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

Nico Kühnel, Felix Zwick, Sebastian Hörl
Technical University of Munich
Department of Civil, Geo and Environmental Engineering
Assistant Professorship of Modeling Spatial Mobility

MATSim User Meeting, March 22, 2021
Introduction
Ridehailing and pooling

CleverShuttle

MOIA

Uber

DiDi

Nico Kühnel (TUM) | MATSim User Meeting 2021
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

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

CNBC, Jul 2019

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?

Relax, experts say it’s at least a decade before you can buy a self-driving vehicle
CNBC, Jul 2019

Why deep learning won’t give us level 5 self-driving cars
TechTalks, Jul 2020

Self-Driving Cars Are Taking Longer to Build Than Everyone Thought
Automakers and suppliers are being increasingly honest about the challenges of autonomous driving.
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 without human interaction 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

Here’s Why Our Gleaming Self-Driving Future Has Been Delayed Indefinitely
Autoweek, Jun 2020

Uber, After Years of Trying, Is Handing Off Its Self-Driving Car Project
Company executives once said having cars that can drive on their own would be a salvation for their business. But the effort turned into a legal and financial headache.
IEEE Spectrum, Apr 2020

Surprise! 2020 Is Not the Year for Self-Driving Cars
The AV industry has had to reset expectations as it shifts its focus to Level 4 autonomy

Why your dream of driving an autonomous car is still decades away
The Telegram, Dec 2019

This Was Supposed to Be the Year Driverless Cars Went Mainstream
Perfecting the technology has taken longer than expected. The coronavirus pandemic has made it even more difficult.
NY Times, Jun 2020
Autonomous Driving: Move fast and break things?

'Peak hype: why the driverless car revolution has stalled
The Guardian, Jan 2021

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.
Car And Driver, May 2020

Sorry, Elon: Fully Autonomous Tesla Vehicles Will Not Happen Anytime Soon
Elon Musk says Tesla vehicles could be ready within five years, but the human interaction 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

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 Stagerburg, February 17, 2021

Hour Detroit, Feb 2021

Why deep learning won’t give us level 5 self-driving cars
TechTalks, Jul 2020

Here’s Why Our Gleaming Self-Driving Future Has Been Delayed Indefinitely
Has Level 5 autonomy become a mirage this whole time?
AutowEEK, Jun 2020

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

Uber, After Years of Trying, Is Handing Off Its Self-Driving Car Project
Company executives once said having cars that can drive on their own would be a salvation for their business. But the effort turned into a legal and financial headache.
The Guardian, Dec 2019

Surprise! 2020 Is Not the Year for Self-Driving Cars
The AV industry has had to reset expectations as it shifts its focus to Level 4 autonomy
IEEE Spectrum, Apr 2020

Why your dream of driving an autonomous car is still decades away
The Telegram, Dec 2019

This Was Supposed to Be the Year Driverless Cars Went Mainstream
Perfecting the technology has taken longer than expected. The coronavirus pandemic has made it even more difficult.
NY Times, Jun 2020

The real self-driving revolution remains years away
CNN Business, Jan 2021
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 start**
- **Pick up/Drop off**
- **Pick up/Drop off**
- **Break start**
- **Break end**
- **Drop off**
- **Break Corridor**
- **Service begin**
- **Shift scheduled 30 min ahead**
- **Pick up**
- **Schedule break at beginning of break corridor**
- **Pick up/Drop off**
- **Changeover scheduled 60 min ahead**
Shift Input

```xml
<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

```xml
<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
Analysis Plots

Shift and Break Histogram
Analysis Plots

Operation facility occupancy
Analysis Plots

Break end time validation
Occupancy plots (with electric fleet and rebalancing, after 5 iterations)
Simulation outcomes

Table 1: Comparison of simulation outcomes

<table>
<thead>
<tr>
<th></th>
<th>Autonomous Service</th>
<th>Shift Service</th>
<th>Autonomous Service</th>
<th>Shift Service</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Electric</td>
<td>Electric</td>
<td>ICE</td>
<td>ICE</td>
</tr>
<tr>
<td>$n_{\text{rides}}$</td>
<td>7,821</td>
<td>5,806</td>
<td>7,045</td>
<td>5,671</td>
</tr>
<tr>
<td>Rejections</td>
<td>1,207</td>
<td>3,222</td>
<td>1,983</td>
<td>3,357</td>
</tr>
<tr>
<td>Rejection Rate</td>
<td>0.13</td>
<td>0.37</td>
<td>0.22</td>
<td>0.37</td>
</tr>
<tr>
<td>$d_{VKT}$ [km]</td>
<td>63,066.52</td>
<td>47,909.87</td>
<td>52,426.27</td>
<td>49,451.76</td>
</tr>
<tr>
<td>$\overline{d}_{\text{direct}}$ [km]</td>
<td>7.83</td>
<td>8.45</td>
<td>8.35</td>
<td>8.46</td>
</tr>
<tr>
<td>$\eta_{\text{RP}}$</td>
<td>0.97</td>
<td>1.02</td>
<td>1.12</td>
<td>0.97</td>
</tr>
</tbody>
</table>
Simulation outcomes

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

<table>
<thead>
<tr>
<th></th>
<th>Autonomous Service</th>
<th>Shift Service</th>
<th>Autonomous Service</th>
<th>Shift Service</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Electric</td>
<td>Electric</td>
<td>ICE</td>
<td>ICE</td>
</tr>
<tr>
<td>$n_{rides}$</td>
<td>8,125</td>
<td>6,061</td>
<td>8,182</td>
<td>6,065</td>
</tr>
<tr>
<td>Rejections</td>
<td>903</td>
<td>2,967</td>
<td>846</td>
<td>2,963</td>
</tr>
<tr>
<td>Rejection Rate</td>
<td>0.10</td>
<td>0.33</td>
<td>0.09</td>
<td>0.33</td>
</tr>
<tr>
<td>$\bar{d}_{VKT}$ [km]</td>
<td>65,431.35</td>
<td>49,498.84</td>
<td>58,062.91</td>
<td>49,625.32</td>
</tr>
<tr>
<td>$\bar{d}_{direct}$ [km]</td>
<td>7.77</td>
<td>8.15</td>
<td>7.90</td>
<td>8.07</td>
</tr>
<tr>
<td>$\eta_{RP}$</td>
<td>0.96</td>
<td>0.99</td>
<td>1.11</td>
<td>0.98</td>
</tr>
</tbody>
</table>
Conclusion // Outlook

- Depending on shift plans and driver availability, today's 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 efficiency** of vehicles.

- **Work in progress**, actively programmed against latest MATSim snapshots.

- 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](https://doi.org/10.13140/RG.2.2.25932.74888)
Questions and Feedback

Contact:
nico.kuehnel@tum.de
https://github.com/nkuehnel