On the Importance of Demand Consolidation in Mobility on Demand

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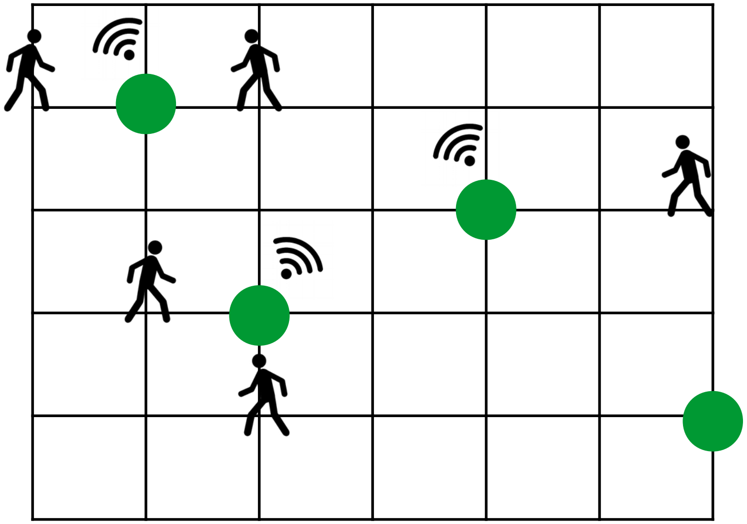
Terms and definition

Consolidation in mobility services

- high capacity in Mobility on Demand
- less admitted stop points to serve more requests
- consolidation as ***aggregation***



AMoDSim

- Open-source simulator for future generation mobility on demand services
- https://github.com/admaria/AMoDSim.git

Outline

Consolidation in MoD systems:

- ➔ Operator cost
- ➔ User QoS

Motivation

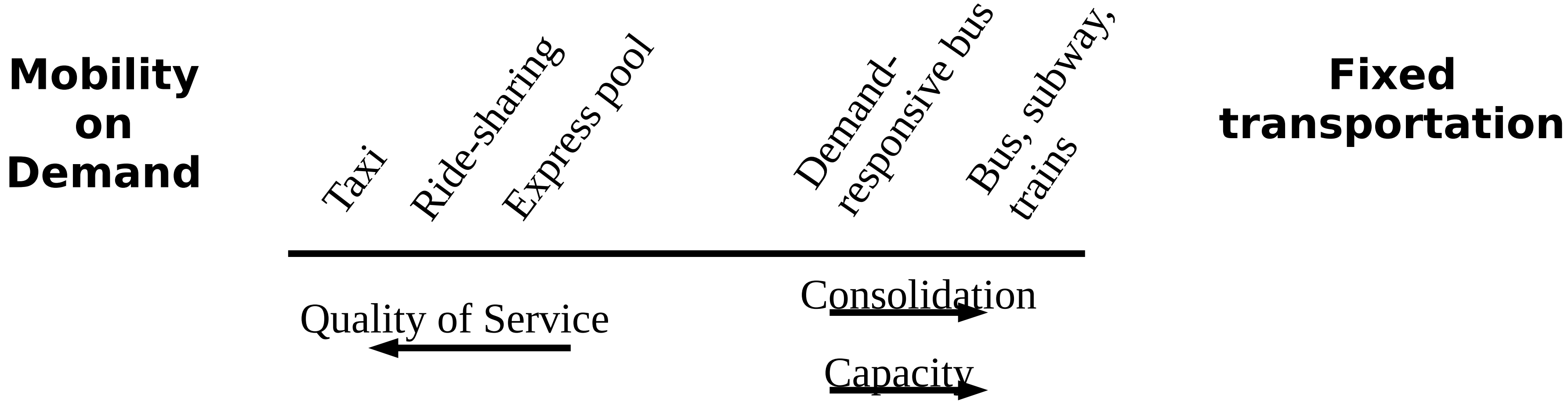
System model

A case study

Introduction

Evolution in landscape of transportation driven by ICT

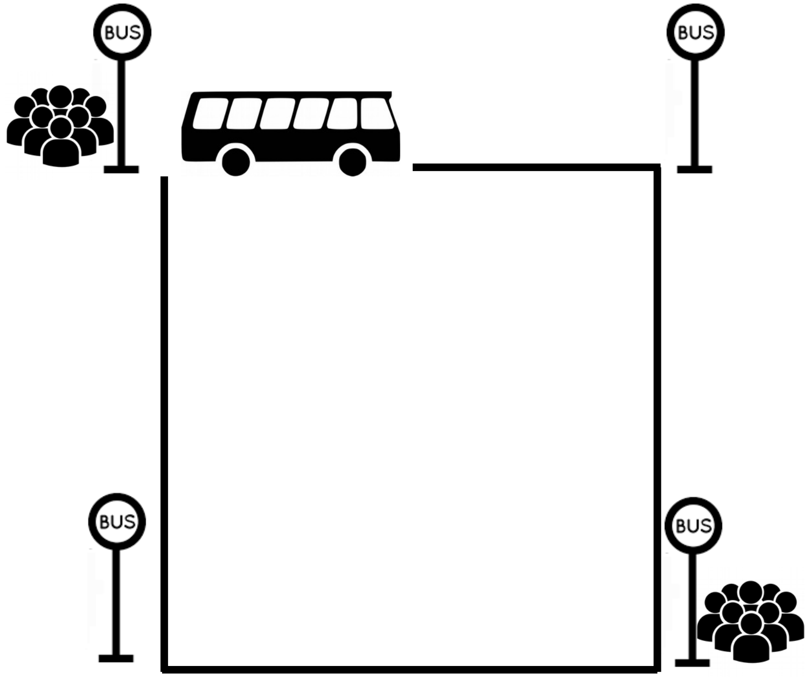
- Emergence of Ride Sharing services
- Autonomous Mobility on Demand services (**AMoD**)



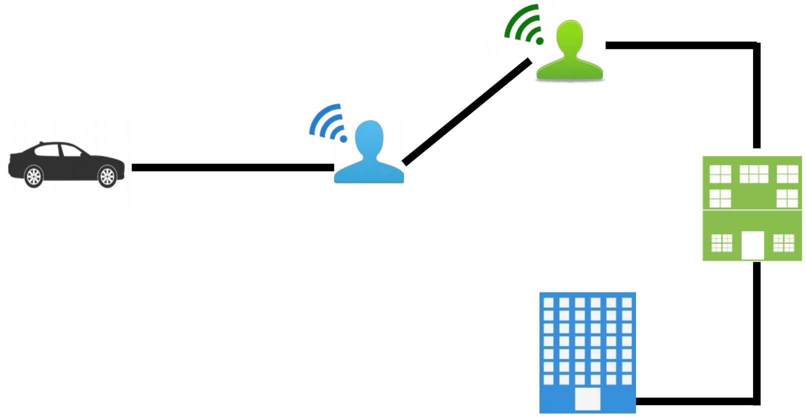
Role of consolidation in mobility on demand

MoD vs fixed transportation

Traditional bus

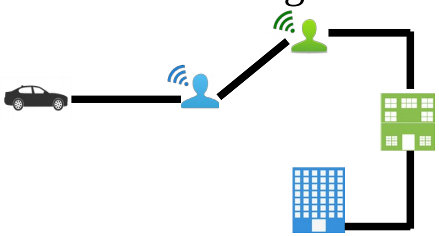


Ride-sharing service

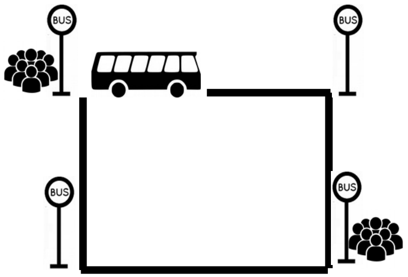


MoD vs fixed transportation

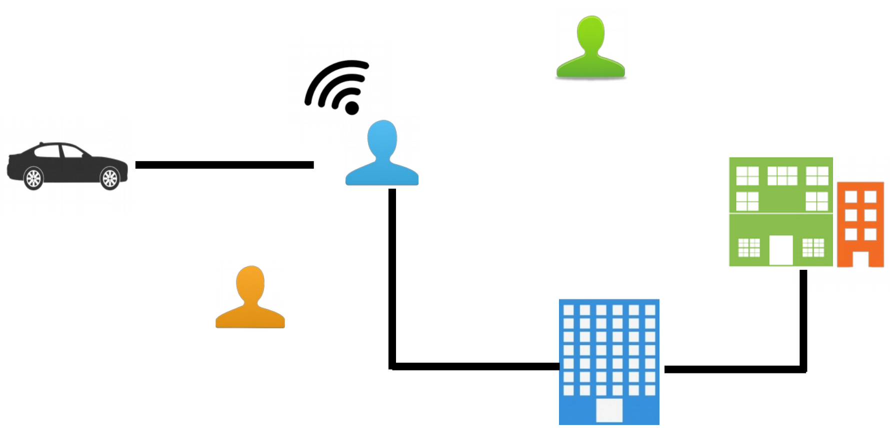
Ride-sharing service



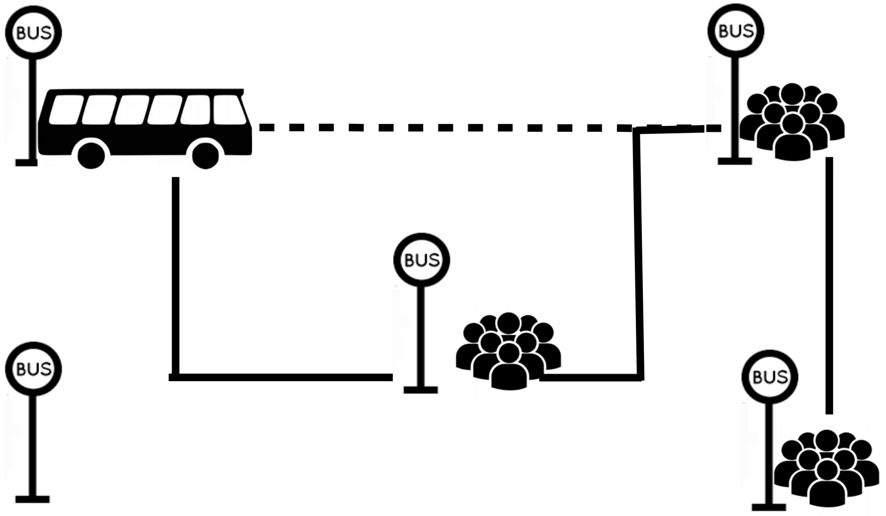
Traditional bus



Express pool service



Demand-responsive bus



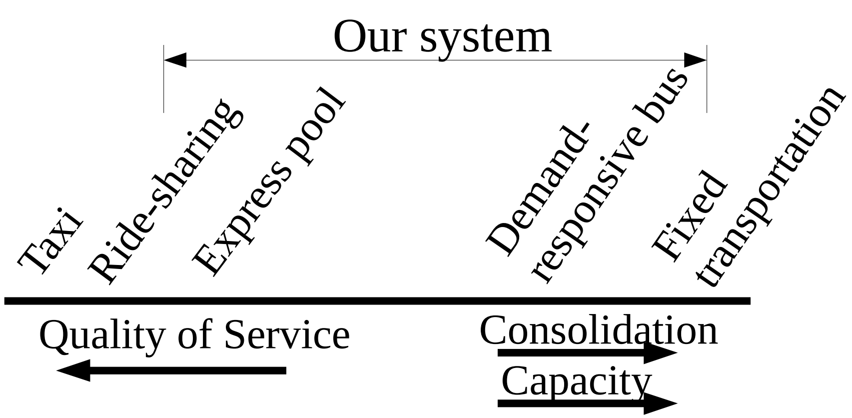
Motivation

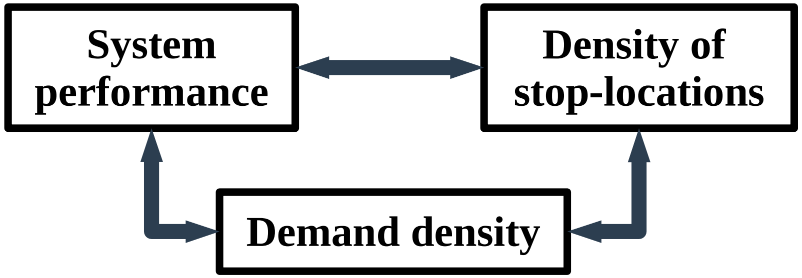
Fill the gap between the door-to-door services and fixed transportation

- ➔ Combine the flexibility of MoD with high capacity

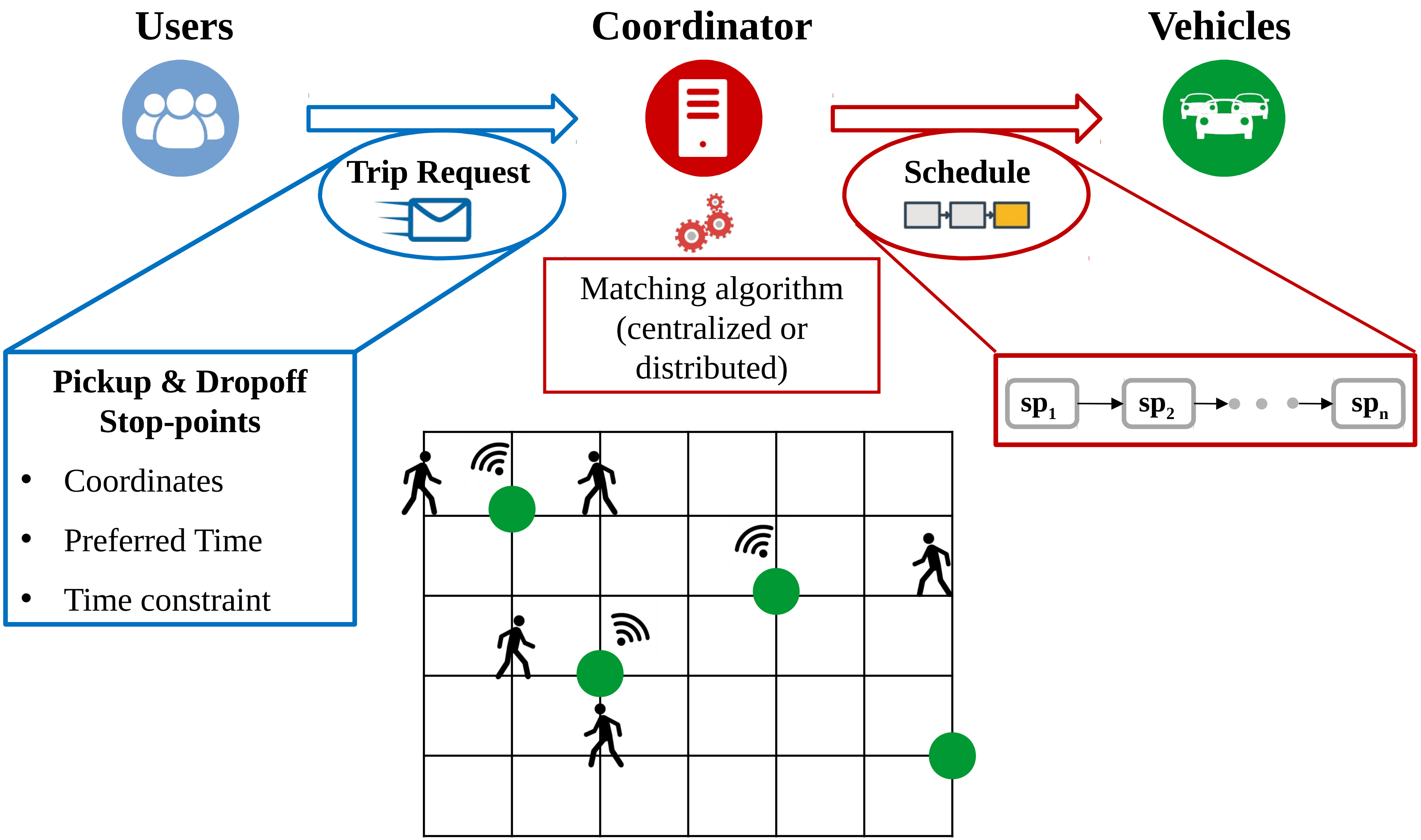
Consolidation in our system…

- Dynamic stop location density
- Flexibility of vehicle routes
- Multiple vehicles per area
- On-line request-to-vehicle matching

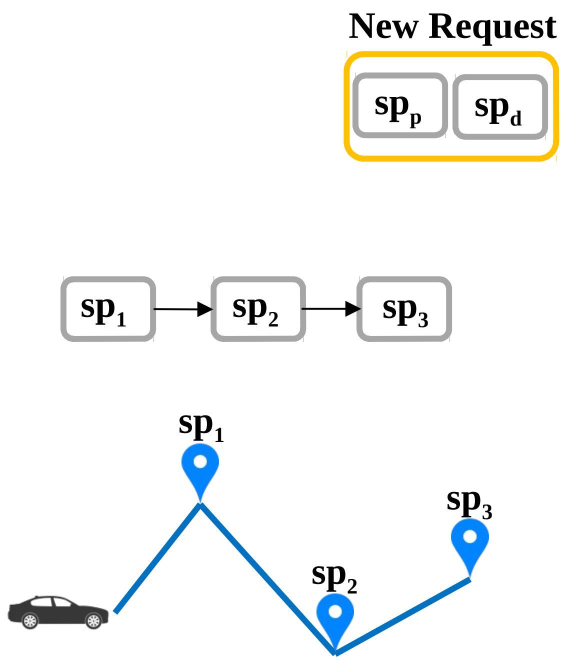


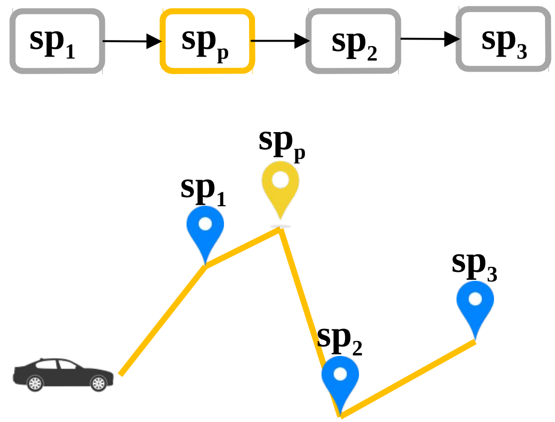


System model



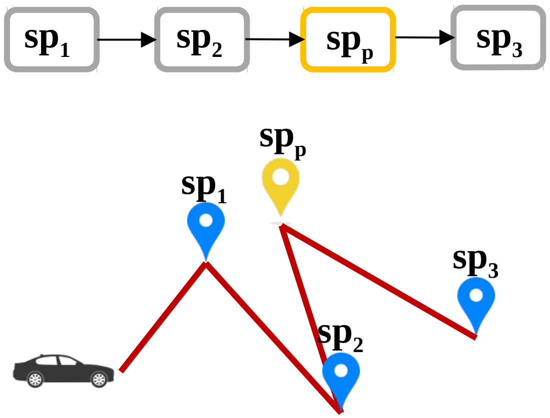
Time constraints





Is feasible?
(max extra-time)

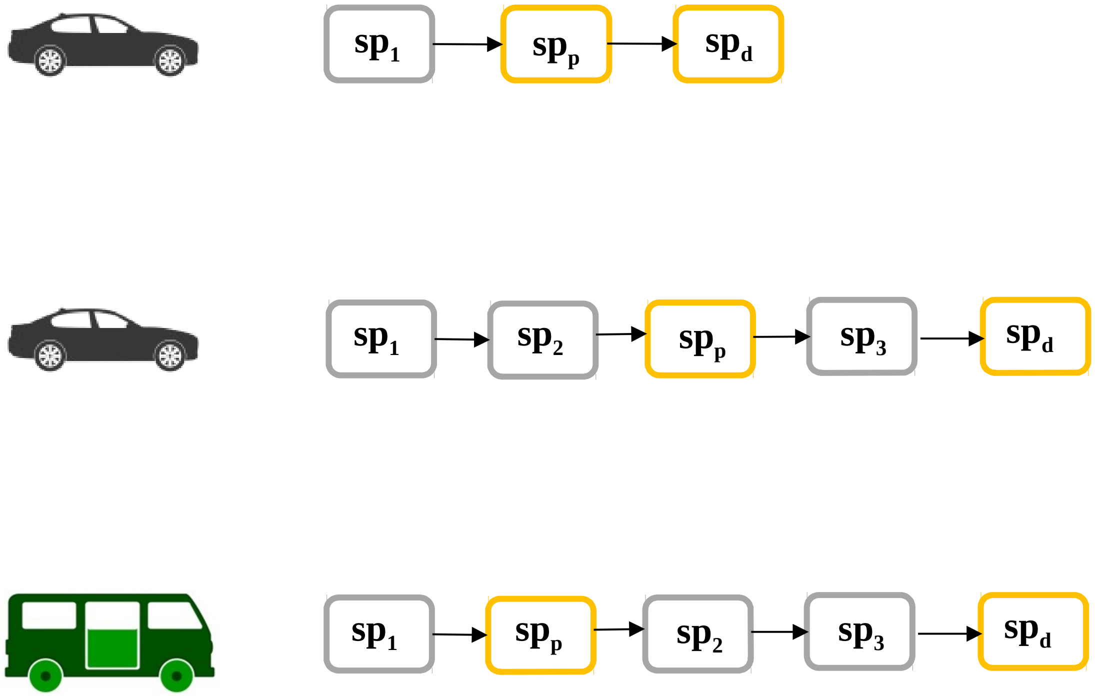
Additional Cost: C1



Is feasible?
(max extra-time)

Additional Cost: C2

Time constraints



Additional Cost: **C1**

Additional Cost: **C2**

Additional Cost: **C2**

Case study: Scenario

Network
Manhattan Grid that cover an area of 60 km^2 *[5]*

Fleet
500 up to 1000 vehicles

Seat
No-limited capacity vehicles

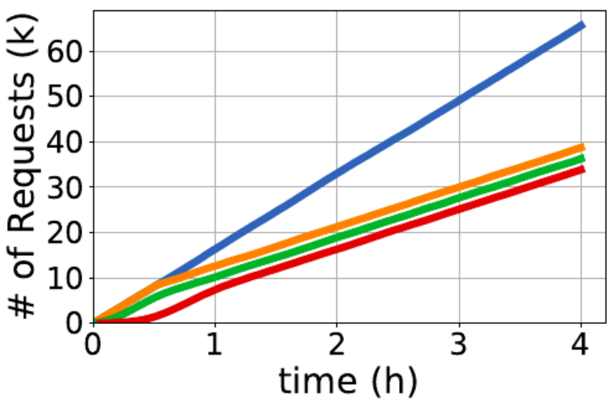
Requests
20 up to 320 per hour per km^2 with Poissonian arrivals *[6,7]*

Space between stops
80m up to 860m

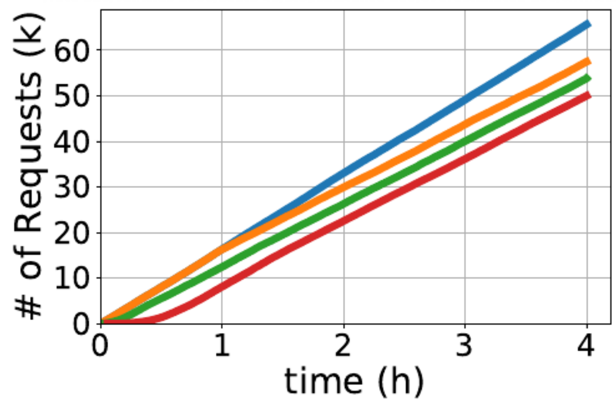
Runs
4 hours simulations
AMoDSim simulator *[8]*

Impact on system capacity

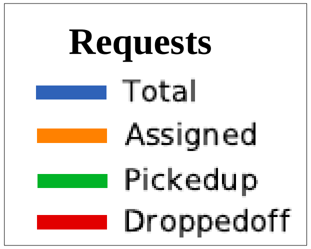
No consolidation

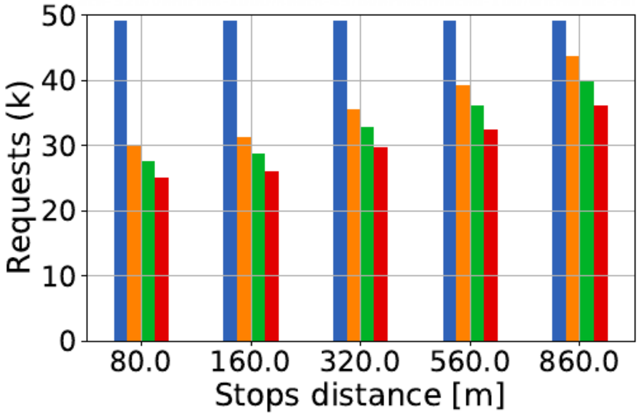


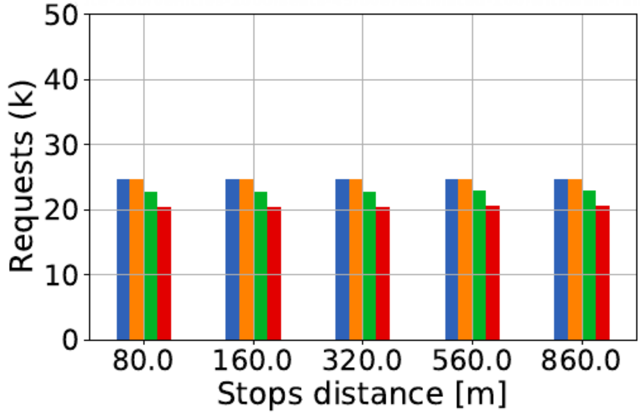
Stop spacing 860m



- 320 requests per h per km² [1, 2]
- 1000 vehicles





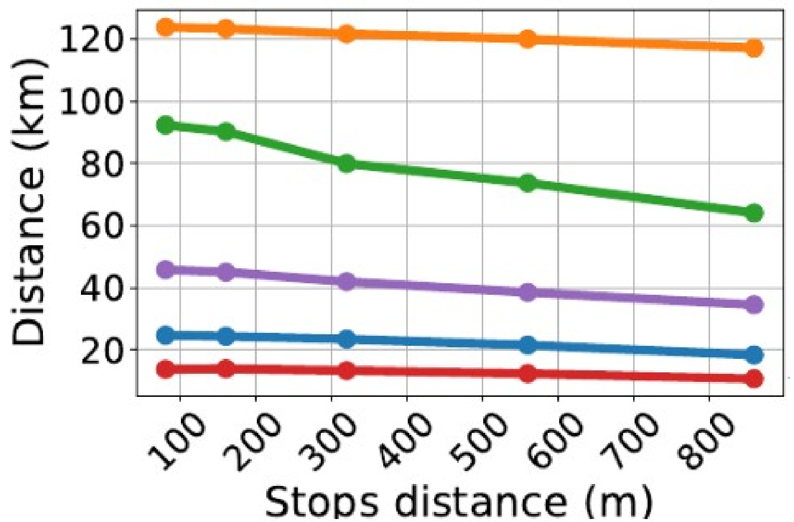


160 requests per h per km²

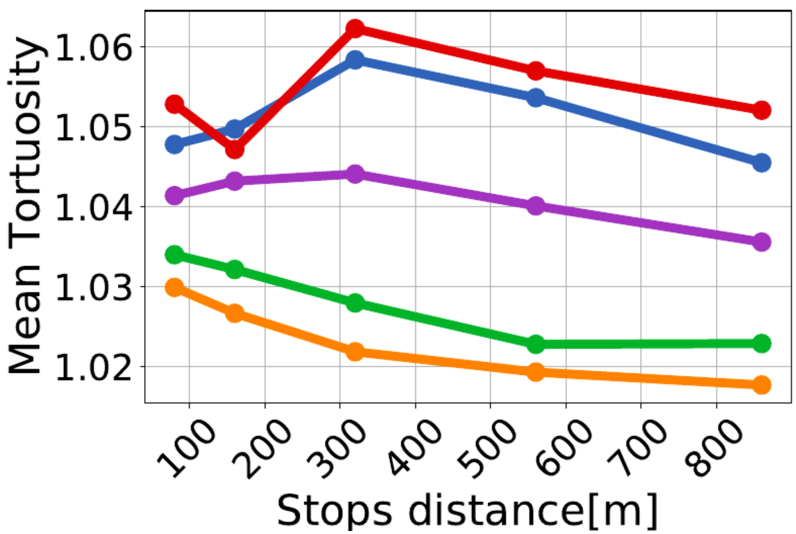
Impact on route efficiency

- 1000 vehicles

Per-vehicle traveled distance



Tortuosity of a vehicle route



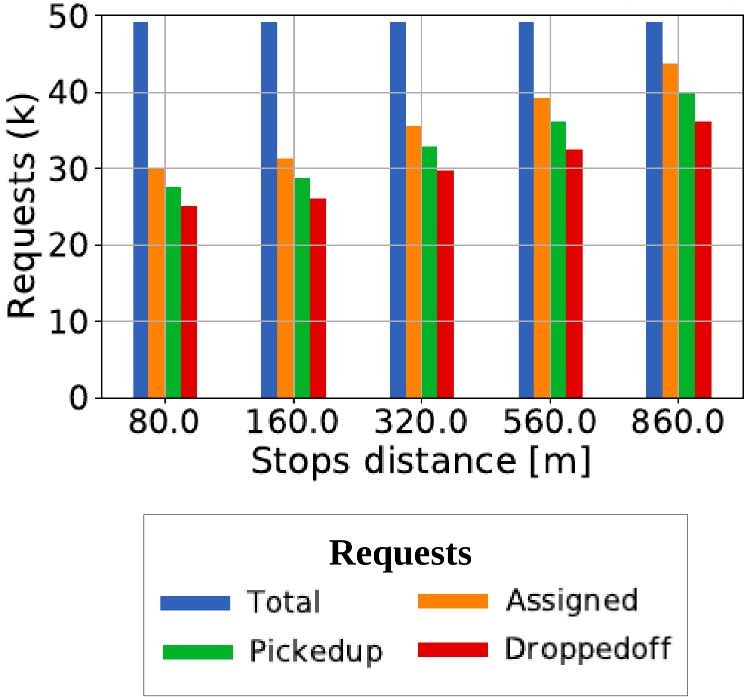
Requests per hour per km^2

20 40 80 160 320

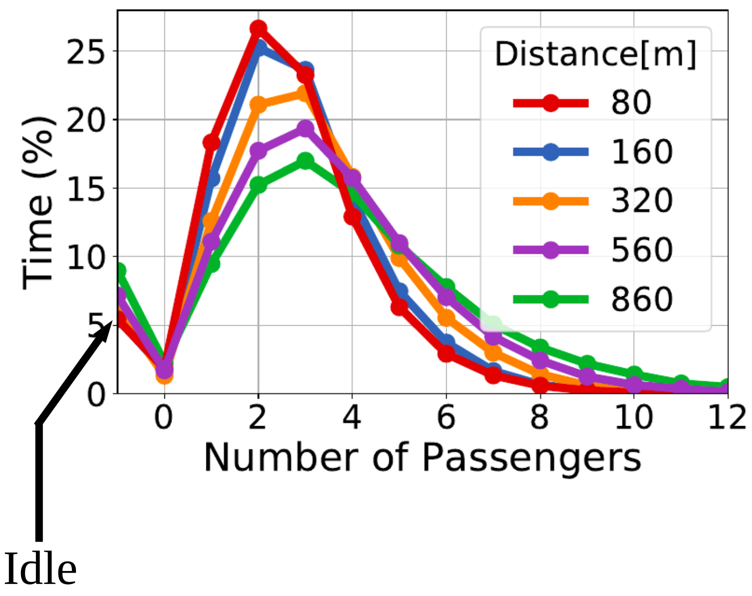
Impact on sharing degree

- 320 requests per h per km² [1, 2]
- 1000 vehicles

System load

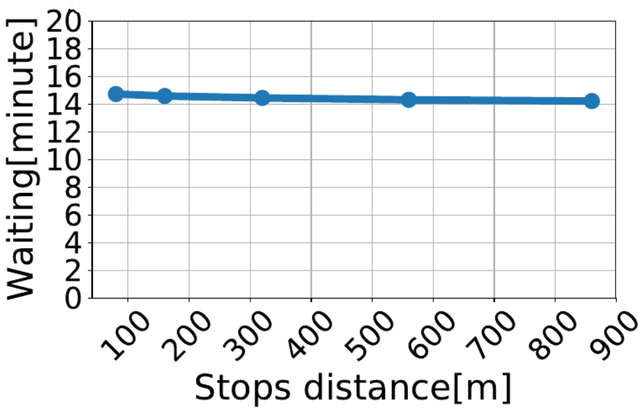


Per-vehicle occupation

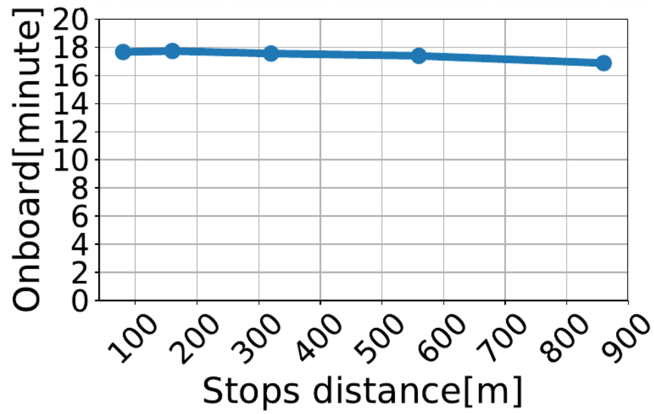


Impact on Quality of Service

Per-person waiting time

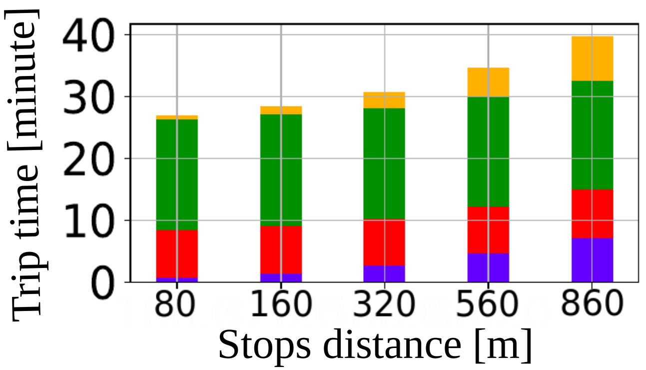


Per-person onboard time

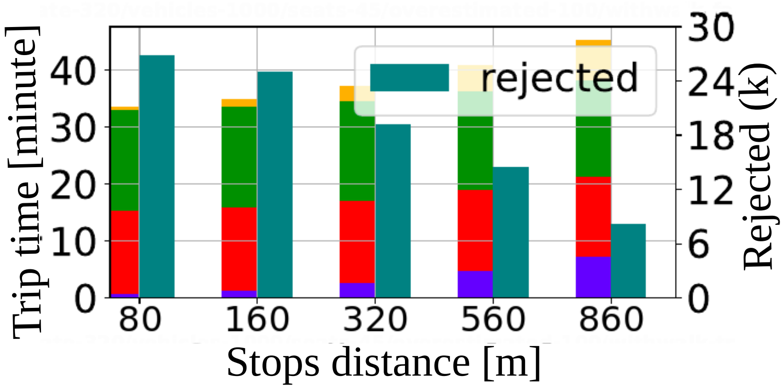


- 320 requests per h per km² [1, 2]
- 1000 vehicles

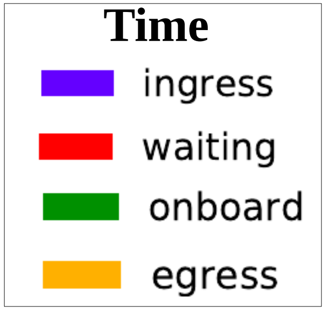
Per-trip total time



20 requests per h per km²



320 requests per h per km² [1, 2]



Conclusions

Varying the Consolidation degree (varying the stop density)...

- you have a system in between ride sharing and bus
- favor *high capacity* or *quality of service*

NOT absolute benefits

- beneficial when demand is high with respect to the number of vehicles

AMoDSim simulator

- Open source
- https://github.com/admaria/AMoDSim.git

References

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External References

Landscape of transportation references

[1] J.Lo and S.Morseman, “The Perfect uberPOOL: A Case Study on Trade-Offs”, in Ethnographic Praxis in Industry Conf., 2018.

[2] A. J. Hawkins, “Uber Express Pool Offers the Cheapest Fares Yet in Exchange for a Little Walking”, 2018.

[3] L. Quadrifoglio and X. Li, “A methodology to derive the critical demand density for designing and operating feeder transit services.”, Transportation Research Part B, vol. 43, no. 10, pp. 922–935, 2009.

[4] S. Chandra and L. Quadrifoglio, “A model for estimating the optimal cycle length of demand responsive feeder transit services”, Transportation Research Part B: Methodological, vol. 51, pp. 1–16, 2013.

Scenario related References

[5] M.Hyland and H.Mahmassani, “Dynamic Autonomous Vehicle Fleet Operations: Optimization-Based Strategies to Assign AVs to Immediate Traveler Demand Requests,” Trans. Res. Part C, vol. 92, 2018.

[6] J.Alonso-mora, S.Samaranayake, A.Wallar, E.Frazzoli and D.Rus, “On-demand high-capacity ride-sharing via dynamic trip-vehicle assignment,” Proceedings of the National Academy of Sciences of the United States of America, vol. 114, no. 3, pp. 462–467, 2017.

[7] J.Jung, R.Jayakrishnan, and J.Y.Park, “Design and Modeling of Real-time Shared-Taxi Dispatch Algorithms,” in TRB Annual Meeting, 2013.

[8] A.Di Maria, A.Araldo, G.Morana, and A.Di Stefano, “AMoDSim: An Efficient and Modular Simulation Framework for Autonomous Mobility on Demand,” in Internet of Vehicles Conference, 2018.

Tortuosity

Tortuosity of a trajectory at the i-th stop-point

$$T(i,v) \equiv {l(q_i, \dots, q_{i+H})} \Big/ {m_{qi}\{q_i, \dots, q_{i+H}\}} \qquad (1)$$

Tortuosity of a vehicle (average of the tortuosity at all its stop-points)

$$T(v) = {1} \Big/ {n-H} \sum_{i=1}^{n-H} T(i,v) \qquad (2)$$

- T(v) ≥ 1
- T(v) = 1 → the vehicle chooses the shortest trajectory at every stop point
- The shortest trajectory may be impossible due to time constraints