TUM TSE research on Shared Autonomous Vehicles

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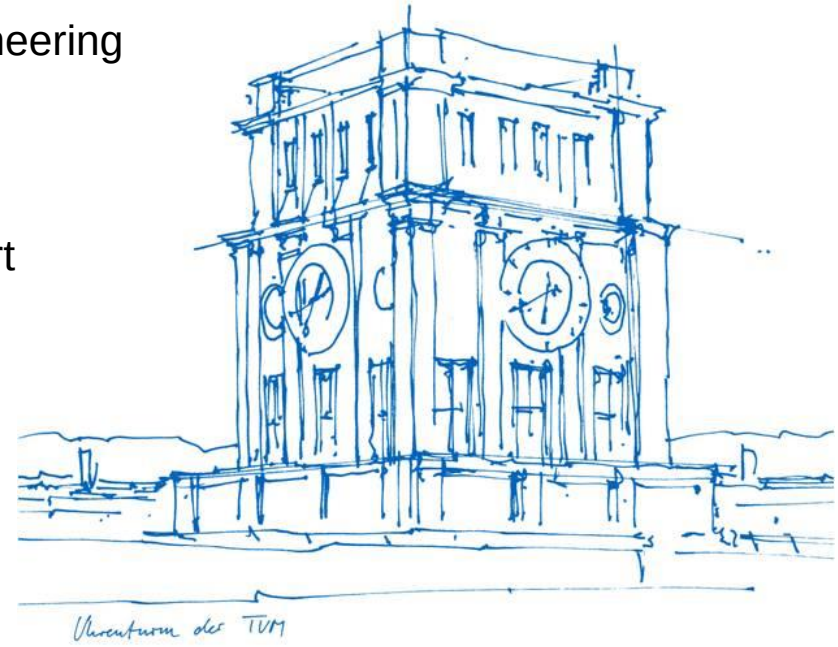
The Future of Shared Mobility and Public Transport

14/05/2019



Contents

- Review on Shared Autonomous Vehicles (SAV)
- Modelling reservation based SAV services
- Optimization model for SAV chain formation

Review on Shared Autonomous Vehicles (SAV)

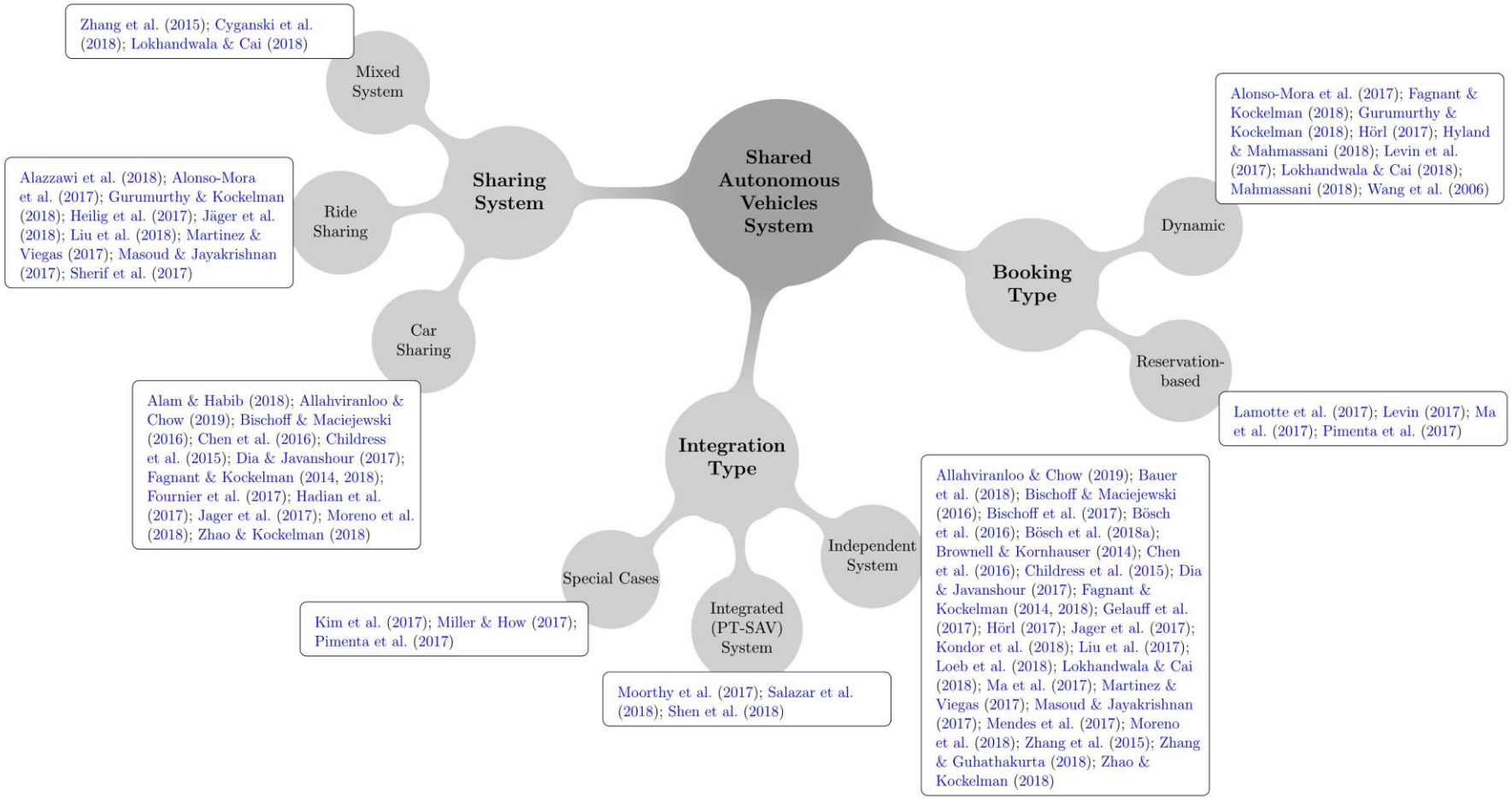
About the review

- SCOPUS database query using 13 keywords
- Top 3 keywords: *shared autonomous, autonomous taxi, autonomous mobility on demand*
- Screening based on relevance and additional papers from the references of the screened papers
- Type of documents: journal papers, conference papers and technical reports
- Number of documents: ~160 (Collection completion: Jan, 2019)

Basic definitions

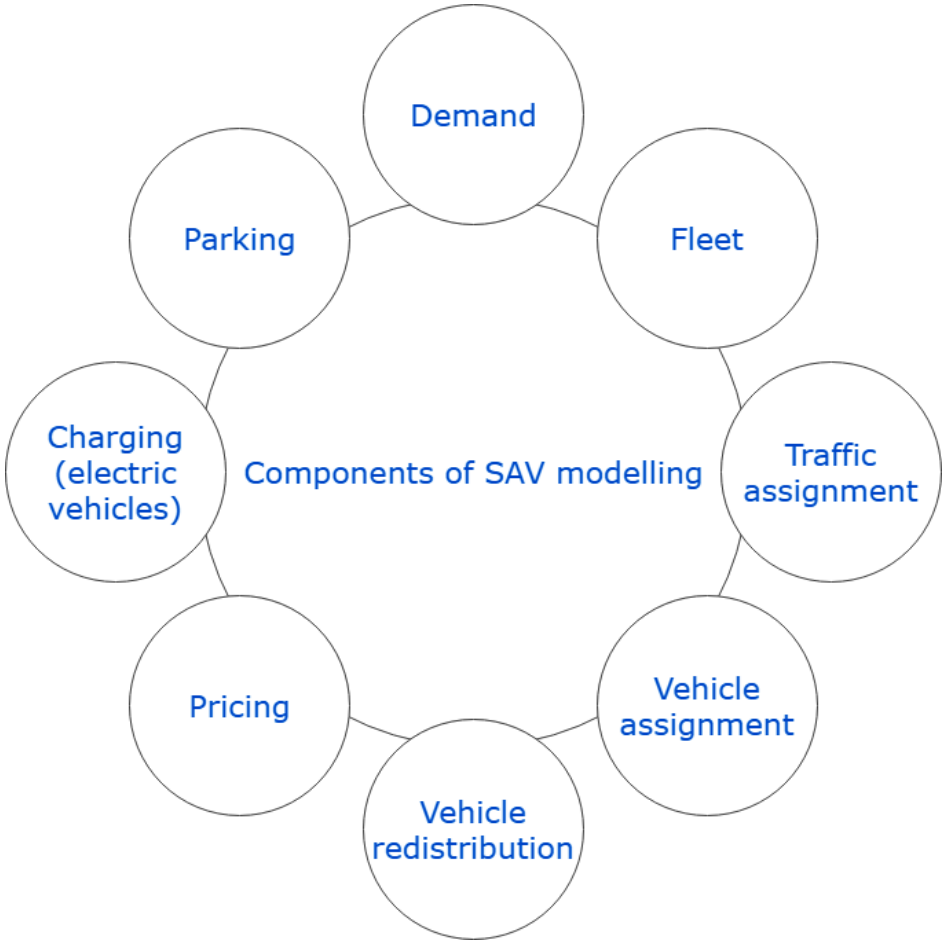
- **Shared mobility** - shared use of a vehicle for performing a trip. E.g., Car–sharing, ride-sharing, bike–sharing & scooter–sharing
- **Automated vehicles** - vehicles with some level of automation to assist or replace human control
- **Autonomous/self-driving vehicles** - Level 5 automation
- **Shared Autonomous Vehicle (SAV) services** - diffusion of growing shared mobility services and emerging autonomous vehicle technology

SAV typology



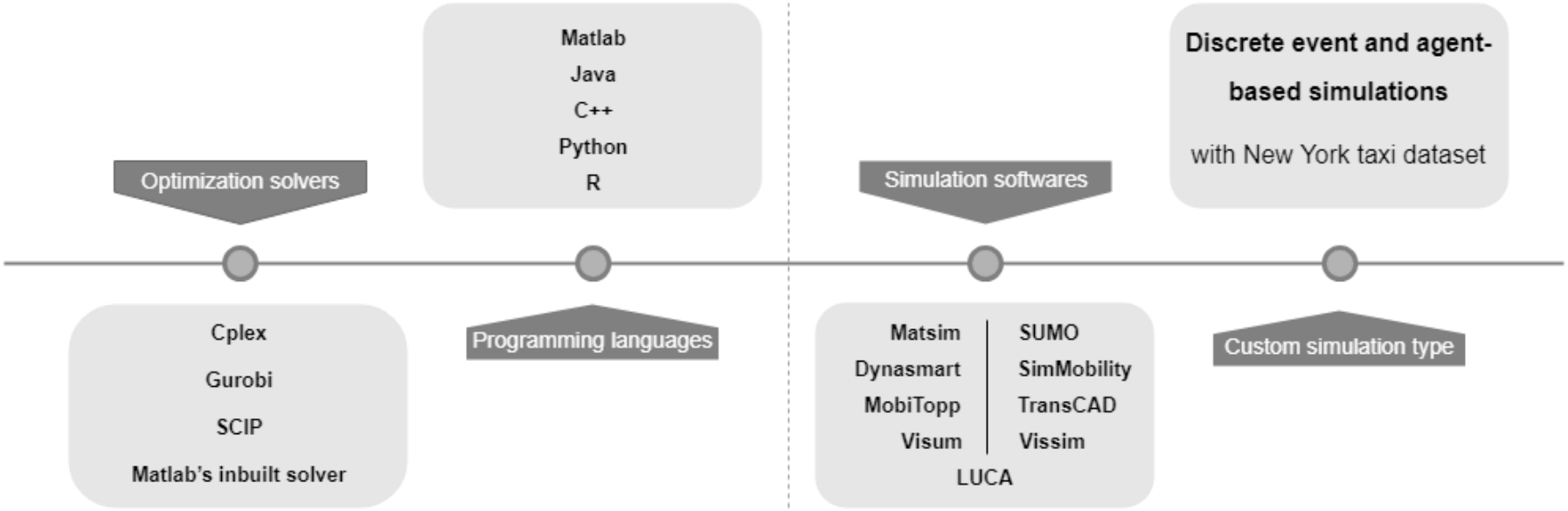
Source: Narayanan S., Chaniotakis E., & Antoniou C. (2019). Impacts of Shared Autonomous Vehicles Services: a Comprehensive Review. Manuscript submitted to Transportation Research Part C.

Components of SAV modelling



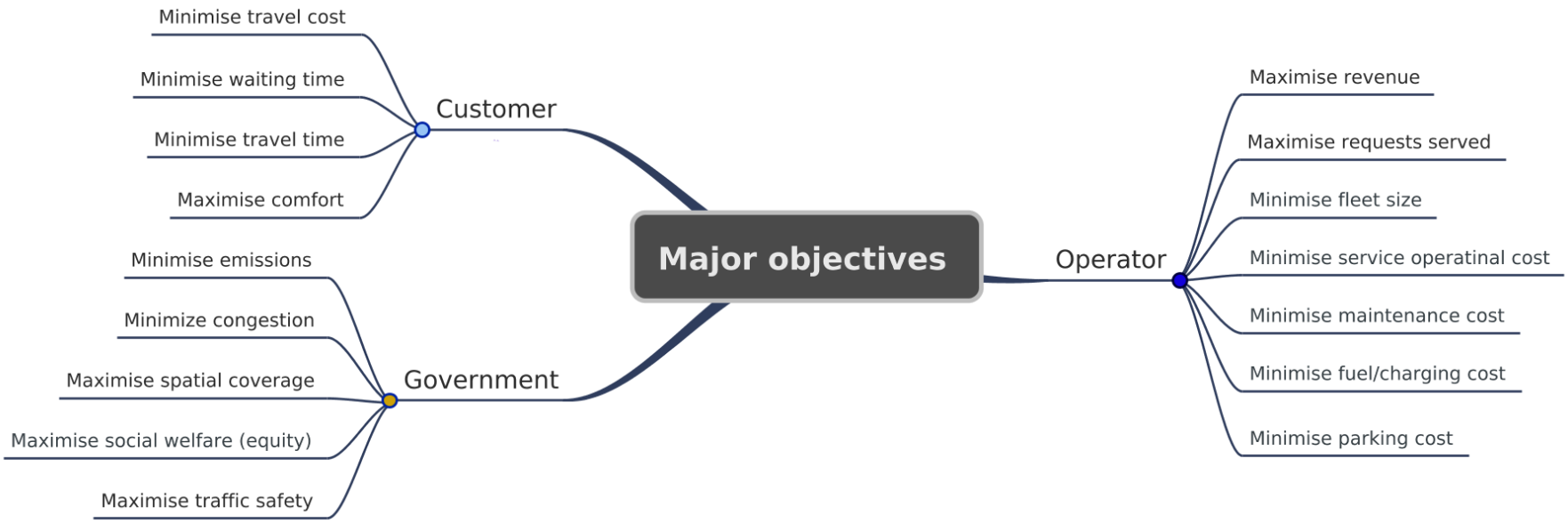
Source: Narayanan. (2019). *Modelling reservation based SAV services: A bilevel approach* (Master's thesis to be submitted).

Tools Used



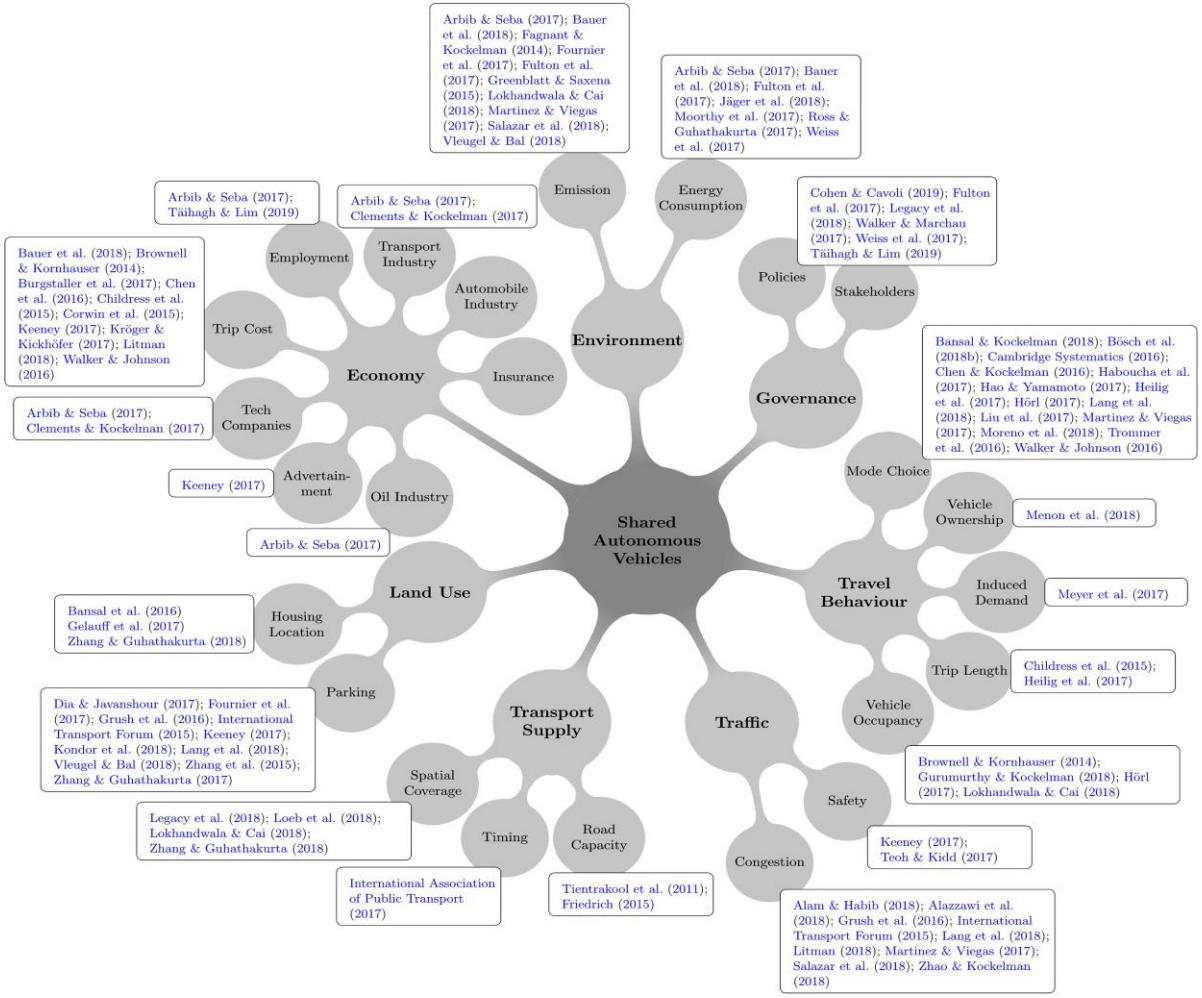
Source: Narayanan. (2019). *Modelling reservation based SAV services: A bilevel approach* (Master's thesis to be submitted).

Objectives incorporated in SAV modelling



Source: Narayanan. (2019). *Modelling reservation based SAV services: A bilevel approach* (Master's thesis to be submitted).

Categories of Impacts of SAV services



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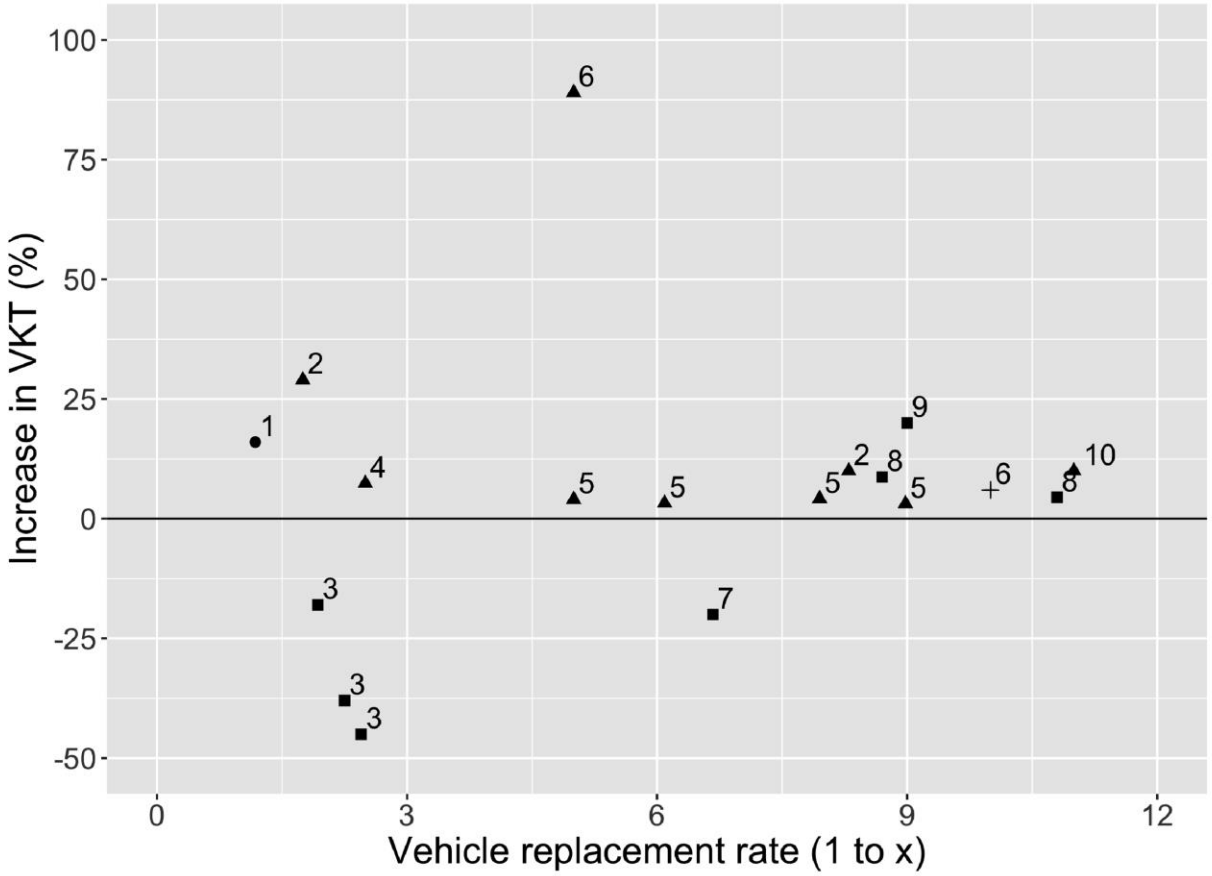
Impacts of SAV services ctd.



SAV service type:

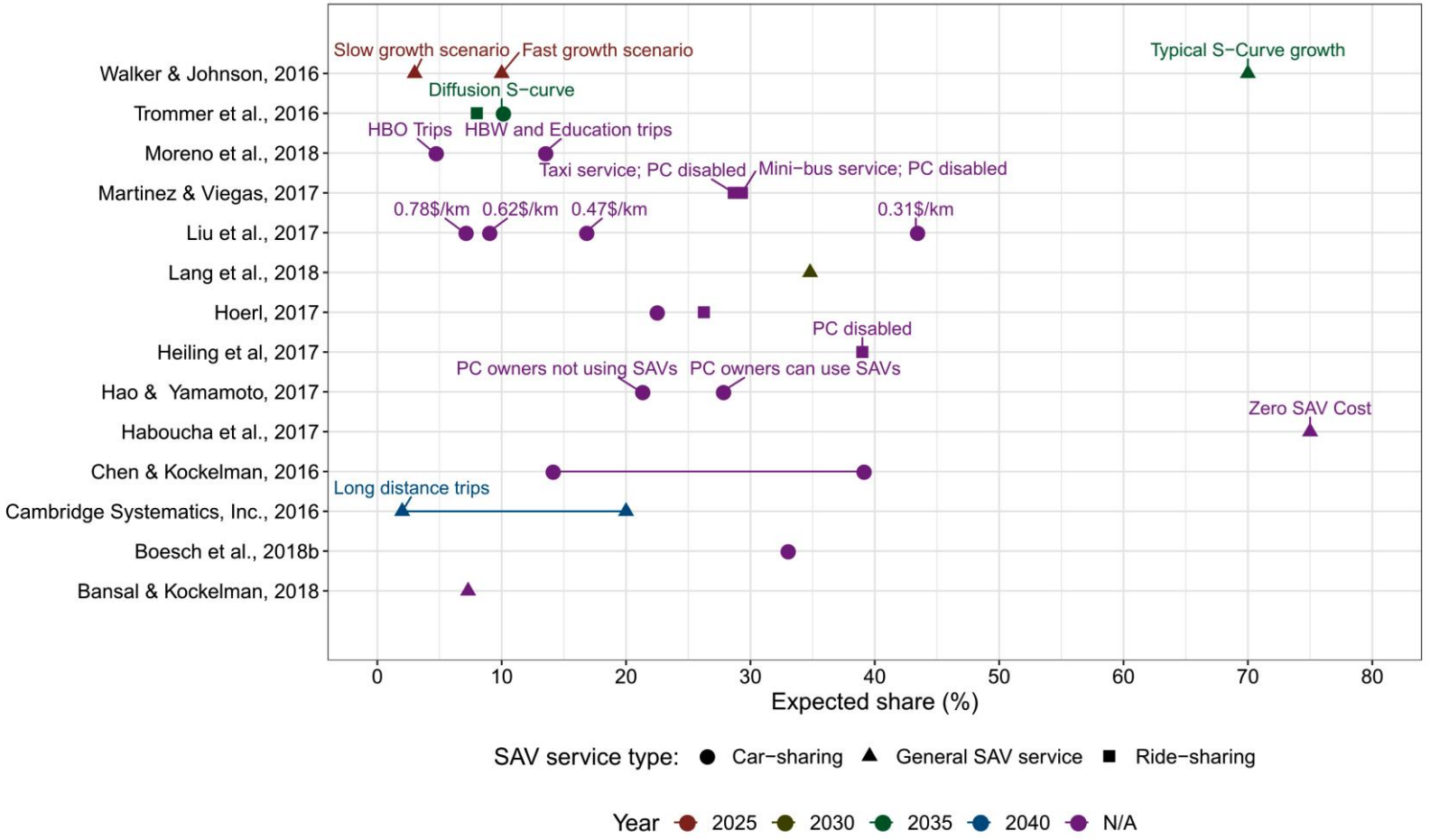
- Both Car-sharing & Ride-sharing
- Car-sharing
- Ride-sharing
- \+ Ride-sharing integrated with PT

Label	Study
1	Lang et al., 2018
2	Dia & Javanshour, 2017
3	Lokhandwala & Cai, 2018
4	Moreno at al., 2018
5	Chen et al., 2016
6	ITF, 2015
7	Heilig et al., 2017
8	Fagnant & Kockelman, 2018
9	Masoud & Jayakrishnan, 2017
10	Fagnant & Kockelman, 2014

Most studies predict moderate increase of VKT, independent of the vehicle replacement rate

Source: Narayanan S., Chaniotakis E., & Antoniou C. (2019). Impacts of Shared Autonomous Vehicles Services: a Comprehensive Review. Manuscript submitted to Transportation Research Part C.

Expected penetration of SAV services



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Policy requirements

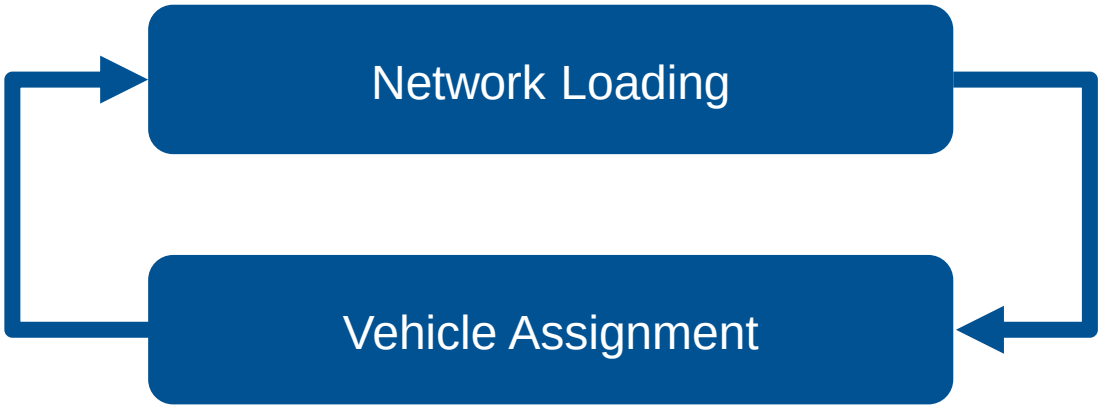
- **Laissez-faire governance** approach: less sustainable outcomes
- Need for **regulation** and interventionist approach
- **Dynamic adaptive policy** framework (set up basic policies, monitor the system and prepare trigger Responses)
- Reinforce public transport system and support walking & cycling
- Requirement of close cooperation between operational control centre, traffic control centre and the transport network operator

Modelling reservation based SAV services

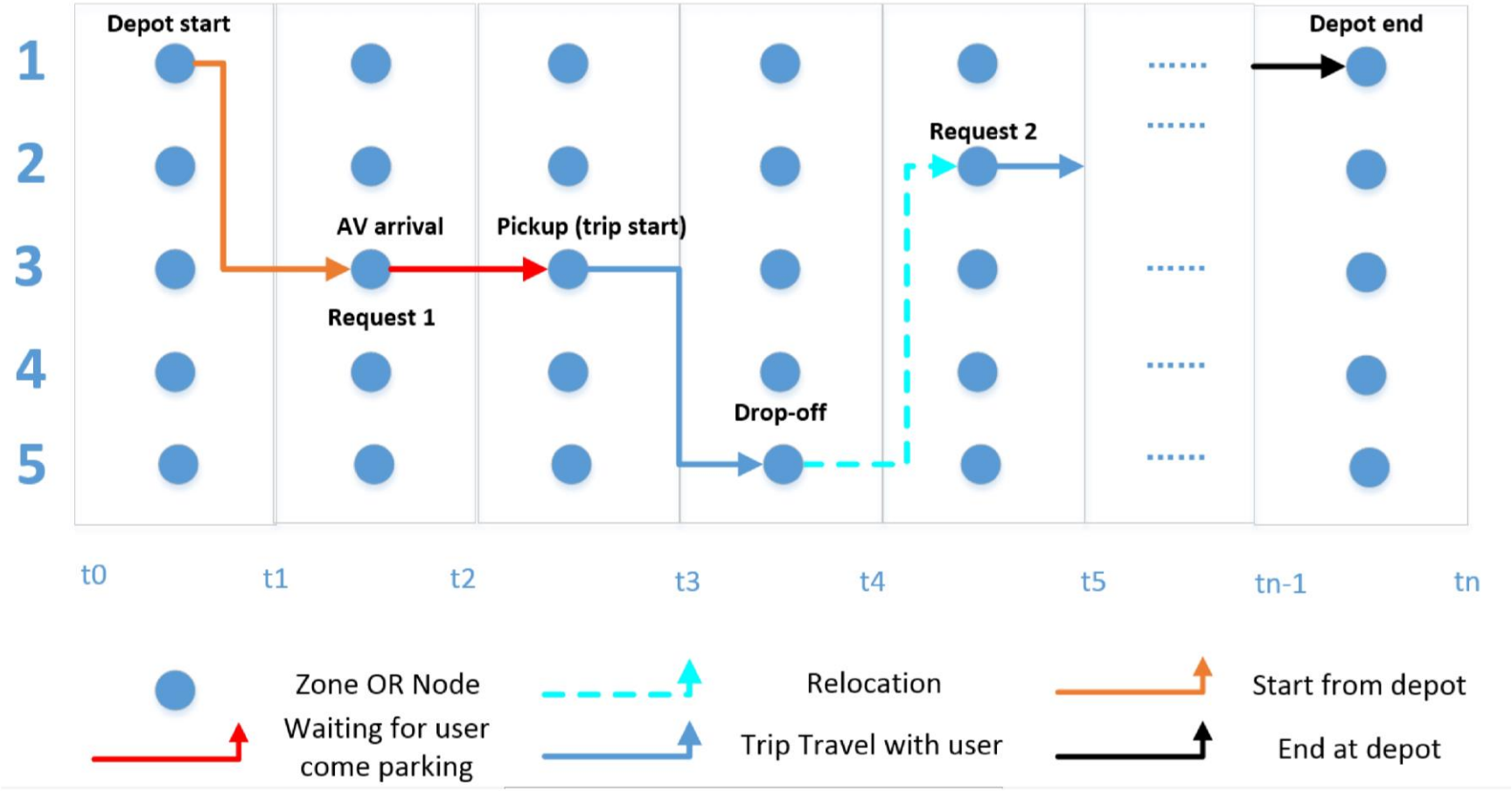
Narayanan. (2019). *Modelling reservation based SAV services: A bilevel approach* (Master's thesis to be submitted).

SAV network assignment modelling

- Formulation as Nash-Cournot game between two players
- Players: Road users and SAV operator

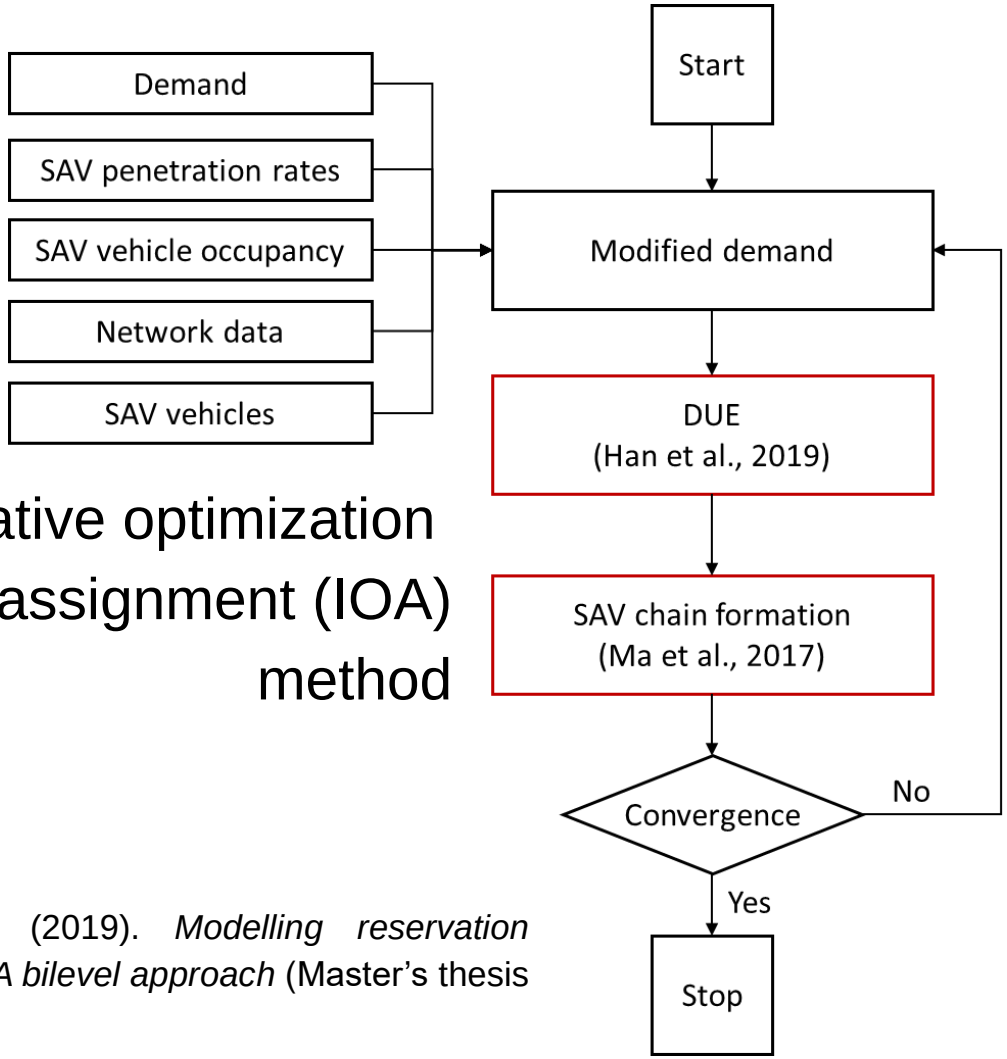


SAV chains



Source: Shun Su. (2018). *An optimization model for reservation based autonomous car sharing routing problem* (Master's thesis). Retrieved from https://mediatum.ub.tum.de/doc/1455443/011510051623.pdf

Model flow chart



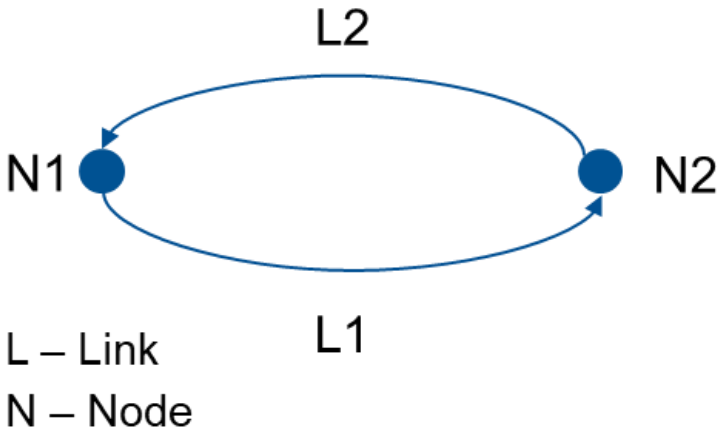
Iterative optimization and assignment (IOA) method

Source: Narayanan. (2019). *Modelling reservation based SAV services: A bilevel approach* (Master's thesis to be submitted).

Model features

- Private and shared-autonomous vehicles
- Car sharing & ride sharing (trips with same OD pair)
- Scenario analysis (different penetration rates and vehicle occupancies)
- Usable for different networks with little effort (input files & parameters)

Test network



Network data

Link capacity:	1800veh/hr
Link length:	8km
Link free flow travel time:	12min
Depot node:	1
DUE model time step:	2min

Planning data

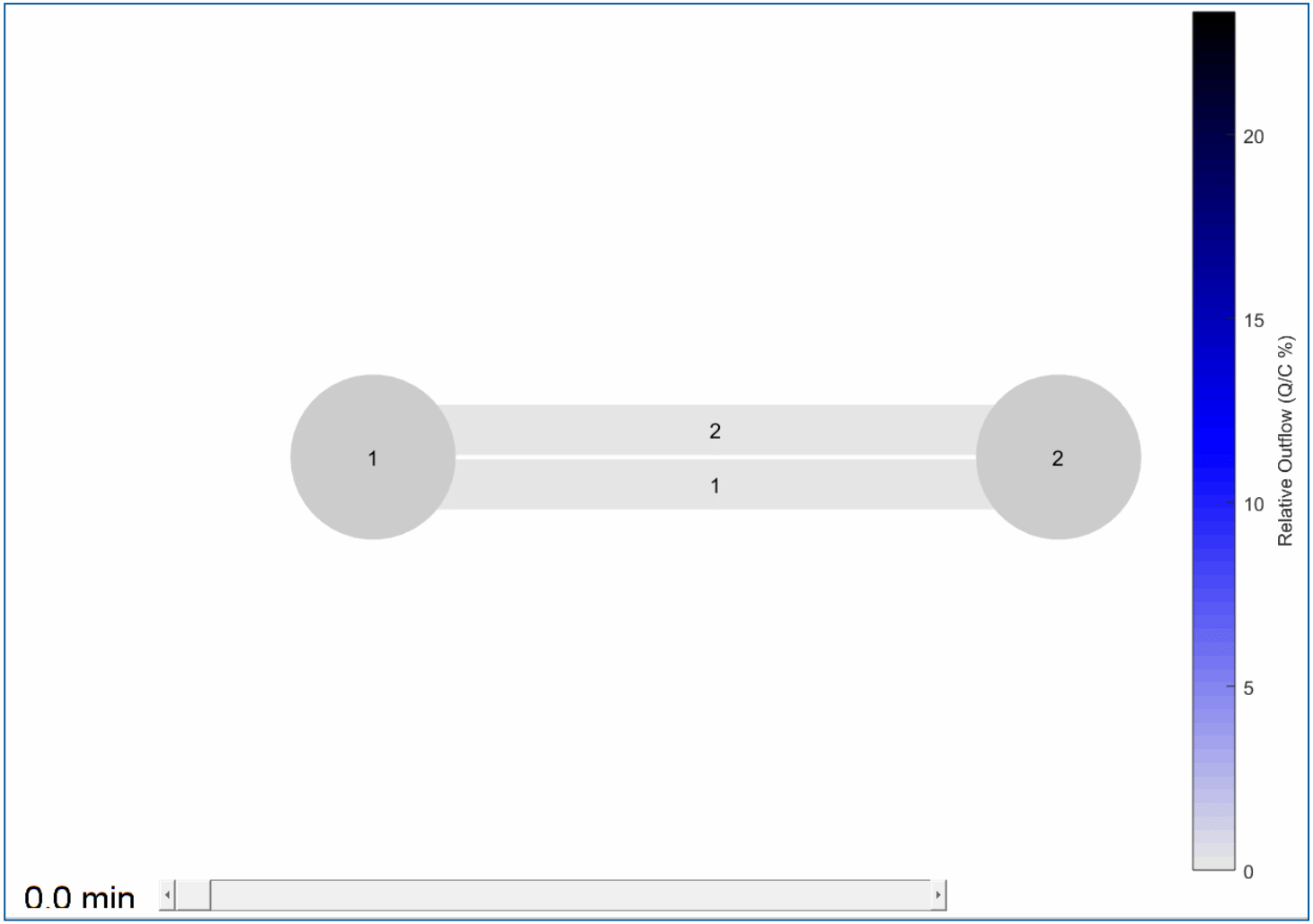
Time horizon in hour:	(0, 5)
Demand per OD:	100
SAV penetration rate:	100% CS
Number of SAV vehicles:	200
Expected arrival times in hour:	(1, 4)

Output

Number of vehicles used:	100 (2 trips/veh)
Departure time in min:	OD1 - 38 to 60
	OD2 - 218 to 240
Arrival time in min:	OD1 - 50 to 72
	OD2 – 230 to 252
Elapsed time:	1 min

CS – car sharing

Test network – relative outflow

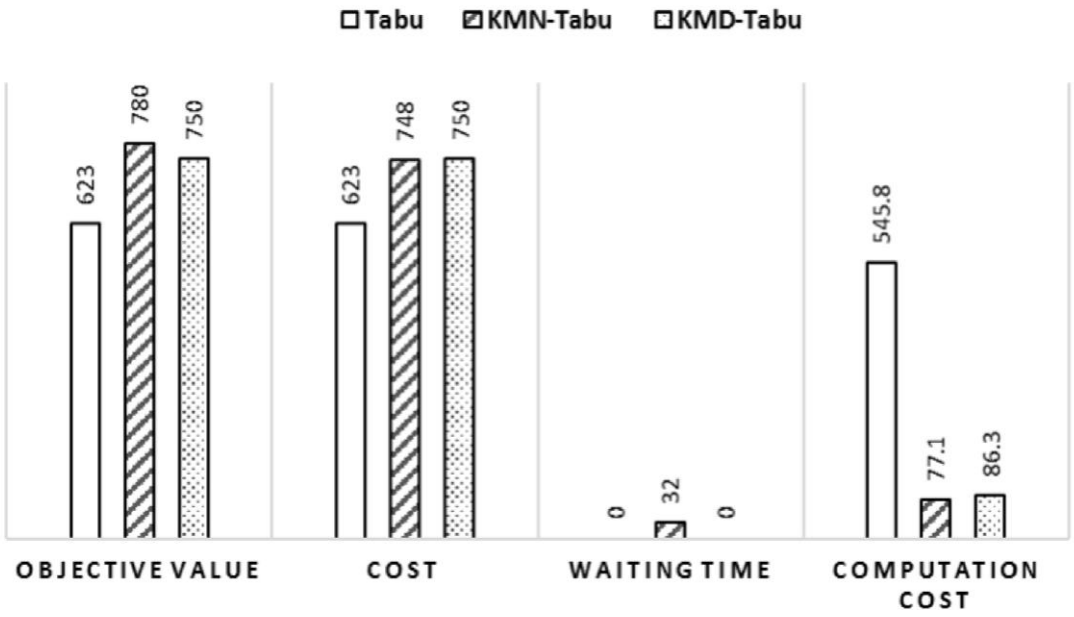


Optimization model for SAV chain formation (Vehicle assignment)

Shun Su. (2018). *An optimization model for reservation based autonomous car sharing routing problem* (Master's thesis). Retrieved from https://mediatum.ub.tum.de/doc/1455443/011510051623.pdf

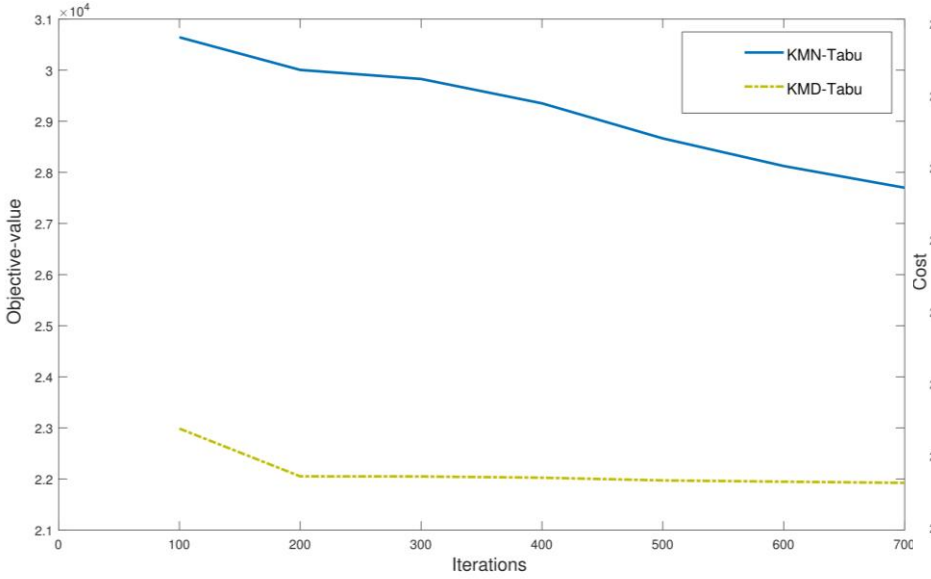
Optimization model

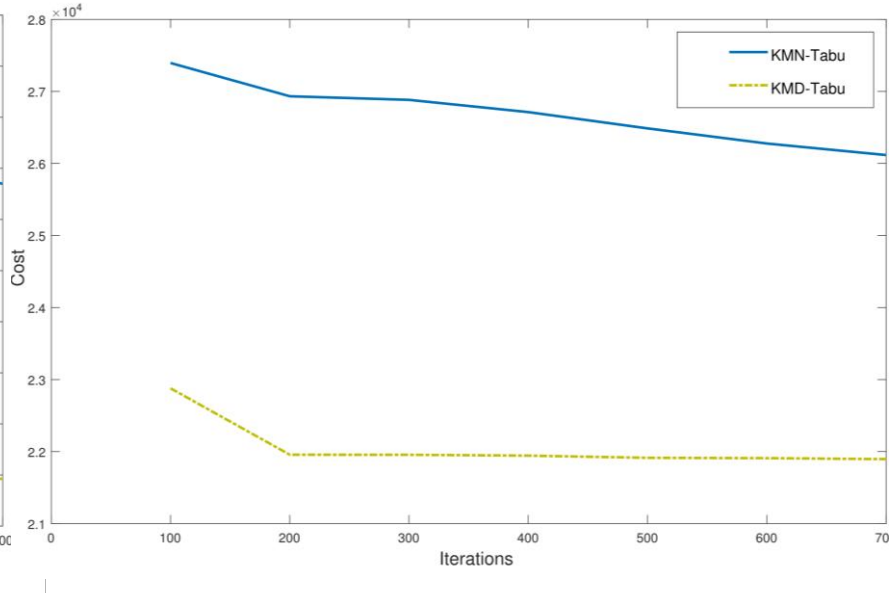
- Metaheuristics: tabu search (random assignment, request switching, tabu list)
  Based on the methodology of Cordeau and Laporte (2007)
- Clustering method: K-means & K-medoids
- Numerical test 1: SiouxFalls (100 requests, 40 vehicles & 4 clusters)



Optimization model for SAV chain formation

- Numerical test 2: NY taxi dataset (3986 requests, 800 vehicles & 100 clusters)





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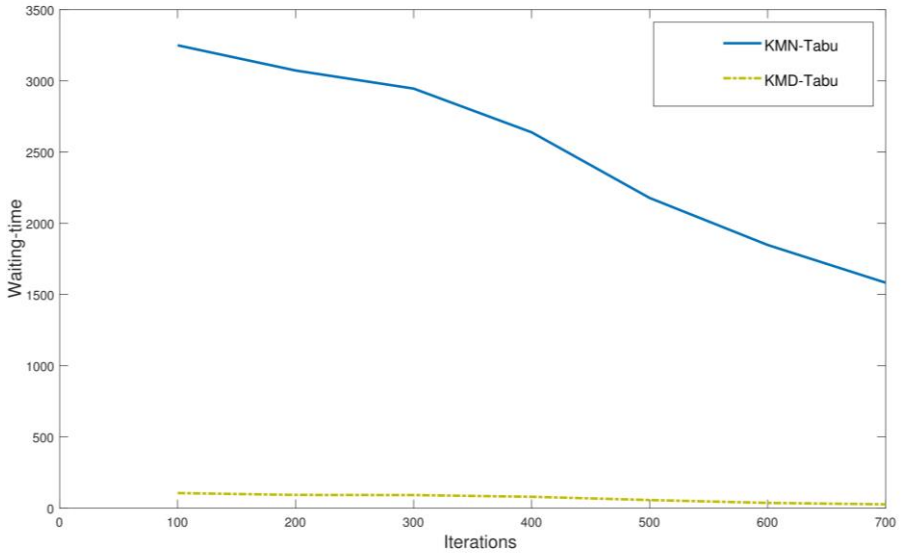

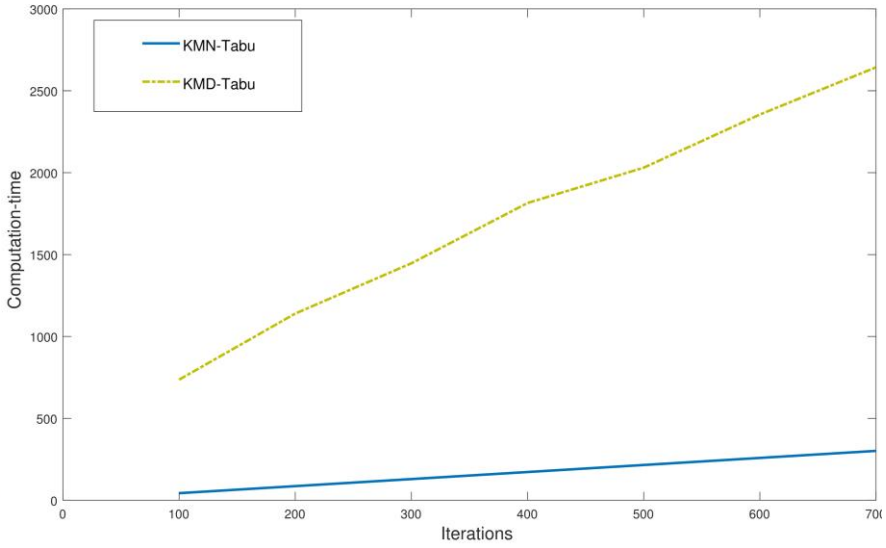

Thank you for your attention!

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