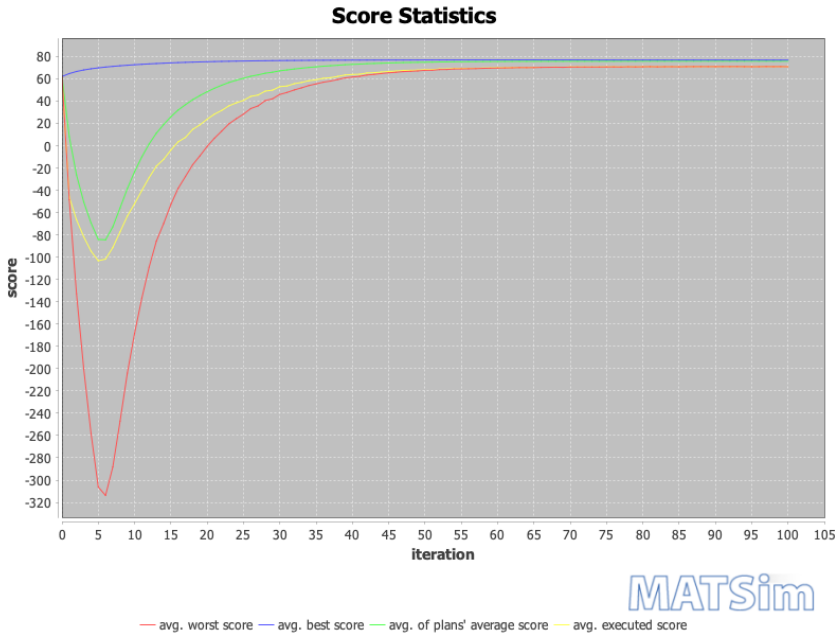


Figure: Score statistics (rebalance)

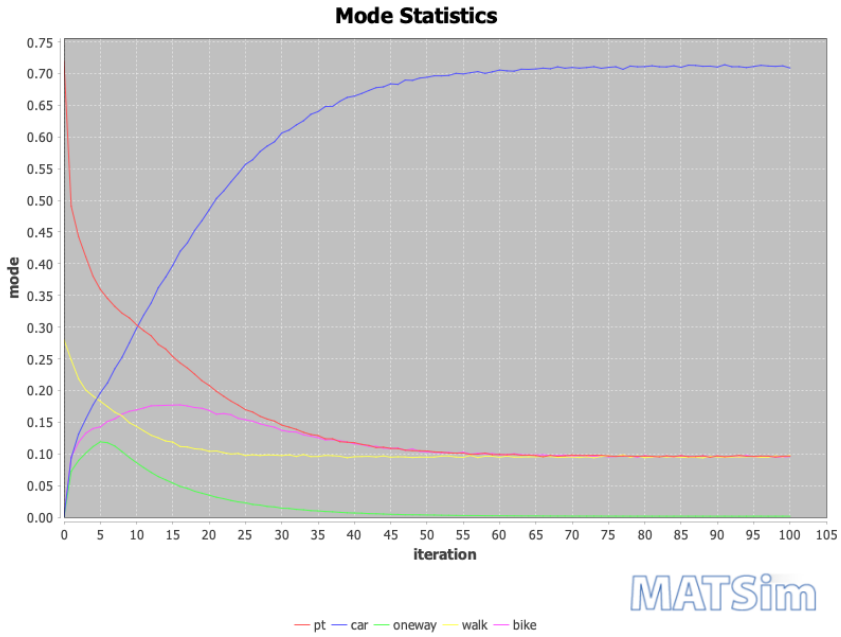


Figure: Mode statistics (rebalance)

Comparison of two strategies

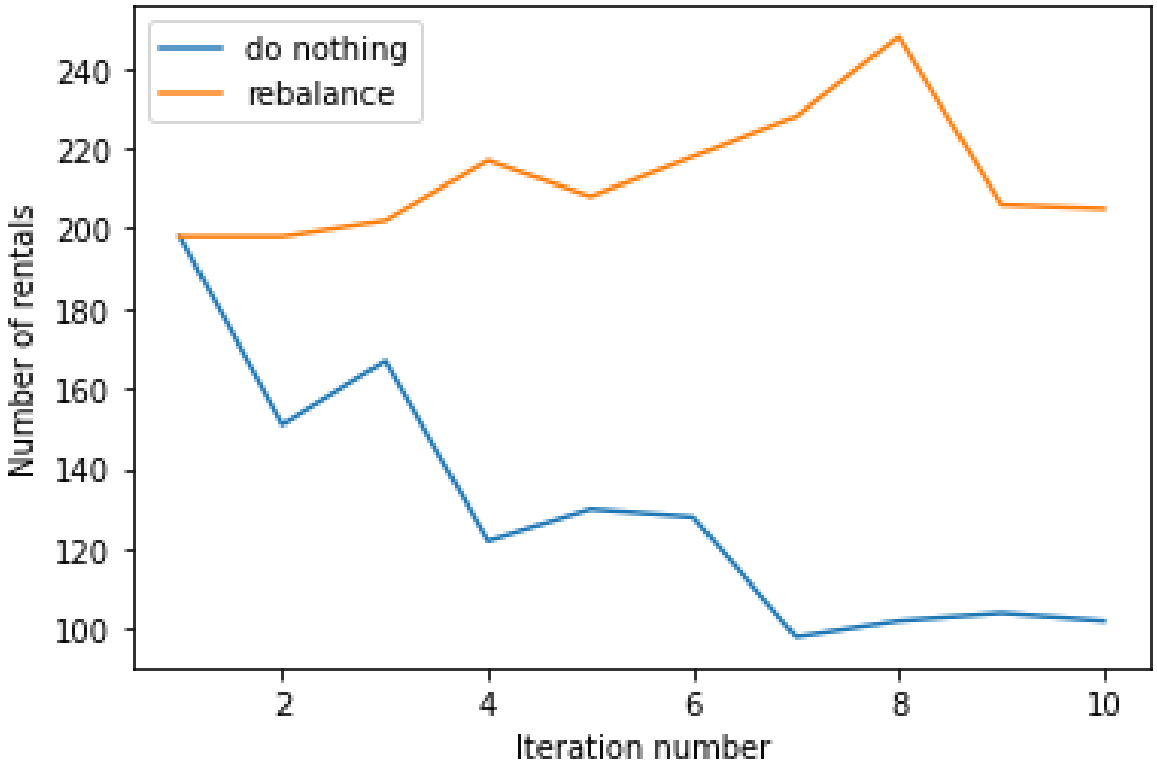


Figure: Number of rentals for both strategies

Conclusions and future work

- A generic framework to evaluate different rebalancing operations strategies is presented.
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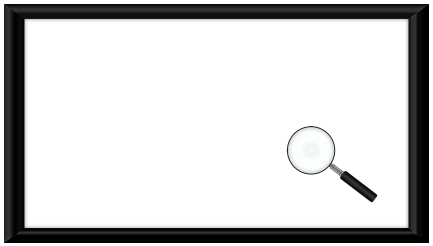
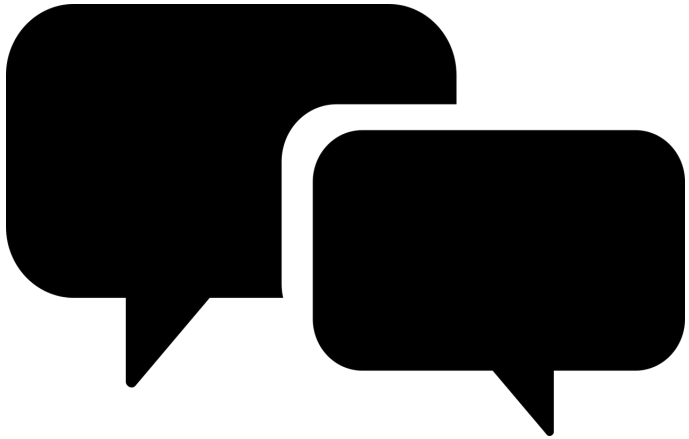
- The next steps include
  - selecting a choice model and rebalancing operations strategies from the literature and
  - analyzing the effect of rebalancing operations that consider different strategies.
  - applying to a bigger case study, such as Zurich, Switzerland.



Questions and discussion



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Transport and Mobility Laboratory (TRANSP-OR)
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selin.atac@epfl.ch