Modeling automated flexible feeder solutions

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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
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

• 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?

![Diagram showing fixed and dynamic route scenarios](example_scenarios.png)

*Example scenarios: Feeder/Last-mile*

- Fixed route & timetable
- Dynamic timetable
- Empty-vehicle redistribution
- Dynamic route & timetable

*Increasing flexibility*
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 surprising)
- Lower average travel time with on-demand service
- Higher average weighted travel cost per passenger due to differences in waiting time
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
Results - VKT

- Fixed services drive continuously, 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
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