Agent-based simulation of electric taxicab fleets

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Motivation

- Current Battery electric vehicles (BEV) have a range of 100-200km
- For urban taxi services, this range is more than sufficient to serve single requests
- Overall daily mileage of a single vehicle is usually higher than vehicle range, so taxis will need to recharge at some point
- Agent based simulation may help to estimate the consequences of BEV taxi fleets for both drivers and passengers
Motivation

• Which influence does a BEV taxi fleet have on a small town’s quality of taxi service?

• What happens if taxi demand suddenly increases?

• How much additional charging infrastructure is needed for taxi services?

• Can taxi dispatch by battery state of charge (SOC) be more efficient?
Related work

- Some research has been done for Singapore, Seoul and Taipeh
- As far as the authors know, passenger perspective has not been part of this research.
- So far, no combination with a dynamic traffic simulation has been made.
Electric taxis worldwide

- Small fleets of BEV taxis can be found worldwide, e.g. Amsterdam, Tokyo and Tartu (s. below)

- Large scale operations in Shenzhen (600 cars?)
Introducing MATSim

- Multi Agent Transport Simulation
- Simulating peoples’ behaviour over the day over multiple iterations
- People optimize their plans according to utility functions and stick to the plan that suites them best
- Dynamic congestion model
General Concept: Taxis in MATSim

- Taxi allocation in MATSim is dynamic according to demand
- Taxi driver agents do not have ordinary MATSim plans to follow
- After serving a request, taxis return to nearest taxi rank, unless there is an immediate follow-up request
- A driver’s schedule may look like this:
- \( Ra \rightarrow Re \rightarrow Re \rightarrow Ra \rightarrow Re \rightarrow Ra \rightarrow Re \rightarrow Re \rightarrow Ra \)
  Ra – rank
  Re – request
General Concept: electric vehicles in MATSim

- Energy consumption is tracked on link to link base
- It is assumed that vehicles start their day at 100% SOC
- Charging may take place at any taxi rank
- Taxis will be dispatched only to customers if SOC is sufficient
Scenario

- Based on Polish town of Mielec
- Two peaks around 9:00 and 17:00
- Overall, 42'000 trips
  - initially 1528 taxi trips (5% of inner city trips)
- 50 taxis in service
- 5 taxi ranks
- 126 revenue km per taxi

- Two fleet cases:
  - fleet of gasoline powered cars
  - Fleet of BEV (Nissan Leaf, 20 kWh battery, 50kW fast charging possible)
  - 30 min of charging result in 80% SOC (CHAdeMO)
Network

(OSM)
Network
## Experiments

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<thead>
<tr>
<th>Name</th>
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<th>Chargers per rank</th>
<th>Charging power [kW]</th>
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<th>Fleet types</th>
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Results: Everyday operations (STD)

- BEV usage has no negative impact on quality of service for taxi customers
- Average waiting time for a taxi 7:12min
- Average total daily mileage: 270km
- Taxis can recharge during times of weak demand
Fleetwide SOC (STD)
### Results: Increased taxi demand (INC)

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Increased taxi demand

• Big events, bad weather or disruptions in public transit trigger sudden peaks in demand for taxi trips

• Until a certain threshold, an electric powered taxi fleet is able to compete with an ordinary powered one very well.

• Further increasing the demand will results in far higher waiting times for customers of electric vehicles
Increased taxi demand: waiting times

![Graph showing average waiting time vs. taxi demand]

- Average waiting time (hh:mm) vs. taxi demand (%)
- Red line: REY fleet
- Green line: fuel-powered

The graph illustrates the relationship between taxi demand and average waiting time, with the REY fleet showing a steeper increase compared to fuel-powered taxis.
## Results: Charging outlet supply (CHRG)

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Results: Charging outlet supply (CHRG)

- In previous experiments, charger amount was unlimited
- Reducing the amount of chargers to 5, 2 and one per rank
- No influence on quality of service
- different request-to-taxicab assignment
- No charging peaks anymore
Results: Charging outlet supply (CHRG)
Results: Modifications in taxi dispatch (DISP)

• Taxis are usually dispatched out of ranks by FIFO

• Can a dispatch by SOC produce better results if charging is slow?

• One charger per rank with only 22kW power (e.g. during winter) → Wait times for taxis increase to 7:57 min

• Dispatch by SOC reduces waiting times (7:24 min), however some taxi drivers lose revenue
  • Hard to communicate
  • Could only work for companies, not for individual drivers
Conclusion

• BEV may be used in small cities for taxi operations
• No significant behavioural changes for drivers or customers needed
• Sudden demand peaks are harder to serve with BEV
• Ongoing work: Real world taxi demand in Berlin
• How can a taxi operator use ist electric fleet the most efficient?