# Modeling automated flexible feeder solutions

## CTR-dagen 2019-05-14

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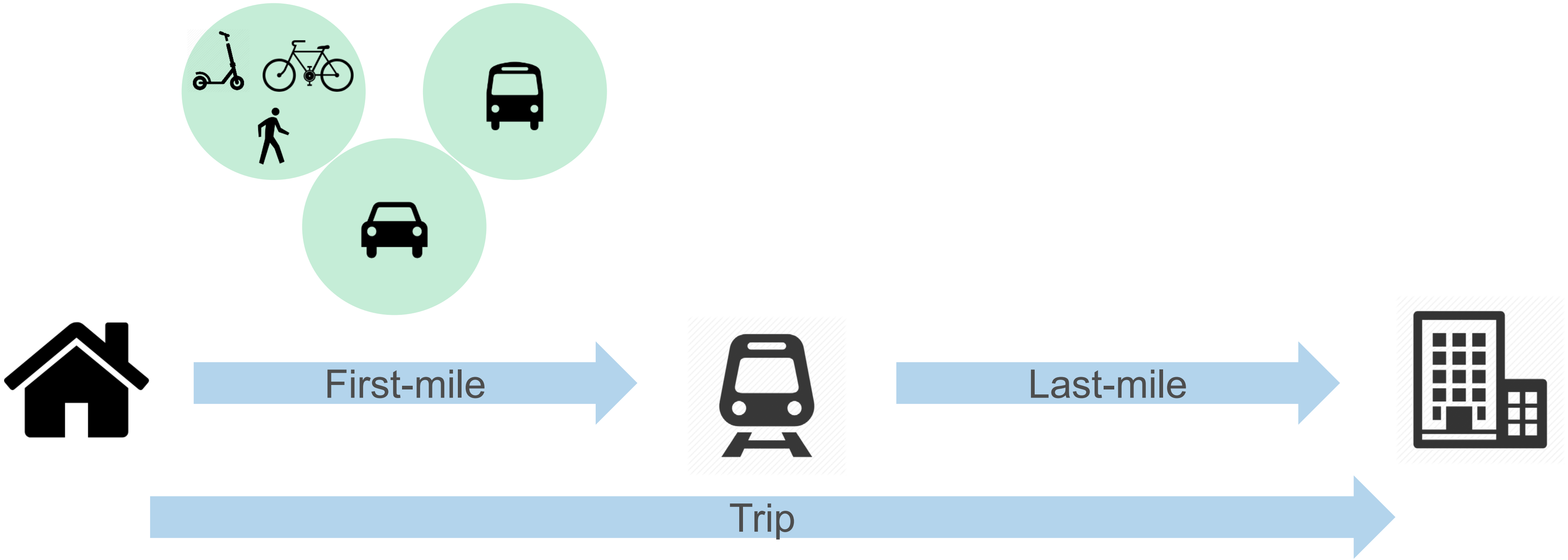
CTR project: Simulation and modelling of autonomous road transport, SMART

# Improving first/last-mile mass transit connectivity

- Widely viewed as a key factor in transit mode choice
- Often difficult to provide fixed transit at high level-of-service for a reasonable operational cost



First-mile

Last-mile

Trip

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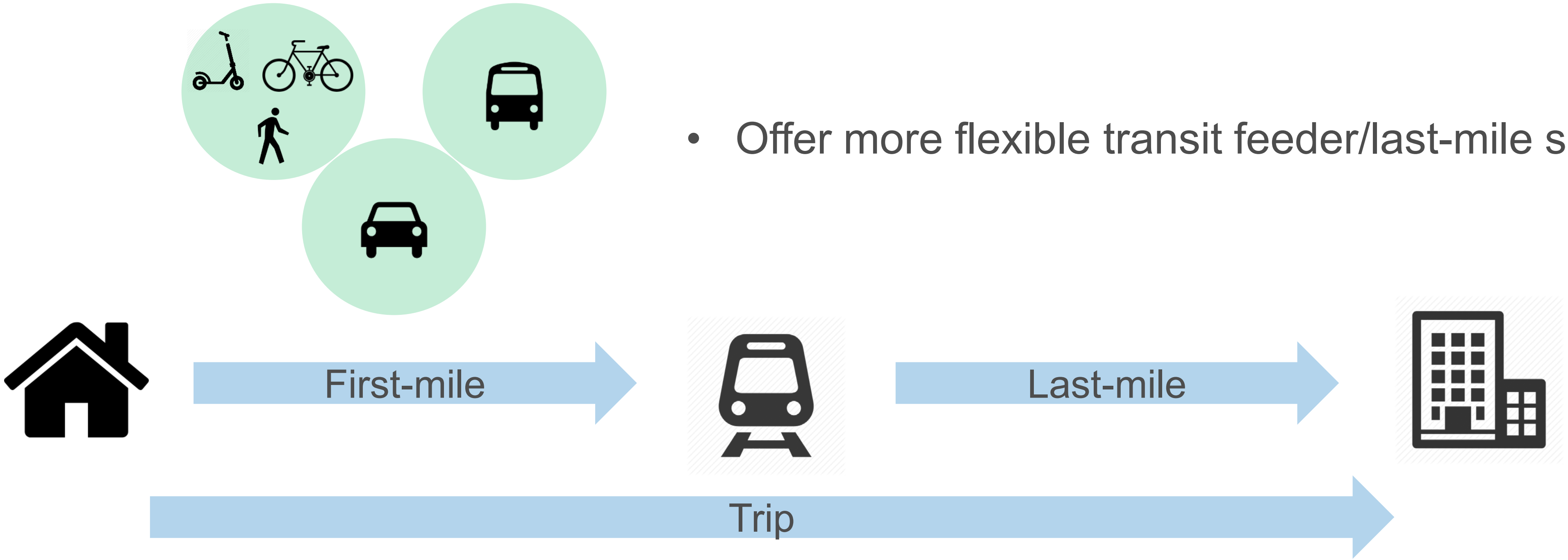

- Offer more flexible transit feeder/last-mile solutions

# A popular use case for automated vehicles

- Integration of automated vehicles with existing public transit a popular pilot study
- Automated vehicles (SAE level 4-5) potentially requires no driver
    - (~50-70% of operational cost in public transit in developed countries)
- Sensor network and connected vehicles reduce uncertainty in public transit situation awareness and real-time cooperative fleet management

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How to evaluate such services prior to implementation?

# Research objectives

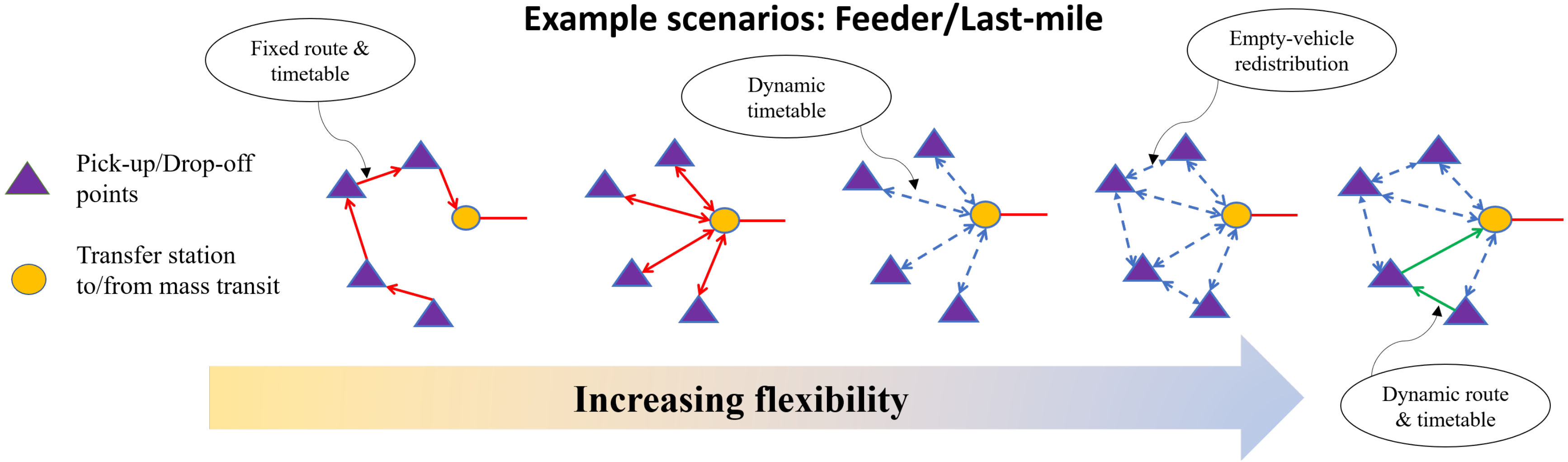
***Research objectives:***

1. Expand the set of simulation tools to evaluate flexible transit systems
2. Evaluate emerging public transit solutions

***Research question:***

Should vehicles within an automated feeder solution follow a fixed, or on-demand operational policy?

**Example scenarios: Feeder/Last-mile**



Pick-up/Drop-off points

Transfer station to/from mass transit

Fixed route & timetable

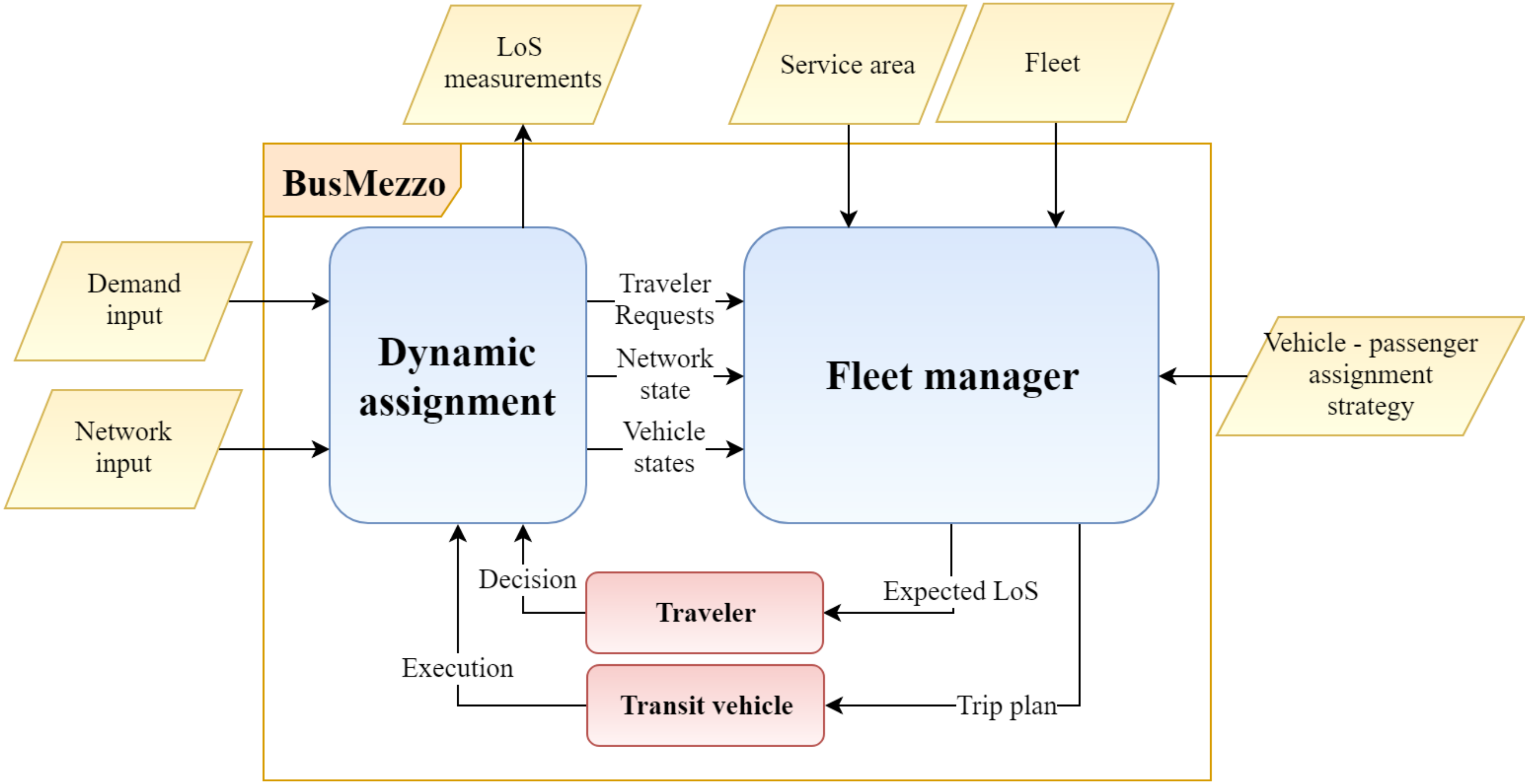
Dynamic timetable

Empty-vehicle redistribution

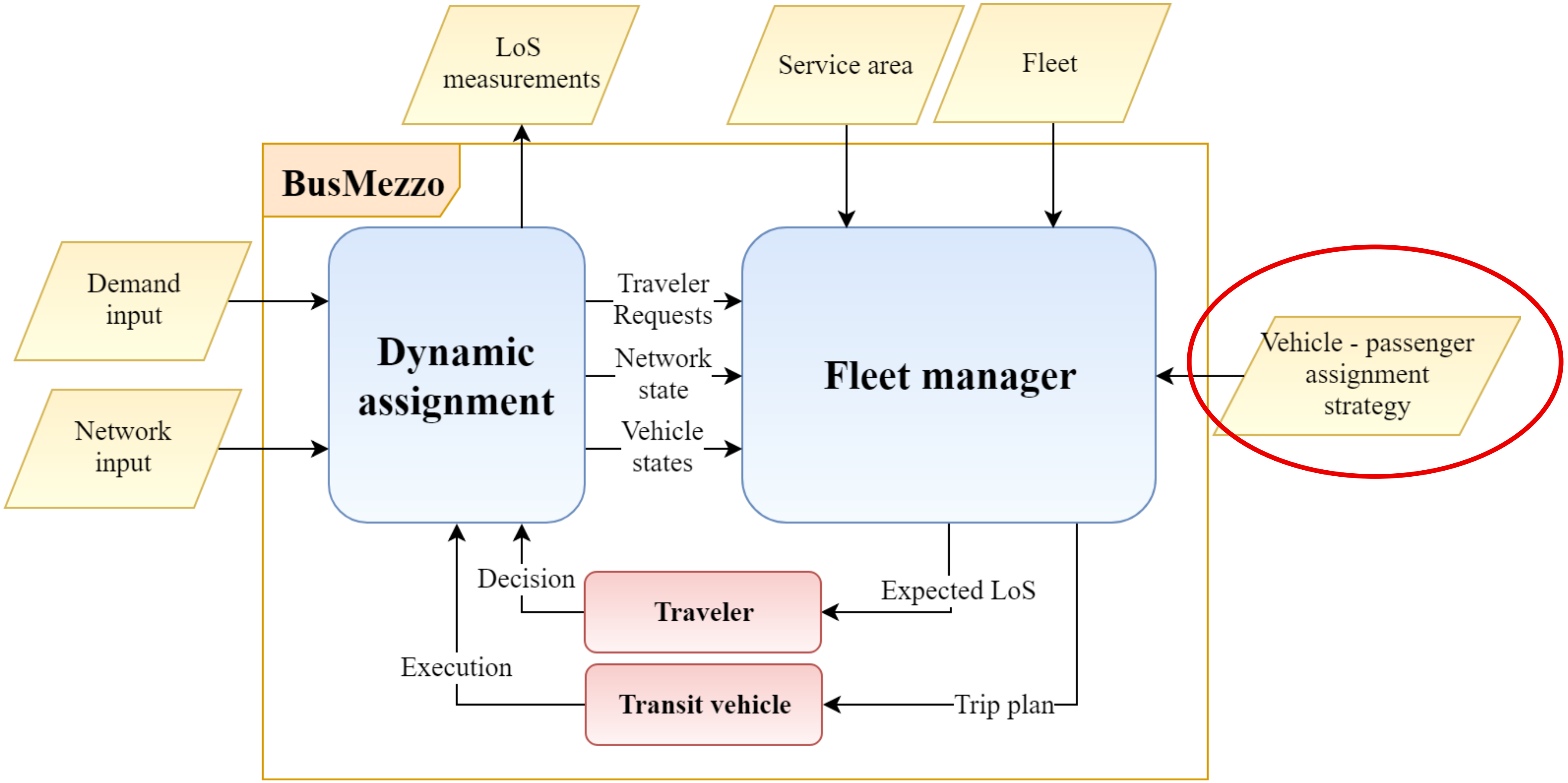
Dynamic route & timetable

**Increasing flexibility**

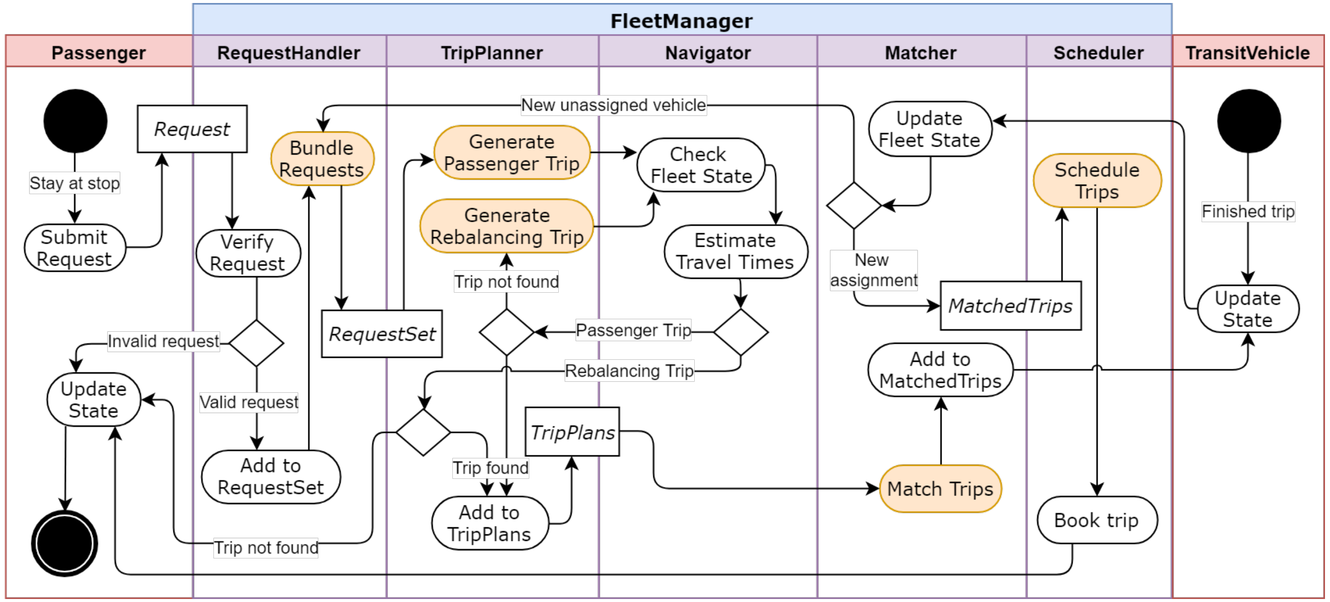
# Methodology



# Methodology

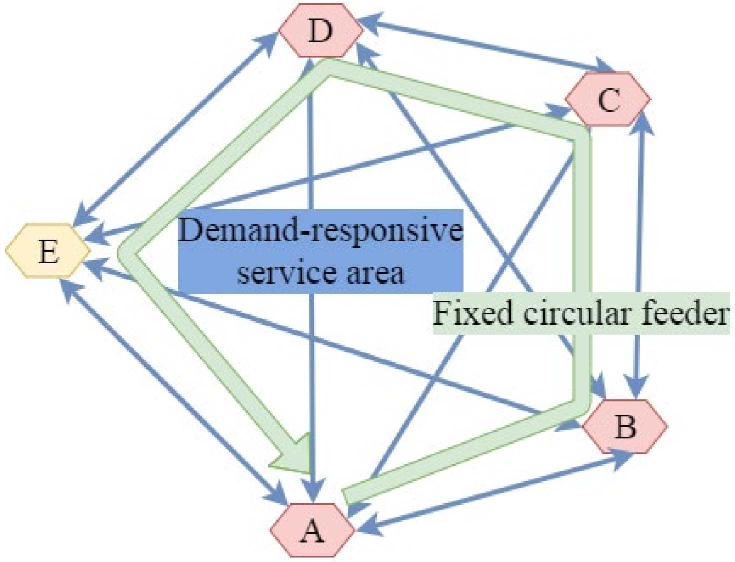


# Greedy and reactive strategy



**Basic idea:** Iteratively assign the closest in terms of expected travel time empty vehicle to the highest currently known count of requests with shared OD

# Case study



- 2 fleets with comparable service capacity and operational cost per hour with vehicle automation
  - 2 non-AVs of passenger capacity 50
  - 4 AVs of passenger capacity 25

- 5 demand levels, highest exceeding fixed service capacity

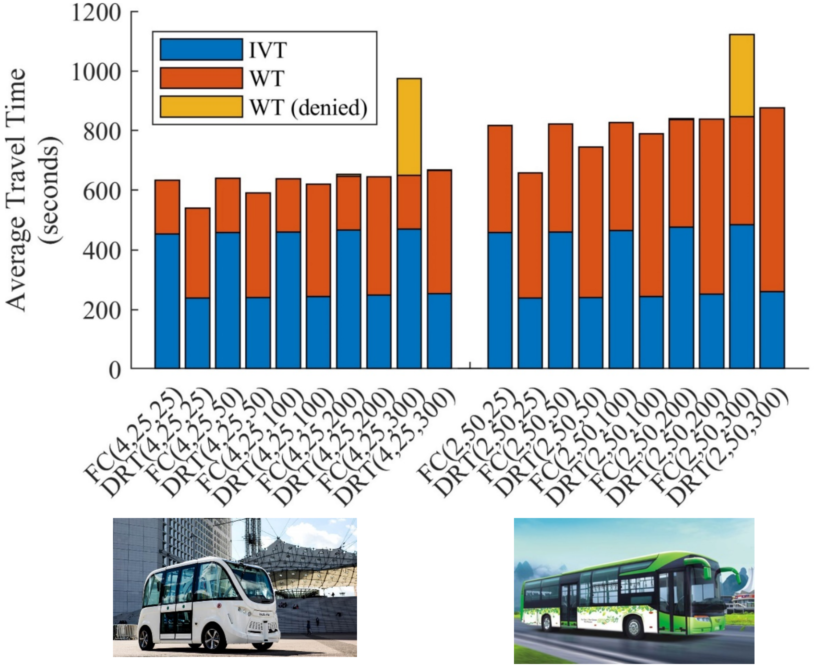
# Performance evaluation

- Nominal travel times (Waiting, In-vehicle, Waiting if denied)
- Weighted travel costs
- Total waiting time reliability  (CV)
- Equity of total waiting time (Gini coefficient)
- VKT
- System cost (operational + weighted travel costs)

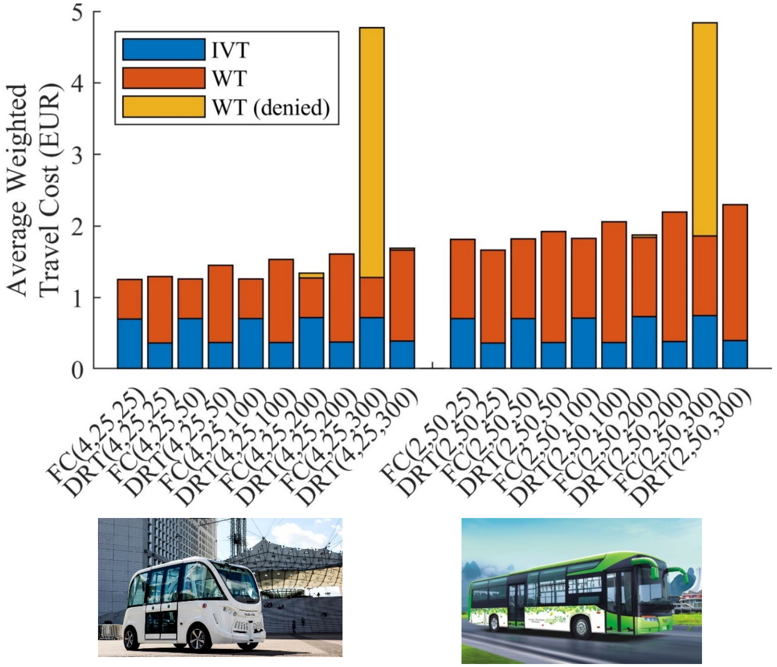
# Results –average LoS

- Larger fleet improves LoS (not suprising)
- Lower average travel time with on-demand service
- Higher average weighted travel cost per passenger due to differences in waiting time

*Nominal travel times*

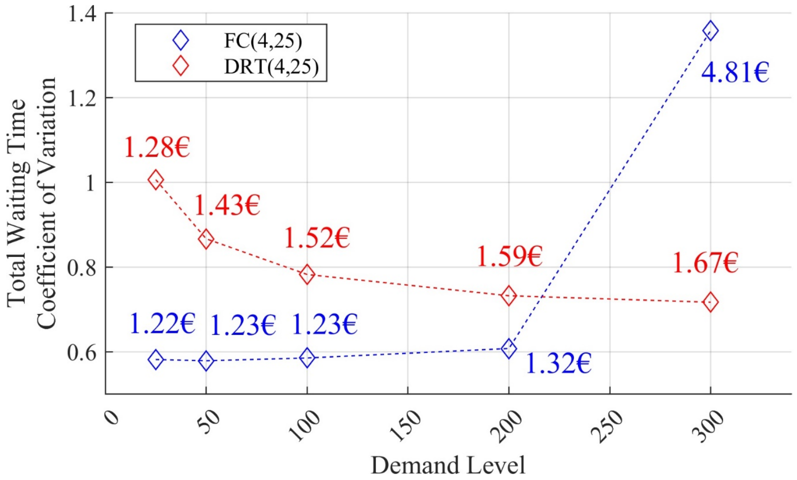


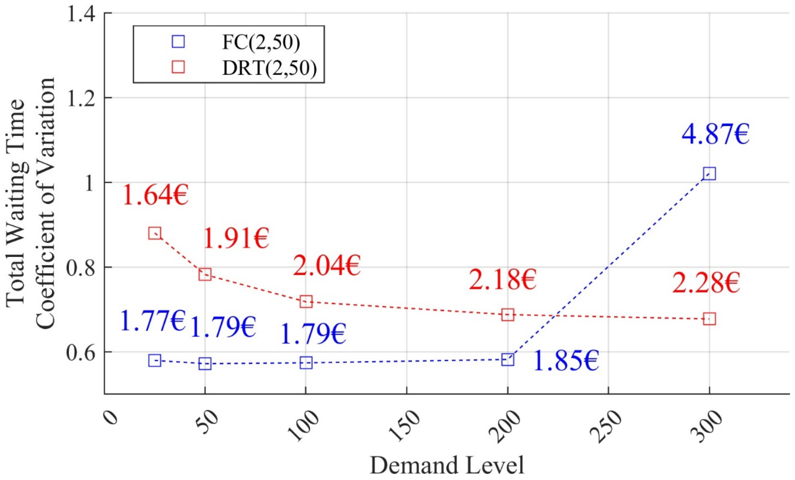
*Weighted travel costs*



# Results – waiting time reliability

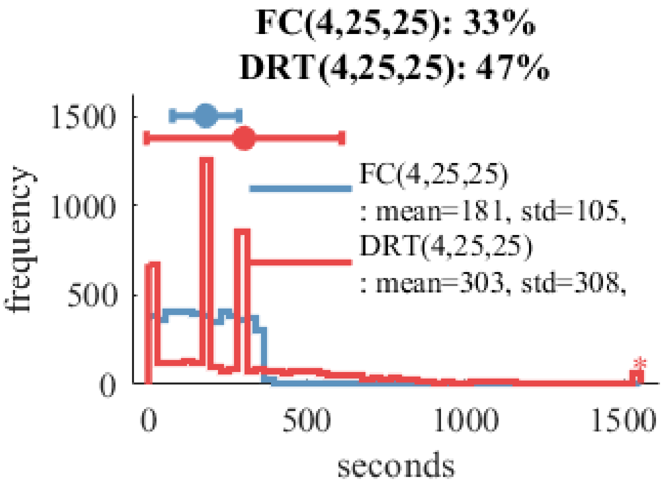
- Fixed service operations more reliable in terms of waiting time
- On-demand strategy results in relative variance that decreases with higher demand levels

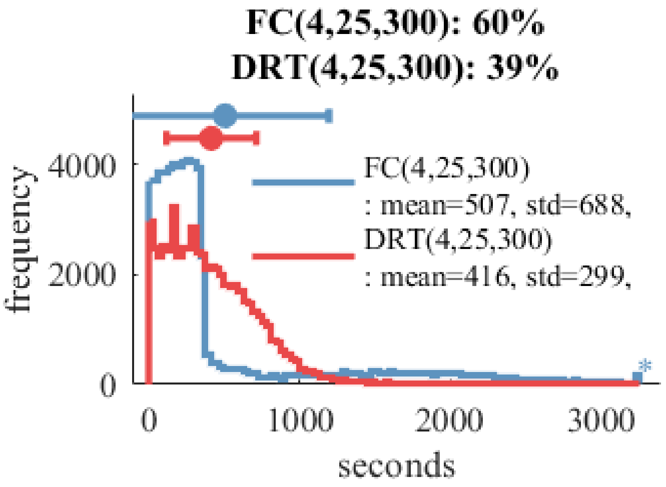




# Results – equity of waiting time

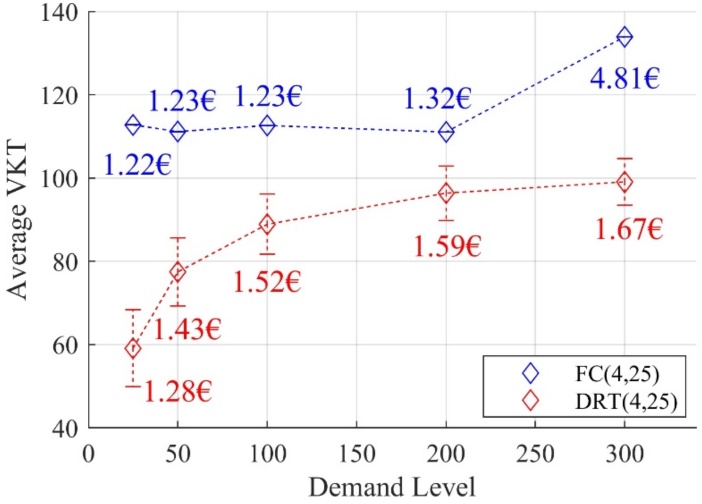
- On-demand coordination results in more even distribution of waiting time costs when service capacity is exceeded
- Waiting time distributed more evenly under fixed operations

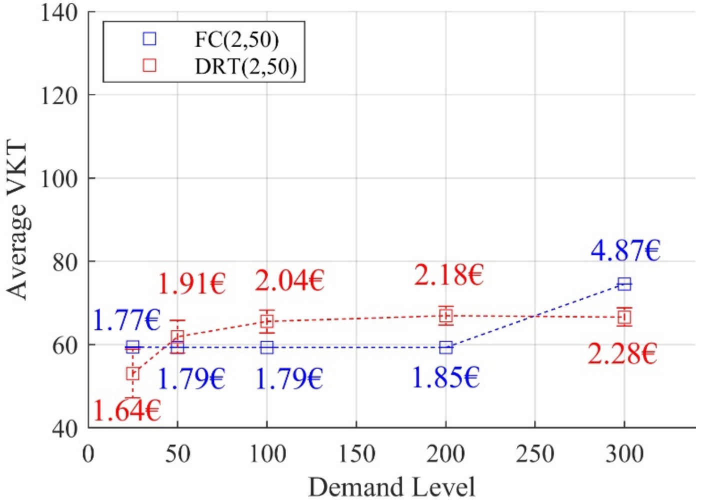

FC(4,25,25): 33%
DRT(4,25,25): 47%


FC(4,25,300): 60%
DRT(4,25,300): 39%

# Results - VKT

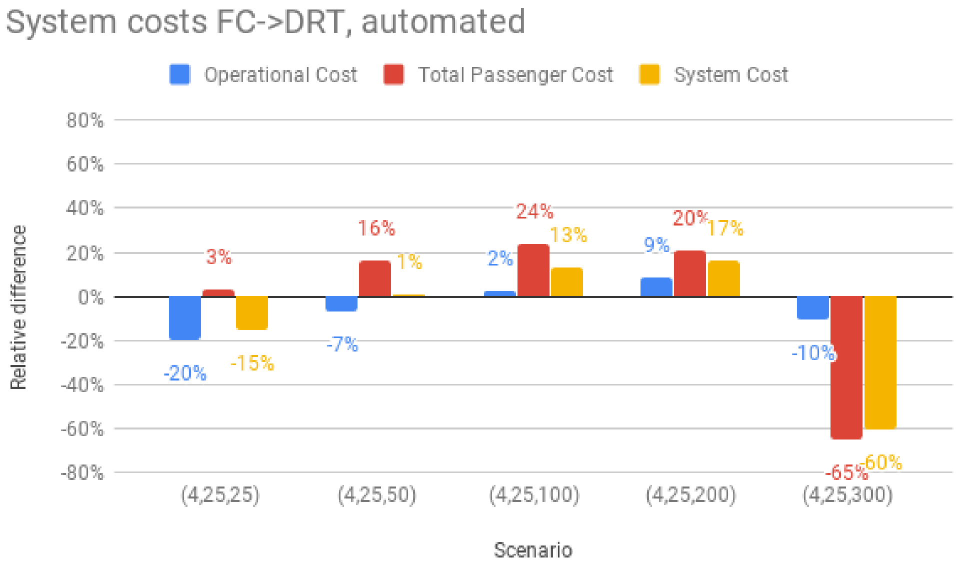
- Fixed services drive continously, higher VKT for larger fleet
- On-demand scheduling results in lower VKT per passenger for lower demand levels

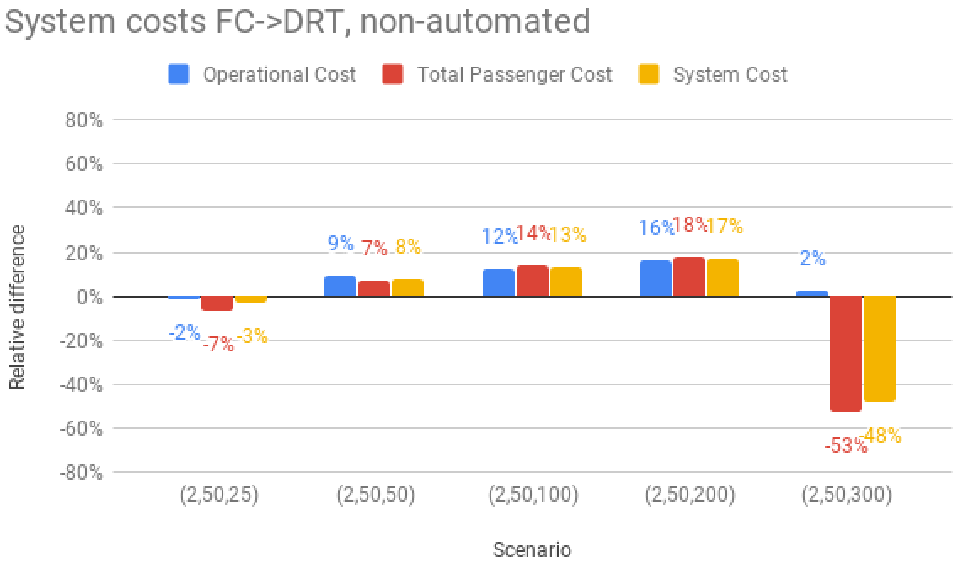




# System costs

- On-demand coordination results in lower system costs for lowest levels of demand due to reduction in distance-based costs
- When service capacity is exceeded, on-demand coordination is superior relative to fixed


System costs FC->DRT, automated


System costs FC->DRT, non-automated

# Conclusions

- Fixed operations more reliable for all demand levels below maximum service capacity and provides higher LoS for mid-range demand
- For decreasing levels of demand intensity, on-demand LoS tends to improve for lower VKT/passenger. Total system costs are reduced for the lowest levels of demand regardless of fleet
- When service capacity is exceeded, on-demand coordination results in a higher, more equal LoS

# Future work

*Two main directions:*

1. Utilize existing framework to evaluate and compare additional strategies for on-demand coordination
2. Extend framework to model co-existing fixed and flexible services

Thank you for your attention!

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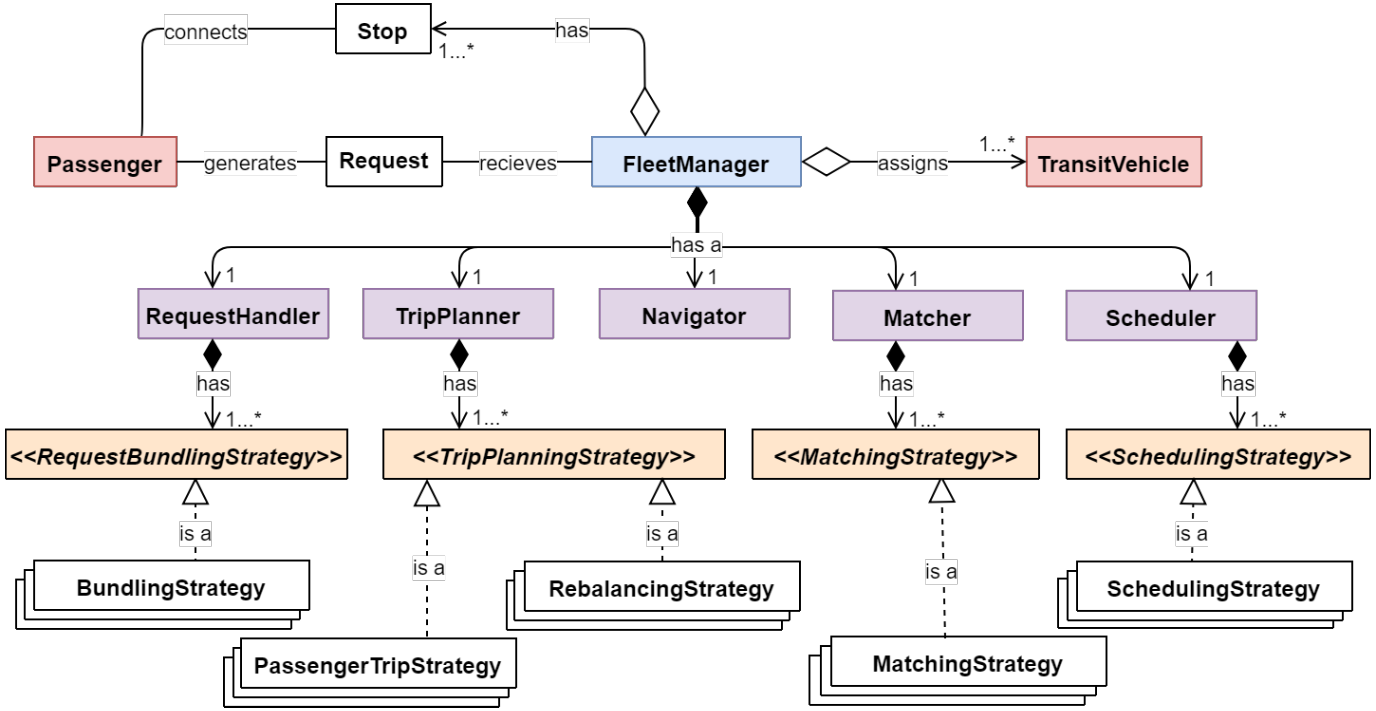
# Appendix - Subproblems of on-demand fleet coordination

1. *RequestHandler*
   - receiving, bundling and sorting requests
2. *TripPlanner*
   - feasibility of trip plans for vehicles to serve currently known and/or forecasted requests
3. *Matcher*
   - evaluate candidate trip plans to matching with available vehicles
4. *Scheduler*
   - adjust dispatch, pick-up and drop-off schedule of matched vehicles
5. *Navigator*
   - Definition of shortest path



# Appendix: FleetManager strategy

**Greedy algorithm for passenger – vehicle assignment:**

- *Request bundling* – Group requests by shared OD
- *Trip Planning* – prioritizes generating trips for OD stop pair with the highest passenger count and most direct (in terms of scheduled in-vehicle time) service route
- *Vehicle Matching* – Match the longest waiting on-call vehicle found at the origin stop of an unmatched planned trip
- *Empty-vehicle strategy* – Generate a trip from the current stop of the closest on-call transit vehicle to the origin stop of the OD with the highest passenger count.
- *Vehicle Scheduling* – Schedule matched trips for dispatch immediately
- *Demand Prediction* – None, all of the above are reactive to requests received in real-time