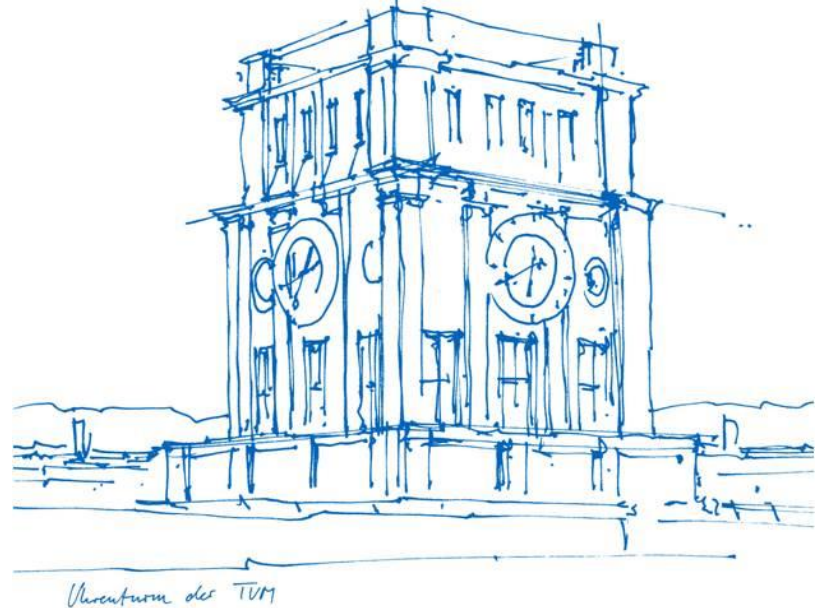# Shifts in Perspective: Modeling Operational Challenges in Non-Autonomous and Electric Ride-Pooling Systems

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Department of Civil, Geo and Environmental Engineering
Assistant Professorship of Modeling Spatial Mobility

MATSim User Meeting, March 22, 2021

# Introduction

Ridehailing and -pooling

# Ridehailing and -pooling

- Great research interest in recent years

- Subject of many **simulation studies** with agent-based models being especially suited for a realistic representation of microscopic interactions

- In MATSim, these simulations are usually carried out with the help of the **DRT** (demand responsive transport) extension

- While the amount of simultaneously active vehicles can be adjusted by individual vehicle service times, many (if not most) studies assumed a fully **autonomous robotaxi fleet** so far

Documents by year
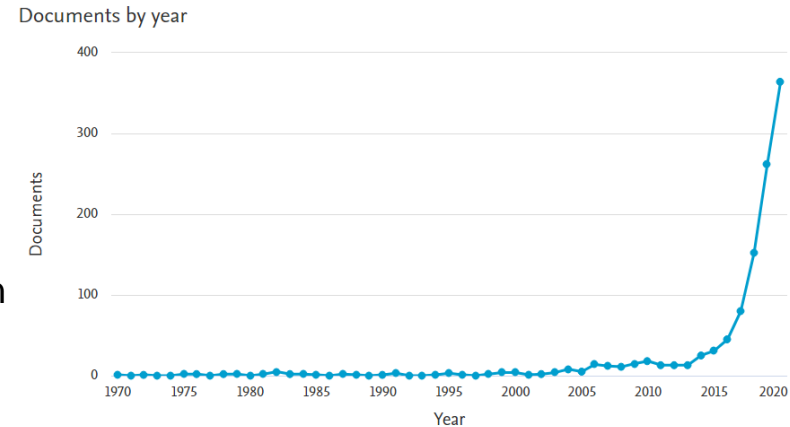
Simple SCOPUS search of 'ride pooling', 'ride hailing' and 'shared rides'. Results 1970-2020

# Autonomous Driving: Move fast and break things?

**Relax, experts say it's at least a decade before you can buy a self-driving vehicle**

PUBLISHED TUE, JUL 30 2019-6:00 AM EDT | UPDATED TUE, JUL 30 2019-12:08 PM EDT

Phil LeBeau
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CNBC, Jul 2019

**whichcar**

**Driverless cars decades away, says Audi tech guru**

By Toby Hagon, 03 Dec 2019 Car News

Why your dream of driving an autonomous car is still decades away

The Telegram, Dec 2019

# Autonomous Driving: Move fast and break things?

**TUM MOIA ETH**zürich **System**x
INSTITUT DE RECHERCHE TECHNOLOGIQUE

**Relax, experts say it's at least a decade before you can buy a self-driving vehicle**

CNBC, Jul 2019

**Self-Driving Cars Are Taking Longer to Build Than Everyone Thought**

Automakers and suppliers are being increasingly honest about the challenges of autonomous driving.

BY ROBERTO BALDWIN MAY 18, 2020

Car And Driver, May 2020

**Sorry, Elon: Fully Autonomous Tesla Vehicles Will Not Happen Anytime Soon**

Elon Musk says Tesla vehicles could soon be fully self-driving, with no human intervention needed. But self-driving cars rely on deep learning, and the technology just isn't there yet.

PCMag, Jul 2020

**Experts say we're decades from fully autonomous cars. Here's why.**

Business Insider, Jul 2020

**Why deep learning won't give us level 5 self-driving cars**

By Ben Dickson - July 29, 2020

TechTalks, Jul 2020

**Here's Why Our Gleaming Self-Driving Future Has Been Delayed Indefinitely**

Has Level 5 autonomy been a mirage this whole time?

BY JAY RAMEY JUN 8, 2020

Autoweek, Jun 2020

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NY Times, Jun 2020

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**'Peak hype': why the driverless car revolution has stalled**

The Guardian, Jan 2021

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Business Insider, Jul 2020

**We're Still a Long Way From Roadways Full of Autonomous Vehicles**

Detroit and Silicon Valley are racing to create self-driving cars, but have they set expectations too high?
Gary Witzenburg - February 9, 2021

Hour Detroit, Feb 2021

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Autoweek, Jun 2020

**Why your first driverless car is decades, not years, away**

February 1, 2021

The technology needed to realize the dream of fully autonomous personal vehicles is growing steadily. But so is the list of hard-to-solve problems.

University of Michigan-Dearborn, Feb 2021

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NY Times, Jun 2020

**The real self-driving revolution remains years away**

By Peter Valdes-Dapena, CNN Business
Updated 1754 GMT (0154 HKT) January 21, 2021

CNN Business, Jan 2021

# Autonomous Driving: Move fast and break things?

→ **Operational challenges that come with manual drivers still apply for such systems at least in the next decade**

# Driver Shifts and Breaks in MATSim

# Shift Dispatcher

- The central logic of the shifts/breaks extension

- (for the connaisseurs: is basically a DrtOptimizer implementation)

- Is called every time step and **handles scheduling, starting and ending shifts/breaks**

- Only vehicles with an **active shift may accept** and serve passenger requests

- Only vehicles with an **active shift may be rebalanced**

- Accepted rides have to **comply** with shift and break durations/locations
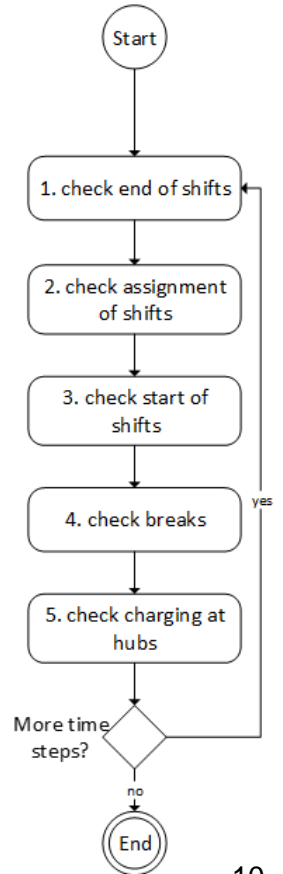
# Exemplary Time Axis
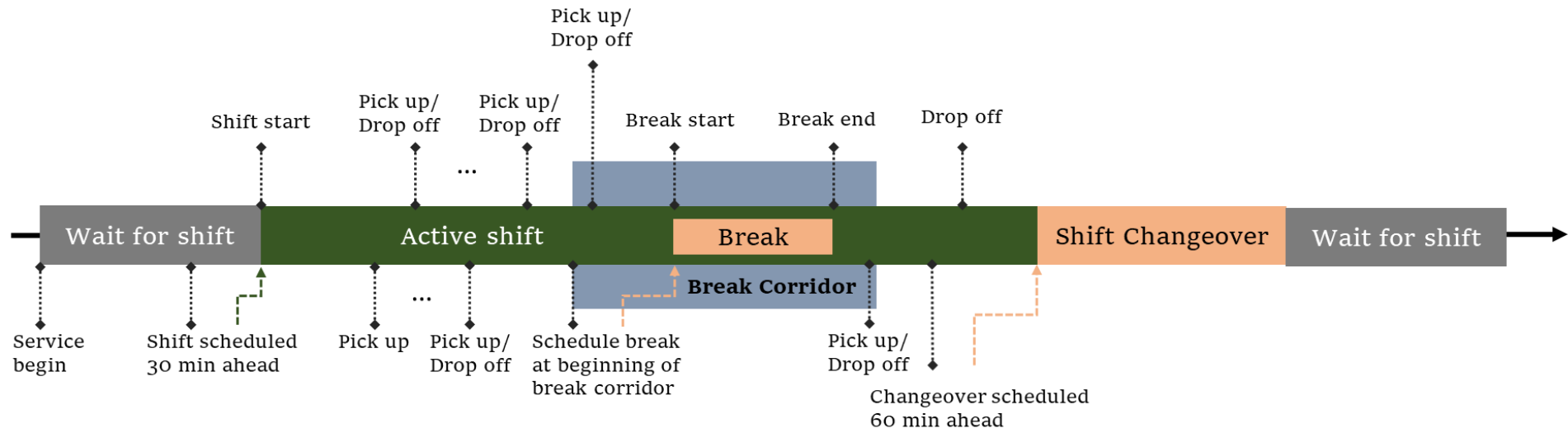
# Shift Input

```
<shifts>
        <shift id="0" start="50400.0" end="81000.0">
                <break earliestStart="60400.0" latestEnd="75000.0" duration="1800.0"/>
        </shift>
        <shift id="1" start="15300.0" end="38700.0">
                <break earliestStart="24300.0" latestEnd="34700.0" duration="1800.0"/>
        </shift>
        <shift id="105" start="72000.0" end="80000.0"> </shift>
</shifts>
```

Figure 1: Illustrative example of shift input for the simulation.

# Operational Facilities Input

```
<facilities>
    <facility id="3800" linkId="3800" x="572510" y="5938267" capacity="10"  chargerId="3800"
        type="inField"/>
    <facility id="59411" linkId="59411" x="563981" y="5940899" capacity="10" chargerId="
        59411" type="inField"/>
    <facility id="9993" linkId="9993" x="571743" y="5933818" capacity="300" chargerId="9993"
        type="hub"/>
    <facility id="25" linkId="25" x="563477" y="5935986" capacity="10" chargerId="25" type="
        inField"/>
</facilities>
```
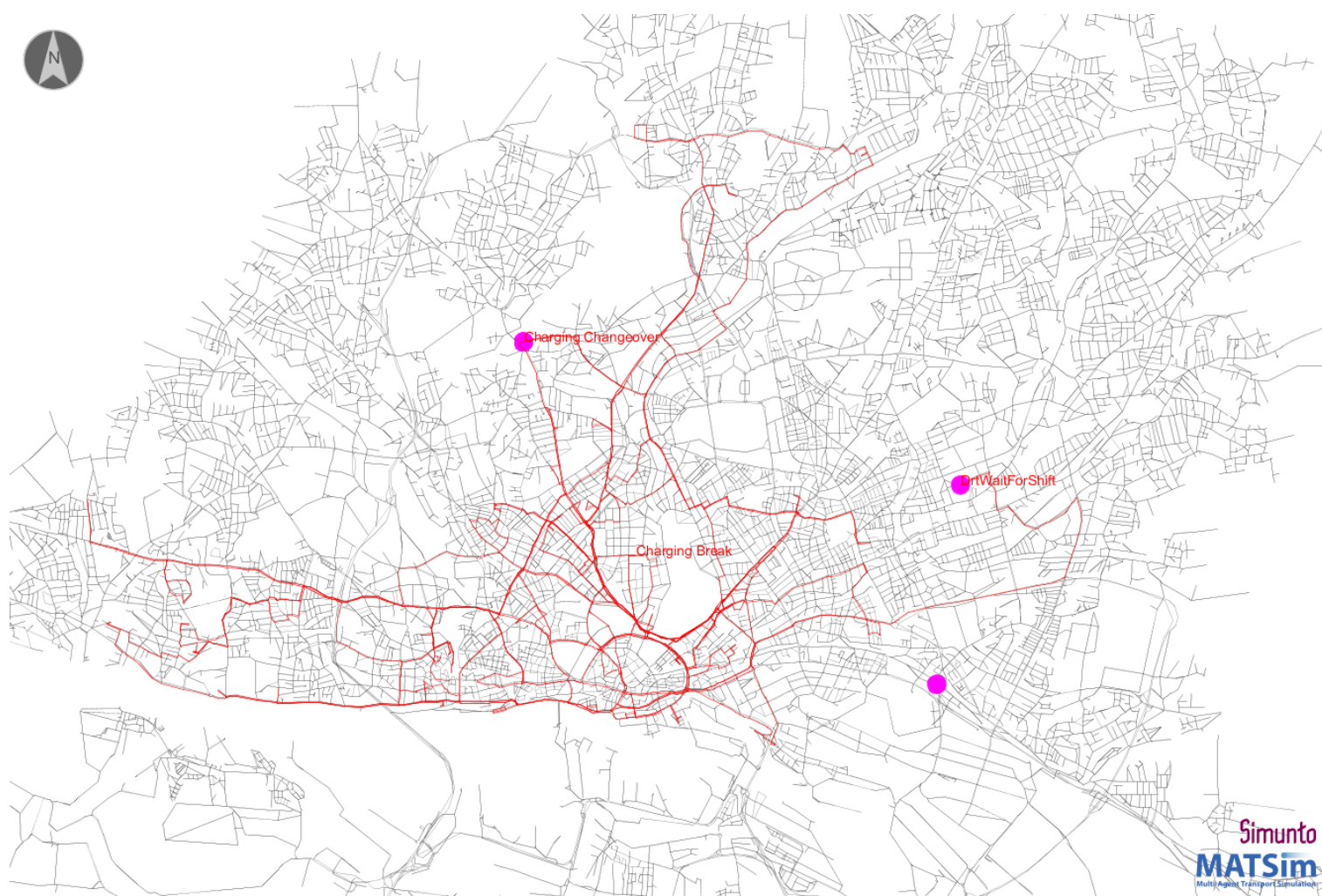
Figure 2: Illustrative example of operational facilities for the simulation.

# Test Scenario

- Realistic test scenario for the city of **Hamburg**

- **Demand and shift data** randomly sampled from four subsequent Mondays of **MOIA operations**

- Realistic travel times obtained by **TomTom data** matched to MATSim network

- Three hubs and two in-field operational facilities
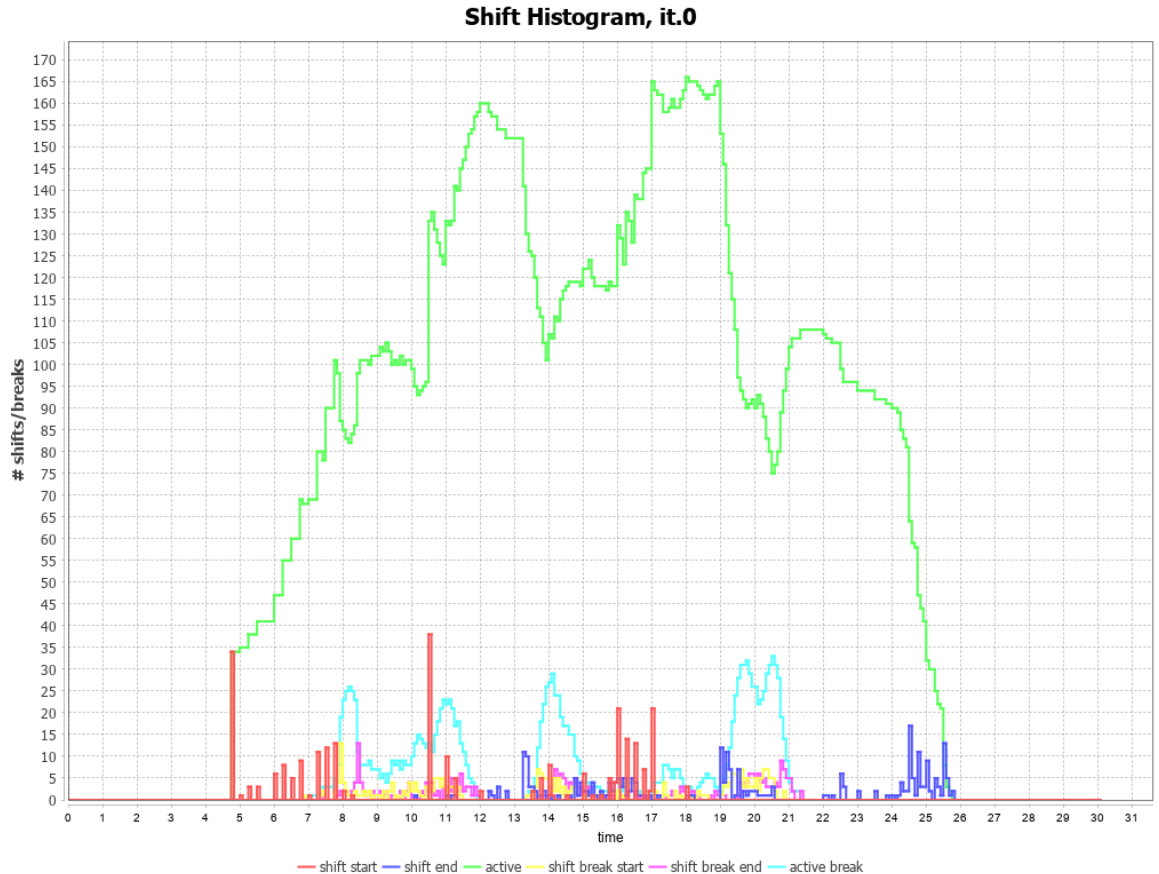
Example

traces of a

vehicle

serving shifts



Charging Changeover

DrtWaitForShift

Charging Break

Simunto

MATSim
Multi-Agent Transport Simulation

# Analysis Plots

Shift and Break Histogram
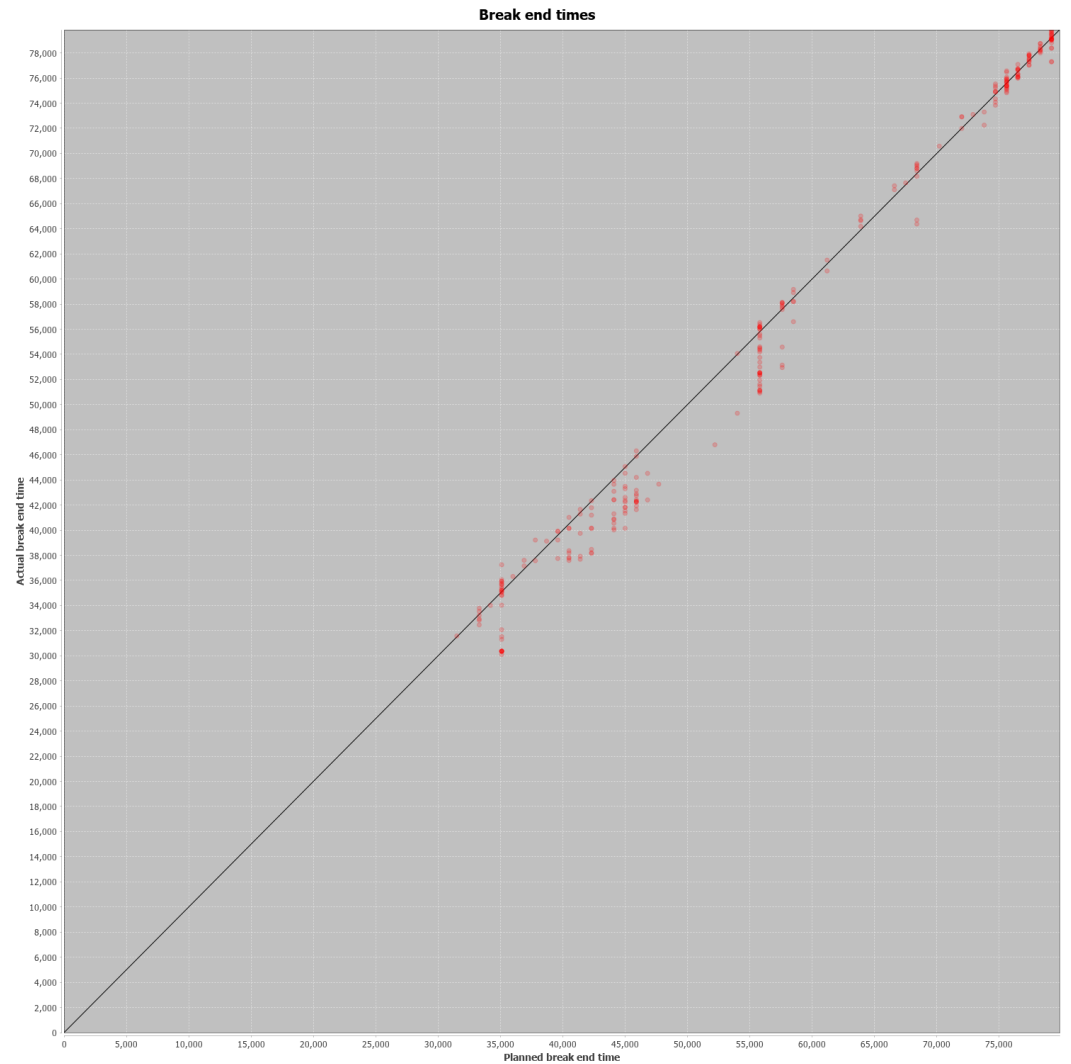


**Shift Histogram, it.0**

# Analysis Plots

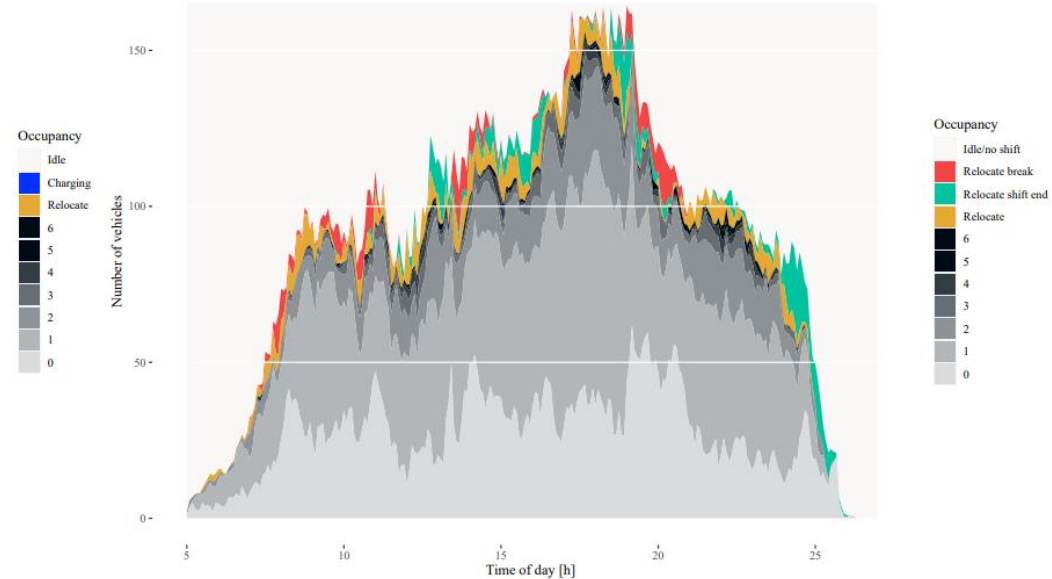Operation facility occupancy
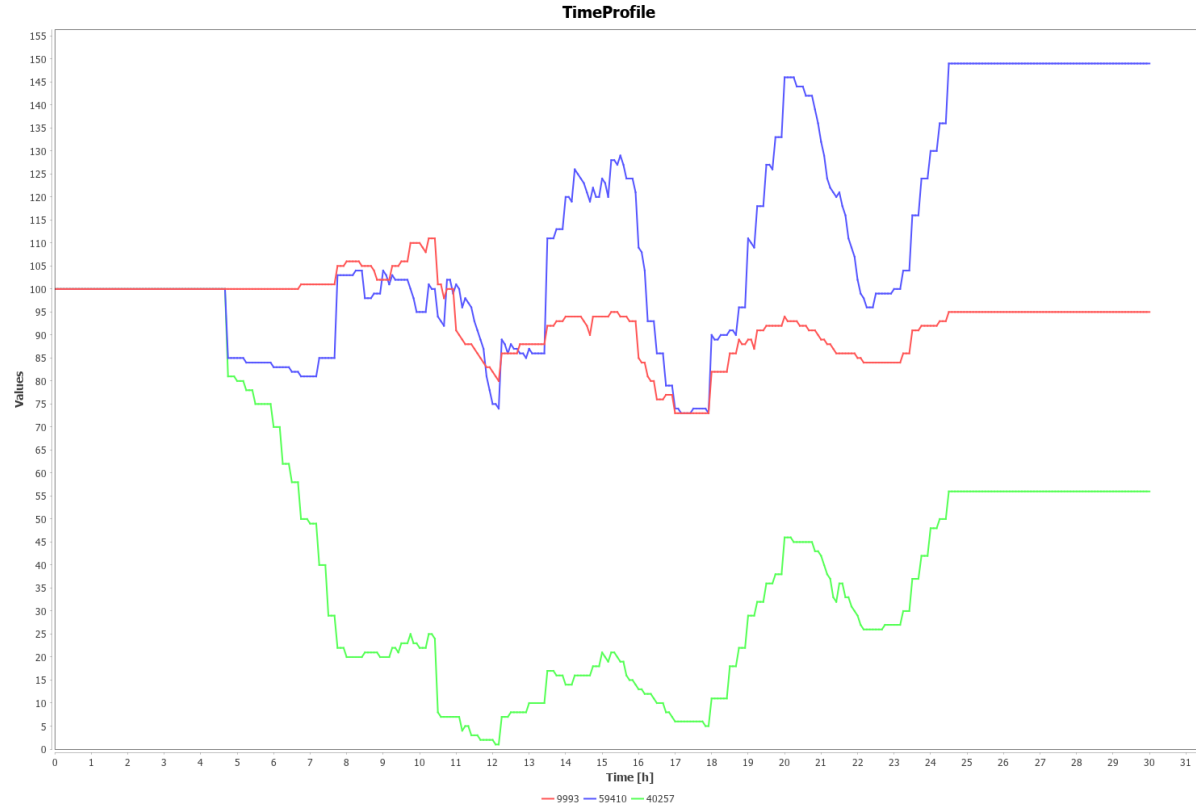
# Analysis Plots

Break end time validation



Break end times

# Occupancy plots (with electric fleet and rebalancing, after 5 iterations)
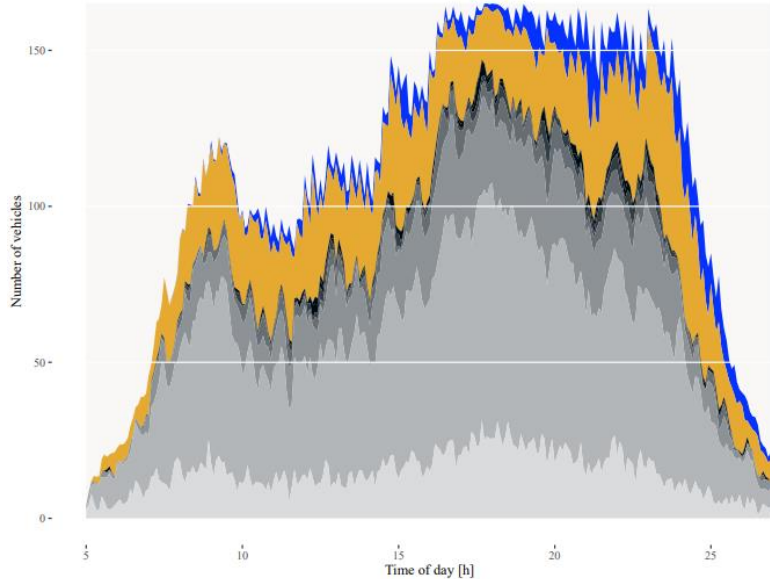
# Simulation outcomes

Table 1: Comparison of simulation outcomes

| | Autonomous Service Electric | Shift Service Electric | Autonomous Service ICE | Shift Service ICE |
|---|---|---|---|---|
| $n_{\mathrm{rides}}$ | 7,821 | 5,806 | 7,045 | 5,671 |
| Rejections | 1,207 | 3,222 | 1,983 | 3,357 |
| Rejection Rate | 0.13 | 0.37 | 0.22 | 0.37 |
| $d_{\mathrm{VKT}}$ [km] | 63,066.52 | 47,909.87 | 52,426.27 | 49,451.76 |
| $\overline{d}_{\mathrm{direct}}$ [km] | 7.83 | 8.45 | 8.35 | 8.46 |
| $\eta_{\mathrm{RP}}$ | 0.97 | 1.02 | 1.12 | 0.97 |

# Simulation outcomes

Table 2: Comparison of simulation outcomes after 5 iterations of rebalancing

|  | Autonomous Service Electric | Shift Service Electric | Autonomous Service ICE | Shift Service ICE |
|---|---|---|---|---|
| $n_{\mathrm{rides}}$ | 8,125 | 6,061 | 8,182 | 6,065 |
| Rejections | 903 | 2,967 | 846 | 2,963 |
| Rejection Rate | 0.10 | 0.33 | 0.09 | 0.33 |
| $d_{\mathrm{VKT}}$ [km] | 65,431.35 | 49,498.84 | 58,062.91 | 49,625.32 |
| $\bar{d}_{\mathrm{direct}}$ [km] | 7.77 | 8.15 | 7.90 | 8,07 |
| $\eta_{\mathrm{RP}}$ | 0.96 | 0.99 | 1.11 | 0.98 |

# Conclusion // Outlook

- Depending on shift plans and driver availability, todays operational challenges may **lower the volume of served rides** considerably when compared to an autonomous service

- However, introduction of shifts and breaks **does not seem to lower the efficency** of vehicles

- **Work in progress**, actively programmed against latest MATSim snaptshots

- Also integrated with an **AMODEUS** extension for MATSim

- If desired, MOIA explicitly allows **transfer** of code to open source community in near future

- A brief summary report of the presented extension can be found here:
  https://doi.org/10.13140/RG.2.2.25932.74888

# TUM MOIA ETH zürich SystemX

## Questions and Feedback

Contact:
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https://github.com/nkuehnel