Comparing different rebalancing operations strategies in car sharing systems: A generic optimization framework

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Outline

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2. Evaluating different rebalancing operation strategies
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   - Literature

3. Methodology
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   - Preliminary experiments
   - Rebalancing operations optimization

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%.

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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
  - Higher car and less parking utilization
  - 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

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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.

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Motivation

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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

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

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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
The framework

**Figure:** The framework
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What is MATSim and how does it work?

- A Multi-Agent Transport Simulation toolkit

Network

Plans

Configuration

Public transportation

Facilities

Membership

Car sharing stations

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Diagram:

- Initial demand
- Mobsim
- Scoring
- Analyses
- Replanning
What is MATSim and how does it work?

51 Female

(686386.7981000002, 4824847.9253) 1339_18 07:36:36

(684264.4409999996, 4824161.4961) 7783_16 07:51:36 17:20:07

(686386.7981000002, 4824847.9253) 1339_18

41 Male

(685633.267, 4823347.2456) 14993_17 16:39:38

(685411.58239999, 4824336.984999) 7747_16 16:54:38 18:04:48

(685633.267, 4823347.2456) 14993_17
Illustrative case study

- Sioux Falls, US scenario
  - 84110 agents
  - 24 stations (5 vehicles and 5 free parking spots per station)
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- Every agent has a membership.
- Parameters are set to default.
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.
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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 rebalancing strategies

**Figure:** Number of rentals for the two rebalancing strategies
What happens if we plug in an optimization model?

Three strategies:

- Models proposed in Gambella et al. (2018)\(^7\) and Zhao et al. (2018)\(^8\).
  - Gambella et al. (2018): maximize system profit with fixed numbers of vehicles and staff and limited station capacity.
  - Zhao et al. (2018): determine the optimal numbers of vehicles and staff to serve all demand while minimizing costs, with unlimited capacity at all stations.
- A third strategy based on these two models.
  - Derived from the first strategy by considering a priority trip list and forcing the model to serve them.

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\(^7\) Claudio Gambella, Enrico Malaguti, Filippo Masini, and Daniele Vigo. Optimizing relocation operations in electric car-sharing. Omega, 81:234-245, 2018.

What happens if we plug in an optimization model?

- A case study from Turin, Italy.
  - 10 stations
  - 10-70 number of vehicles
  - 0-3 staff
  - 418 trips/day on average
  - 96 timesteps (15 mins intervals)
  - Each instance is solved by CPLEX 22.10 on a server with Xeon(R) Gold 6140 CPU clocked at 2.30GHz and 36 processors with a time limit of 72 hours.

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Conclusions and future work

- A generic framework to evaluate different rebalancing operations strategies is presented.
- Preliminary experiments on Sioux Falls scenario using MATSim carsharing API show promising results for naive heuristics.
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- The next steps include
  - selecting a choice model and rebalancing operations strategies from the literature,
  - analyzing the effect of rebalancing operations that consider different strategies, and
  - applying to a bigger case study, such as Zurich, Switzerland.
Questions and discussion

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