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# Review and Evaluation of Approaches to Modeling Autonomous Transport Modes using MATSim: A Case Study For Switzerland

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# Scenarios & Literature: Summary of Drivers

Scenarios of how the use of AVs will spread are numerous and use different approaches. Yet, there is substantial consensus regarding which factors will drive:

The type and extent of AV usage

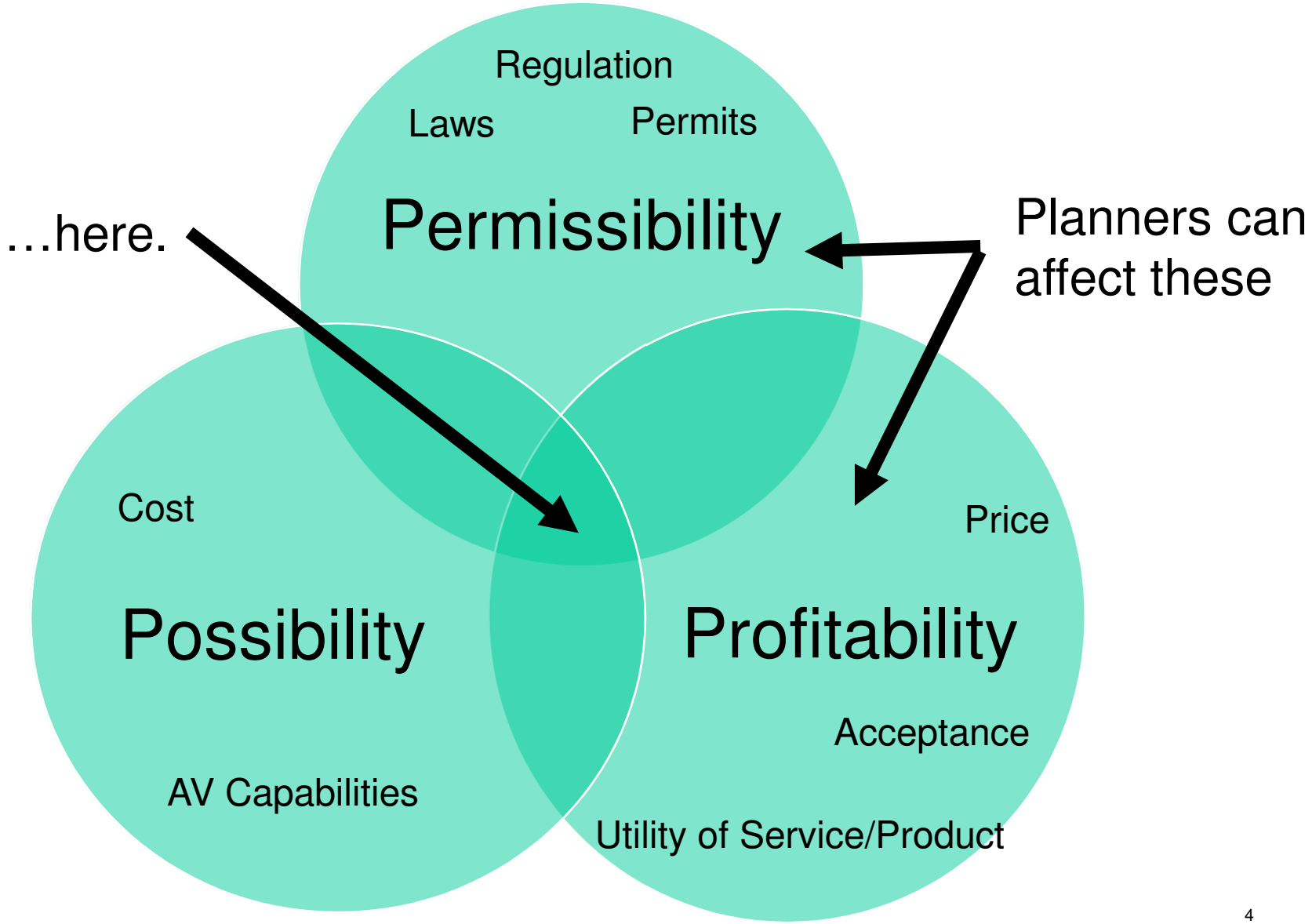
- Capabilities of AV technology
- Regulation
- Acceptance
- Cost vs Utility

Infrastructure effects

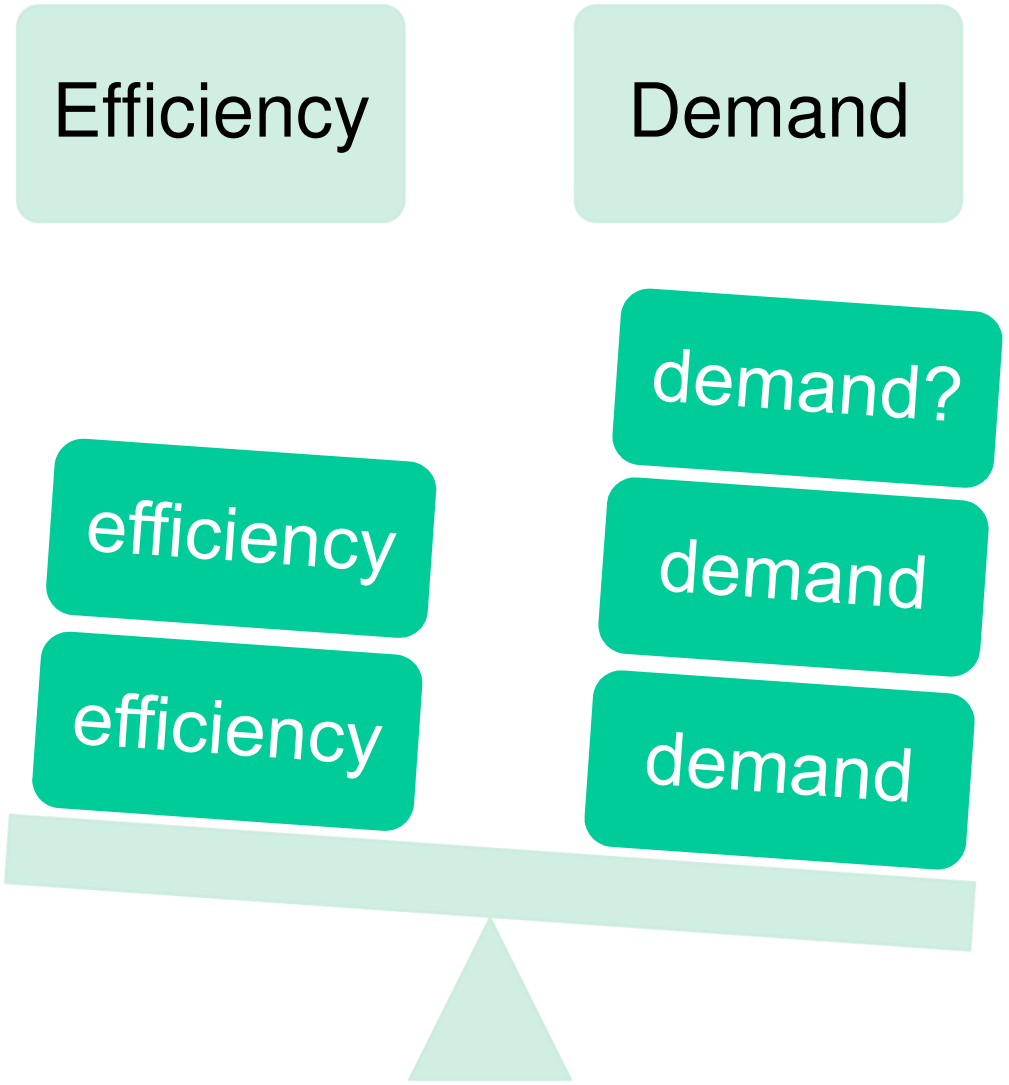
- Degree of Automation
- Degree of Communication/Coordination
- Extent of Market Penetration
- Efficiency vs Demand

Reviewed works: Fagnant & Kockelman (2015), Perret et al. (2017), Oehry et al. (2018), Hörl et al. (2018), Maurer et al. (2015)

# The future lies….



# Will an increase in demand outweigh gains in efficiency?



# What affects….

…Demand as Person-km

- Value of Time
- Access
- Costs
- Travel Time
- Transfers
- Convenience, Comfort

…Demand as Vehicle-km

- empty trips
- vehicle occupancy

…Efficiency of flow:

- following distances
- ability to anticipate signal changes/actions of others
- speed of on-street shunting actions (parallel parking)

Key to affecting above factors:

- Reaction times
- communication
- coordination

…Efficient use of urban space:

- pick-up/drop-off
- parking search, parking space

Reviewed works: Fagnant & Kockelman (2015), Perret et al. (2017), Oehry et al. (2018), Hörl et al. (2018), Maurer et al. (2015), Fischer (2019)

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- Costs
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- Convenience, Comfort

…Demand as Vehicle-km

- empty trips
- vehicle occupancy

**Demand Models (meso, macro)**

…Efficiency of flow: **Microscopic Models**

- following distances
- ability to anticipate signal changes/actions of others
- speed of on-street shunting actions (parallel parking)

Key to affecting above factors:

- Reaction times
- communication
- coordination

…Efficient use of urban space:

- pick-up/drop-off
- parking search, parking space

**Both**

Reviewed works: Fagnant & Kockelman (2015), Perret et al. (2017), Oehry et al. (2018), Hörl et al. (2018), Maurer et al. (2015), Fischer (2019)

# Future AV Options for Passengers: What might be available?

Private AVs

- fully private, like a car/like an camper van

Chauffeuring services

- semi-private, for use by members/customers of a organization

AV-Taxis

- publically accessible, on-demand or via bookings

Ridesharing/Pooling with AV Taxis

- publically accessible, on-demand or via bookings

“Feeder” AV Taxis

- publically accessible, on-demand or via bookings, single or shared

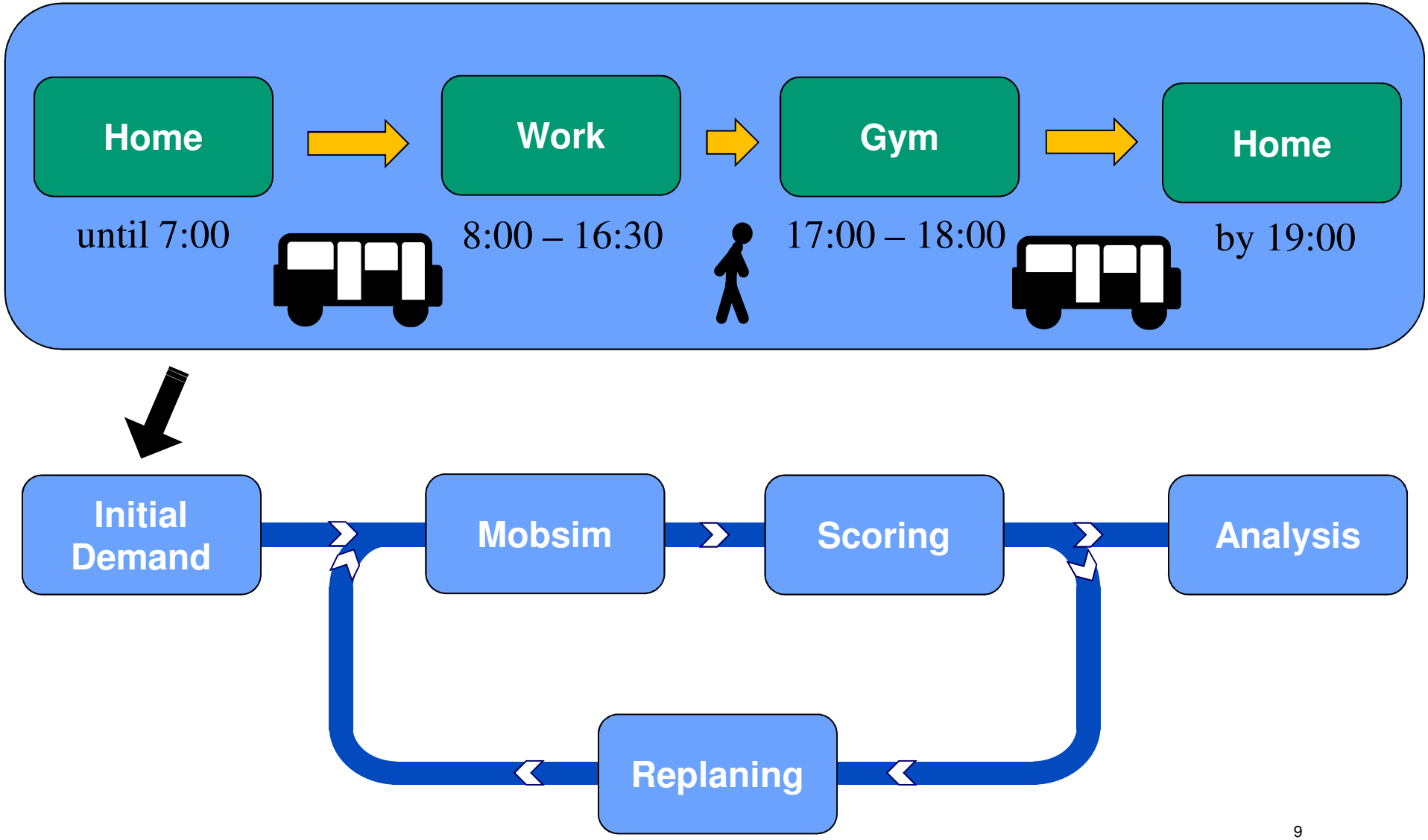
On-Demand Transit

- publically accessible, on-demand or via bookings, D2D or station based

Conventional Transit, operated autonomously

Summary of service forms proposed in Jermann (2019)

# The Multi-Agent Transport Simulation (MATSim)



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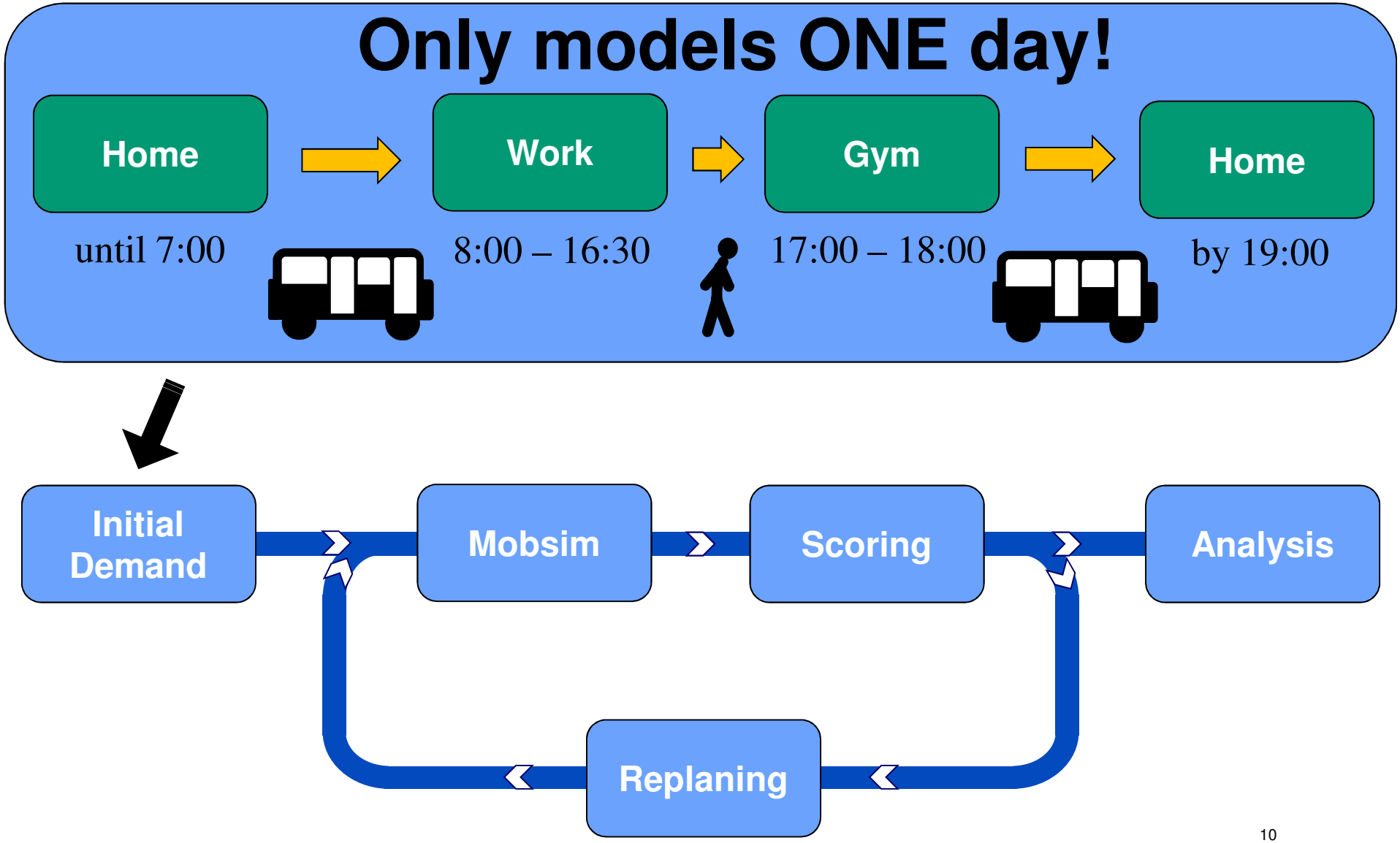

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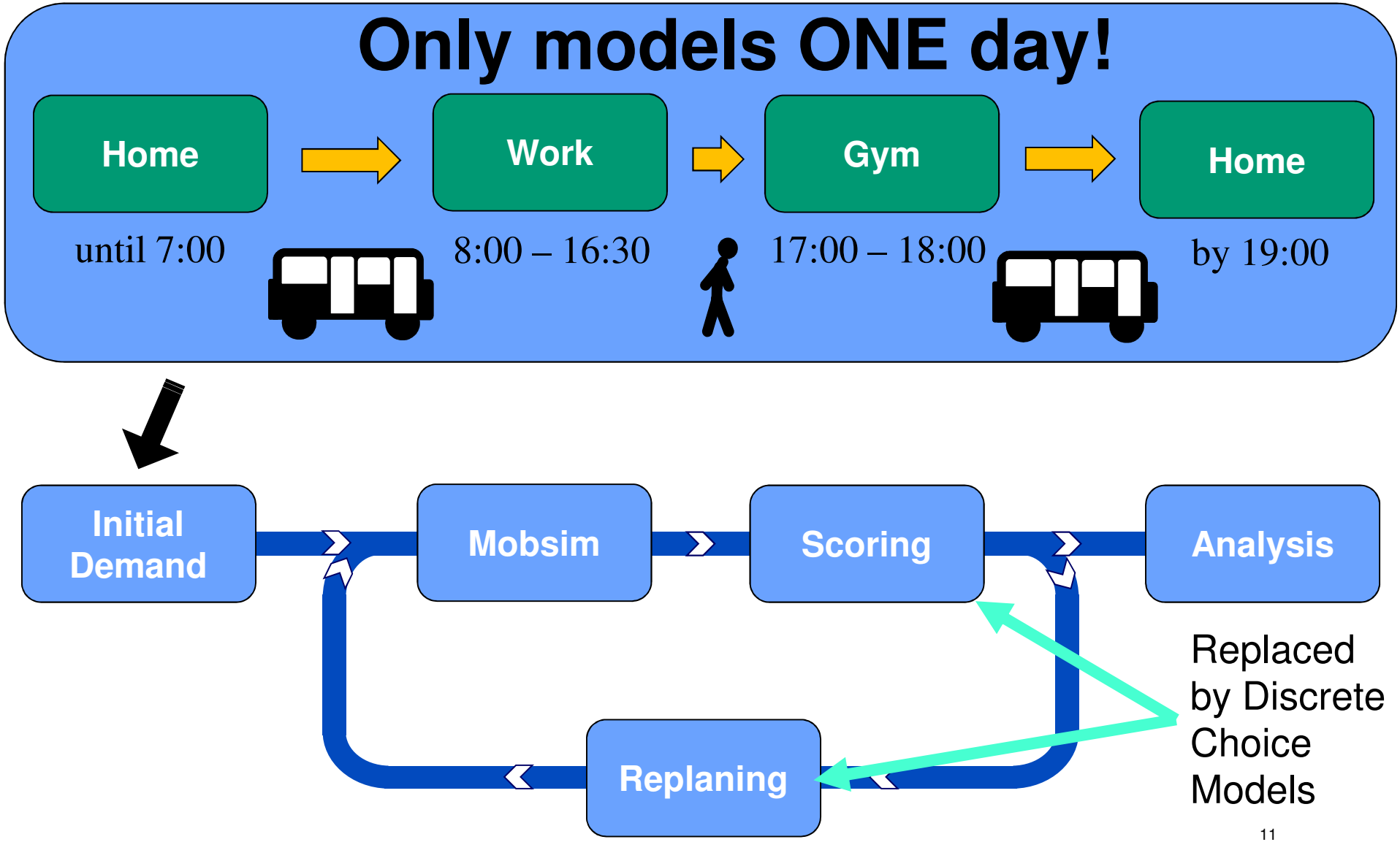


# What can our version MATSim currently simulate?

Agent Choice:

- Route Choice
- Mode Choice

Vehicles:

- Flow Efficiency (consumption of road capacity)
  - By vehicle type and roadway type
- Passenger Capacity

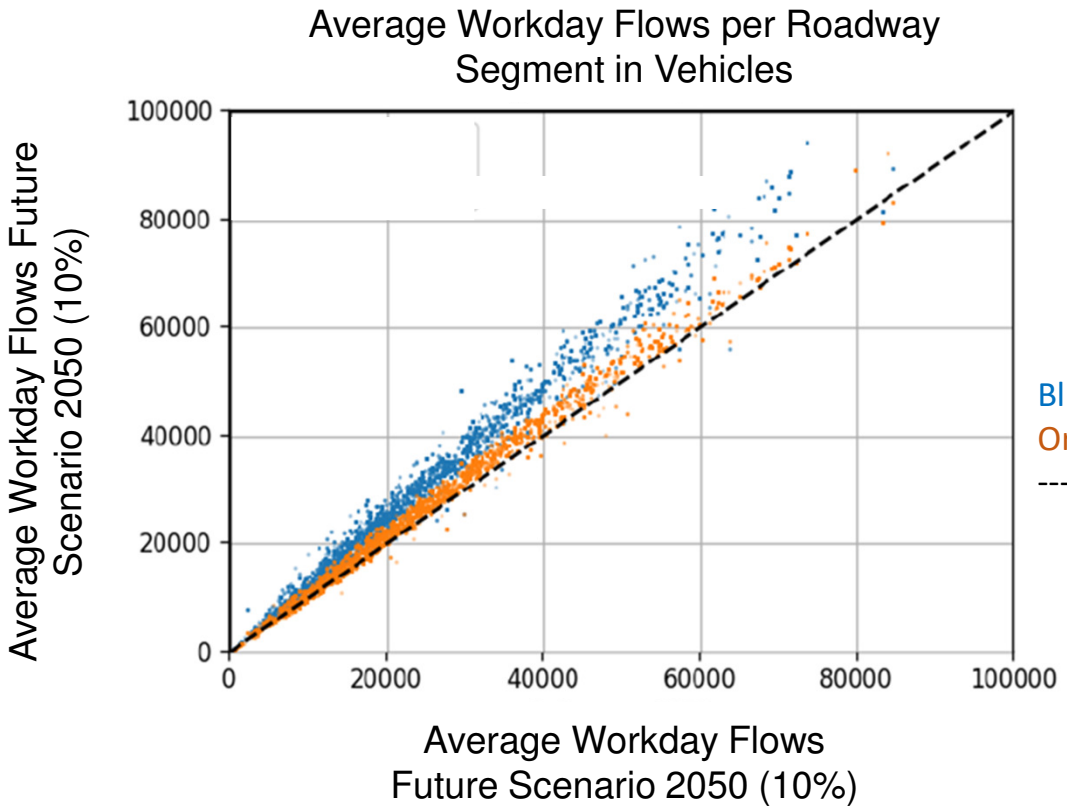
AV Taxi Fleets (D2D, on-demand):

- Dynamic dispatching
- Adaptive pricing
- Pooling (only pools at endpoints!)

Network:

- Road capacities
- Permitted maximum velocity
- Vehicle use restrictions/permissions

# Average Workday Flow on Switzerland's high capacity network, comparing the base scenario 2020 and future scenario 2050




Cause of the increase in AWF:

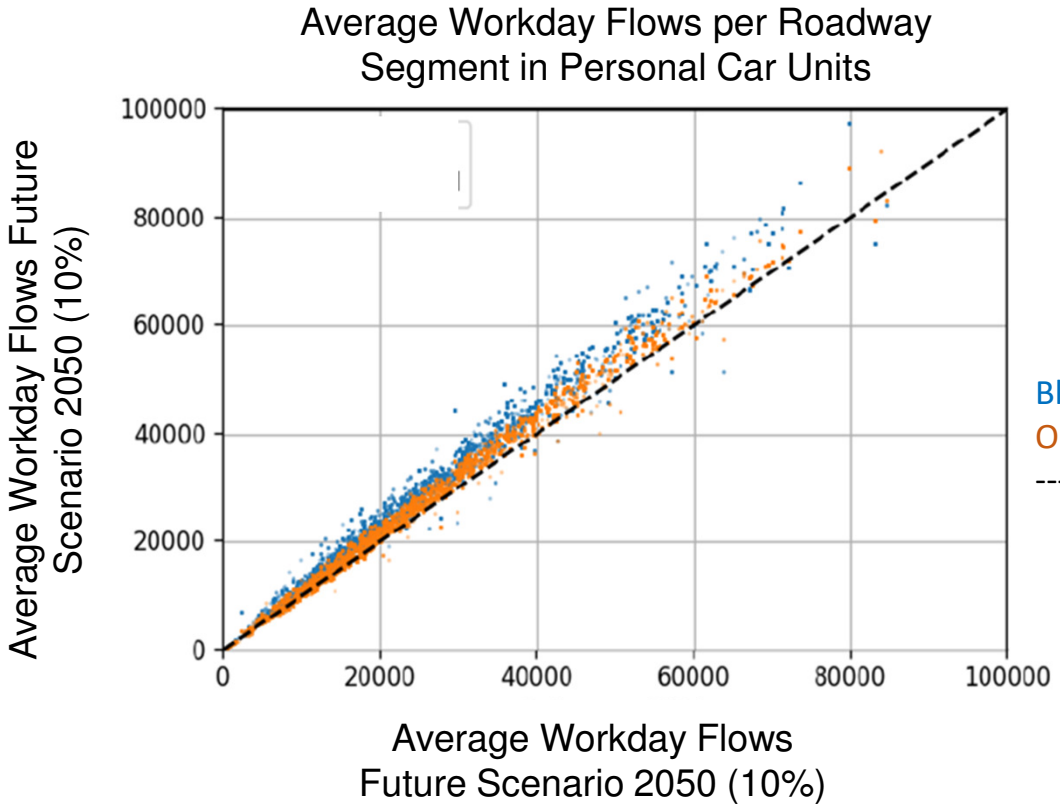
- Mode Choice

Blue = 2050 with 34% of **private** cars being AVs
Orange = 2050 without any AVs
---- = Base Scenario 2020

10% Sample, x10 für 100%-Values

Data and Graphic from: Livingston, Axhausen (2019)

# Average Workday Flow on Switzerland's high capacity network, comparing the base scenario 2020 and future scenario 2050




Conclusion: Demand will outpace efficiency gains

Blue = 2050 with 34% of **private** cars being AVs
Orange = 2050 without any AVs
---- = Base Scenario 2020

10% Sample, x10 für 100%-Values

Data and Graphic from: Livingston, Axhausen (2019)

# What would we need to improve simulation of AV scenarios?

Agent Choice:

- Route Choice
- Mode Choice (monomodal trips, multimodal chains)

Presumed effect on Demand as **Person**-km on Roads

+ Access to PAVs for current “captive riders”
+ Location Choice
+ Activity Choice (“trip making”)
+ allow activities in vehicles
+ Multi-modal trips
+ “score” by vehicle type and road segment, to account for partially automated vehicles
+ Collective travel Households
+ Collective travel Social
+ allow “bookings” “ahead of time” for taxis
+ Personal Goods Trips

Estimated Difficulty:
Medium
Difficult
Very Difficult
Radical Change

# What would we need to improve simulation of AV scenarios?

Agent Choice:

- Route Choice
- Mode Choice (monomodal trips, multimodal chains)

Presumed effect on Demand as **Vehicle**-km on Roads

+ Access to PAVs for current “captive riders”
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# What would we need to improve simulation of AV scenarios?

Vehicles:

- Flow Efficiency (consumption of road capacity)
  - By vehicle type and roadway type
- Passenger Capacity

Presumed effect on Demand as **Vehicle**-km on Roads

+ explicitly simulate private autonomous vehicles acting as "chauffeurs" (enabling PAV-Work-Walk-Shop-PAV-Home, etc.)

+ explicitly simulate autonomous parking search/management (private AVs)

+ explicitly simulate other empty trips associated with households sharing a PAV (private AVs)

+ explicitly simulate parked and stopped vehicles on roads

Estimated Difficulty:
Medium
Difficult
Very Difficult
Radical Change
Questionable Feasibility

# What would we need to improve simulation of AV scenarios?

AV Taxi Fleets (D2D, on-demand):

- Dynamic dispatching
- Adaptive pricing
- Pooling (only pools at endpoints!)

  + bundle trips along route

  + accept new riders “on-the-way”

+ add “feeder” taxis (extension exits, but is it compatible?)

+ allow “bookings” “ahead of time” for taxis

Presumed effect on Demand as **Vehicle**-km on Roads

Estimated Difficulty:
Medium
Difficult
Very Difficult
Radical Change
Questionable Feasibility

# What about Freight?

In the Verkehrsperspektiven 2040, a report by the Swiss Federal Agency for Spatial Development (ARE) (Justen et al., 2016) :

- Assuming a GDP growth of 46% and population growth of 28%,
- Freight T-km will grow by 37% on both road and rail, whereas passenger P-km will only grow by 25%
- Higher costs of road freight will push some to rail, about a 2% shift, resulting in a modal split of 61% road and 39% rail.
- The type of freight transported will change, shifting from heavier goods such as ores, construction materials, and glass to chemicals, synthetics, and wastes.
    - These high-growth goods are lighter, so will vehicle-km grow faster than T-km?

Reviewed works: Justen et a. (2016)

# What about Freight with AVs?

- AVs could lower the cost of road-freight, and cause a shift from rail to road instead of road to rail
- The types of freight projected to grow the most are largely those predicted to be likely to shift to autonomous operation, potentially exacerbating the above rail to road shift.

Current Status of our version of MATSim:

Currently heavy freight is being integrated into MATSim as simple background loading.

- Freight “agents” use 1 vehicle type and always follow the same plan: they do not perform choices

Delivery vehicles are still missing.

Reviewed works: Oehry et al. (2018), Jerman (2018)

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- The types of freight projected to grow the most are largely those predicted to be likely to shift to autonomous operation, potentially exacerbating the above rail to road shift.

+ “active” freight agents that can make choices

Current Status of our version of MATSim:

Currently heavy freight is being integrated into MATSim as simple background loading.

- Freight “agents” use 1 vehicle type and always follow the same plan: they do not perform choices

Delivery vehicles are still missing.

+ delivery vehicles as background loading

Reviewed works: Oehry et al. (2018), Jerman (2018)

# What about Freight?

Difficulties with integrating freight and delivery vehicles fully into MATSim:

- Lack of data – especially for delivery vehicles. MATSim requires data to include locations, their sequential relationship, and their temporal relationship.
- Lack of Knowledge on Freight and Delivery Operations
  - How should freight and delivery agents make decisions?
    - Between AV and non-AV? Between routes? Between times of day?
    - What temporal limitations do different freight categories have?

# Conclusion

Priority:

- Access to PAV for current “captive riders”
- Integrate delivery vehicles as background loading
- Develop/find a better algorithm for ridesharing/pooling
- Explicit simulation of parked and stopped vehicles on roads
- Autonomous parking management
- Multi-modal trips
- Collective planning of household travel
- “Active” freight and delivery agents
- “Score” by vehicle type and road segment, to account for partially automated vehicles

Wishlist:

- location choice
- activity choice (“trip making”)
- personal goods trips

# Literature


Published:

Justen, A., Mathys, N., Frick, R., Ickert, L., Sieber, M., Bruns, F., Rieser, N., Menzi, R., Humm, O., Sidler, C. (2016) Verkehrsperspektiven 2040 Entwicklung des Personen- und Güterverkehrs in der Schweiz, *Verkauf Bundespublikationen Art. –Nr.812.104.d*, Schweizerische Eidgenossisches Departement für Umwelt, Verkehr, Energie, und Kommunikation UVEK, Bundesamt für Strassen ASTRA

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