Determining the size of a SAV fleet using flow optimization in an interurban demand context

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Driving2Driverless

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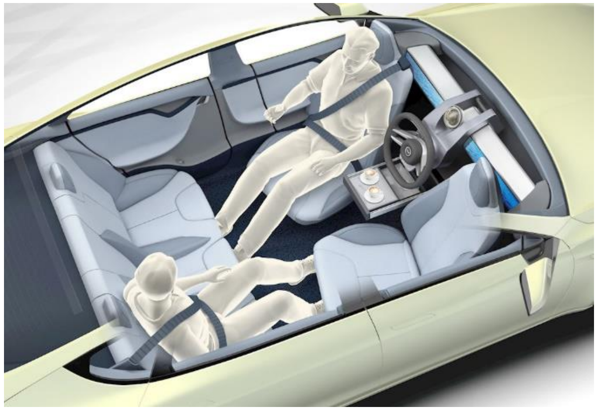
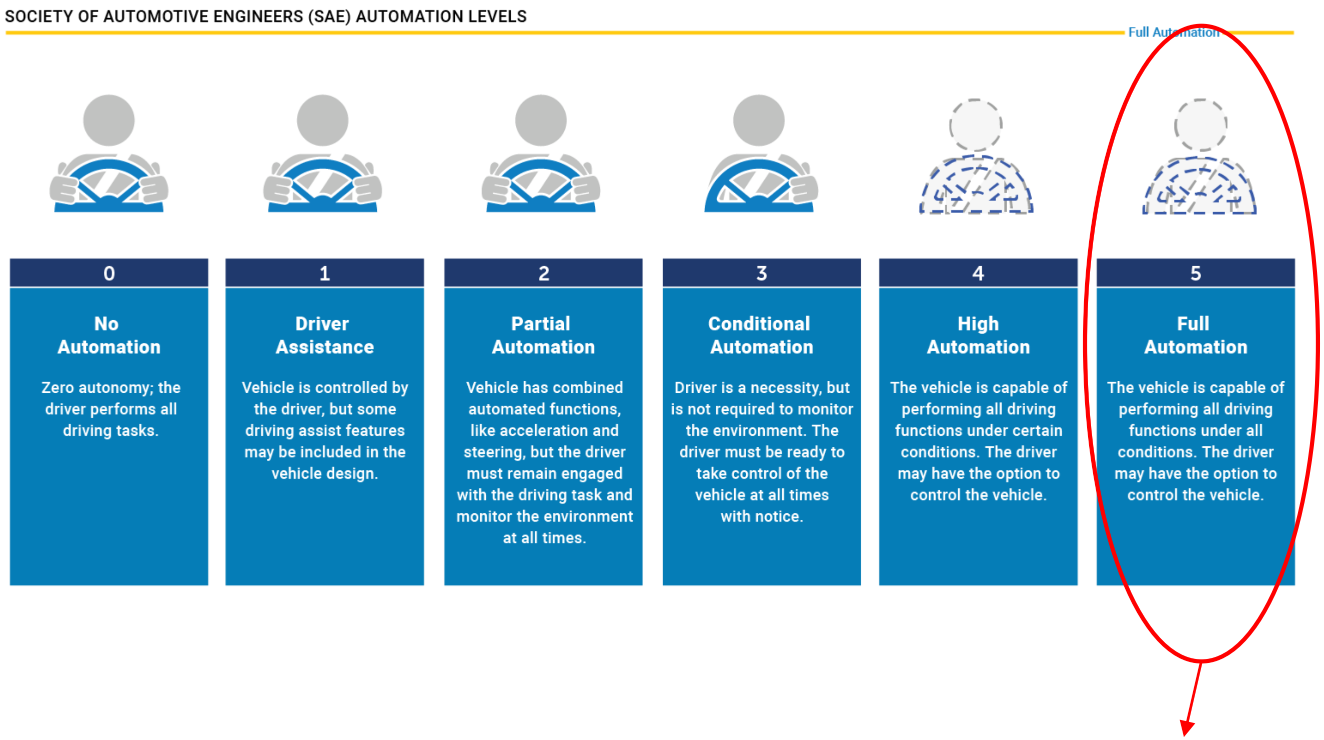


Introduction

- Automation is becoming part of driving



Driverless vehicles (autonomous - AV)

Introduction

SAV- Shared Automated Vehicles

- Solves vehicle rebalancing, need for driver's license, insurance -> carsharing;
- Eliminates the need for a driver -> ride-hailing and taxi.

SAV systems have been studied in urban contexts;

What about heterogeneous or low density regions?

- SAV service can Improve access to mobility for those living in less dense areas and Benefit local economies;

Introduction

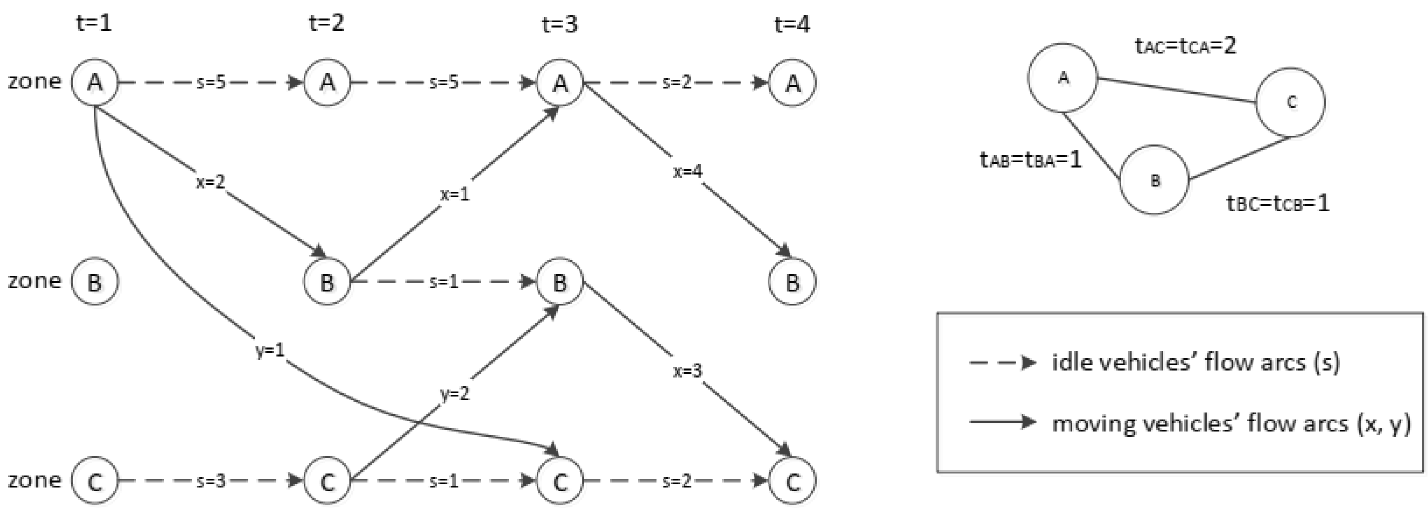
- SAV system design and assessment through integer programming (IP) mainly associated to vehicle routing problems (VRP);
- VRP optimizes the route of each vehicle individually;
- NP-hard, and only viable for small networks;
- Slicing time (rolling-horizon) is a common strategy to overcome this problem;

- A distinct IP approach is Flow-based optimization

Jorge et. al, 2014	carsharing	Design relocation operations (fleet up to 273 vehicles)
Liang et al., 2016	SAV	Small networks
Tsao et al., 2018 Iglesias et al., 2018	SAV	Large networks using Rolling-horizon

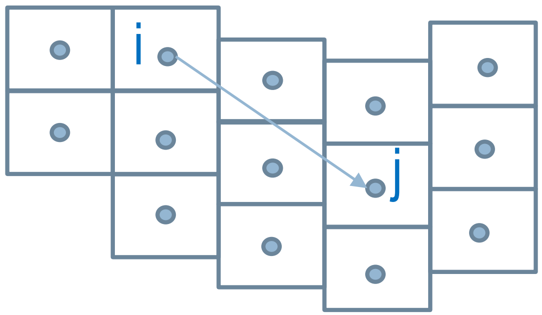
Flow-based optimization model

- A time-space network;
- Nodes = zones, Edges = flows;
- Vehicles can relocate;

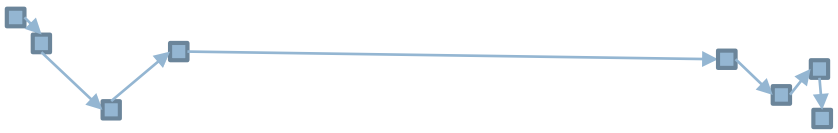


Flow-based optimization model

- Region subdivided in zones; zones represented by centroids.



- Travel time includes pick up and delivery – movement of clients



Zone i

Zone j

Flow-based optimization model

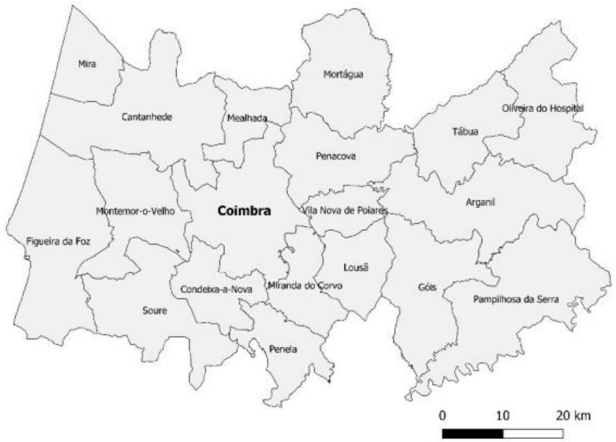
- Objective Function:

Maximize profit = revenues (price) – costs (moving, fixed daily cost)

- Constraints:

1) Conservation of flows;
2) # of passengers do not overpass vehicle capacity;
3) # and position of vehicles at t=0;
4) Additional constraints to turn on-off zones worth to explore.

Case study



- Coimbra region (19 municipalities)
- Demand gathered from survey IMM2008
  total intermunicipal trips: 116179
  average distance: 32.5 km;
- Diferent proportions of demand used (1,3,5,10,15,25,50,75,100%)
- Two types of vehicles
- Service price: 0.10€/km

	Car	Minibus
Seat capacity	4	16
Vehicle daily cost (€)	20	50
Battery capacity (kWh)	52	91
Energy consumption (kWh/100km)	20	36
Driving cost (€/100km)	4	7

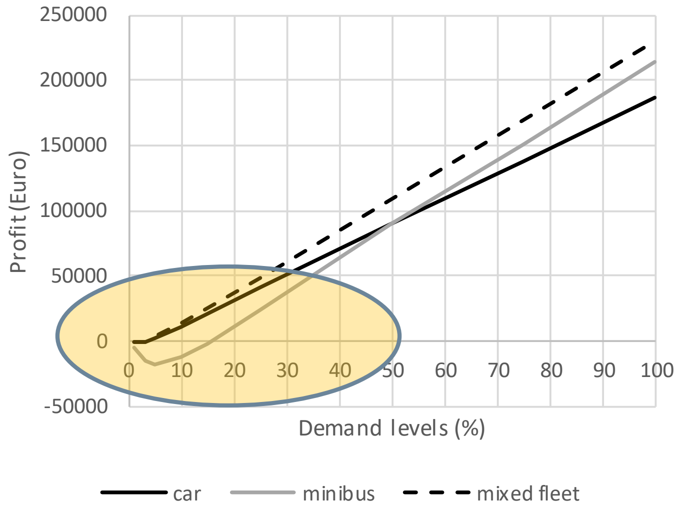
Scenarios

1) A fleet of cars (4 seats capacity)

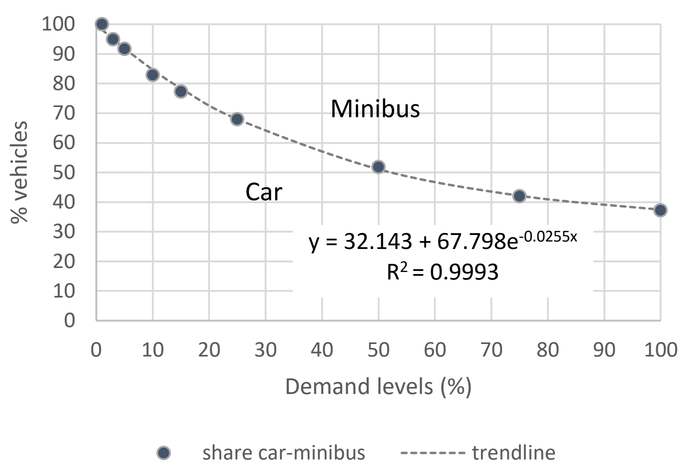
2) A fleet of minibus (16 seats capacity)

3) Mixed fleet (cars+minibuses)

Results - profit



- Maximum profit for mixed fleet serving all municipalities 230 k€/day (23% ↗ car fleet, 14% ↗ minibus fleet)



- Share trendline converges to 1/3 of cars and 2/3 of minibuses.

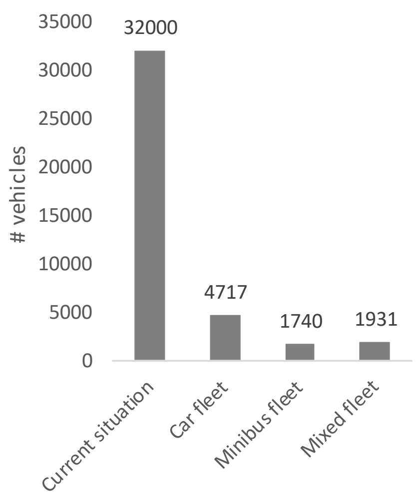
Results - Turn on-off municipalities

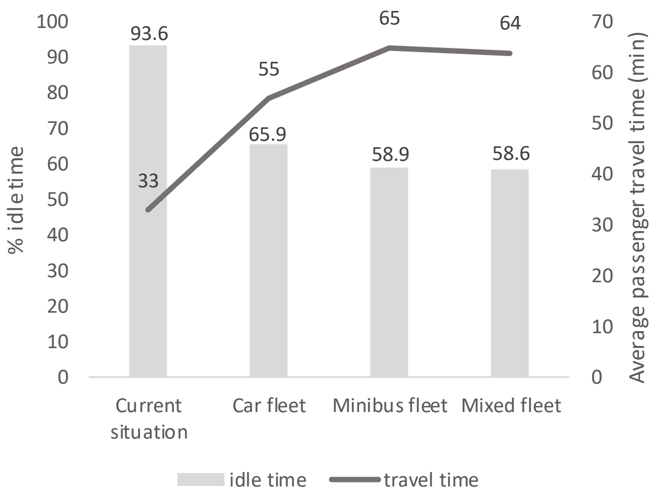
- Improve profit for low demand levels by covering less municipalities (partial coverage).

	Car fleet	Minibus fleet
5% demand	 Profit: 3164€/day (+1021€) Vehicles: 239 Avp/v=2.2 Trips/v=18.4	 Profit: 50€/day (+18091€) Vehicles: 14 Avp/v=3.2 Trips/v=21.1
10% demand	 Profit: 11231€/day (+256€) Vehicles: 570 Avp/v=2.5 Trips/v=19.5	 Profit: 2594€/day (+15469€) Vehicles: 106 Avp/v=5.0 Trips/v=37.9

Results – comparison with BAU

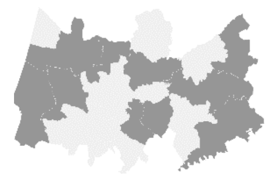
- Comparing BAU with scenarios serving all demand and covering the entire region

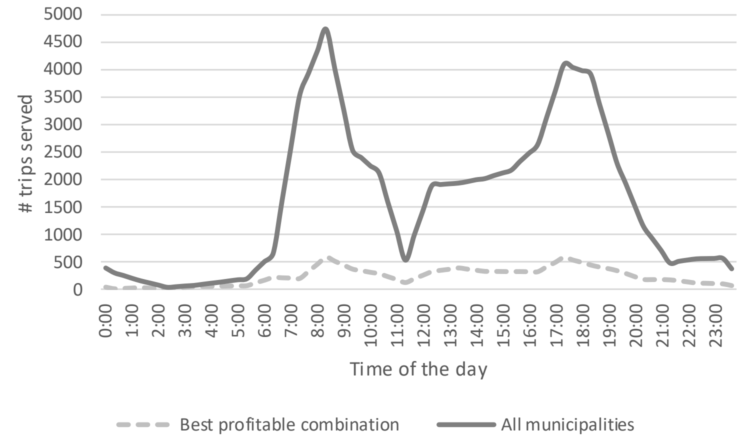




- The improvements are sustained by a negative impact on passenger travel time values

Results – one passenger per vehicle

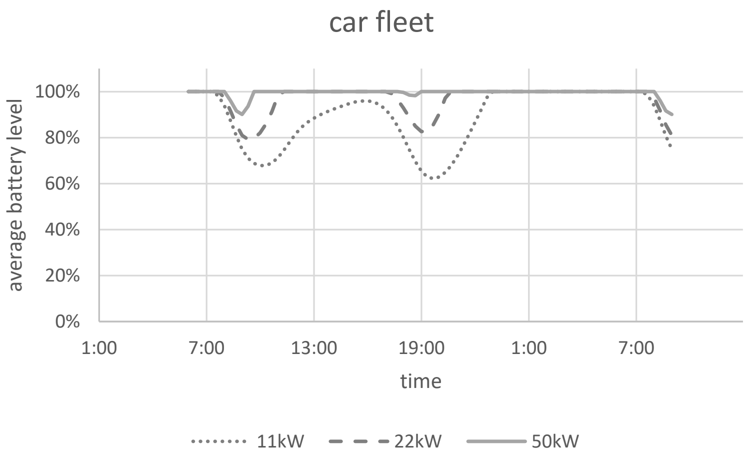
	All municipalities	The best profitable combination of municipalities
		
Profit (€/day)	-134707	8341
Fleet size	13764	1357
Total relocations /day	22638	1950
Relocations per vehicle /day	1.6	1.4
Time moving users (%)	24.8	34.8
Relocation time (%)	4.3	2.9
Idle time (%)	70.9	62.2
Average passenger travel time (min)	32.8	33.2

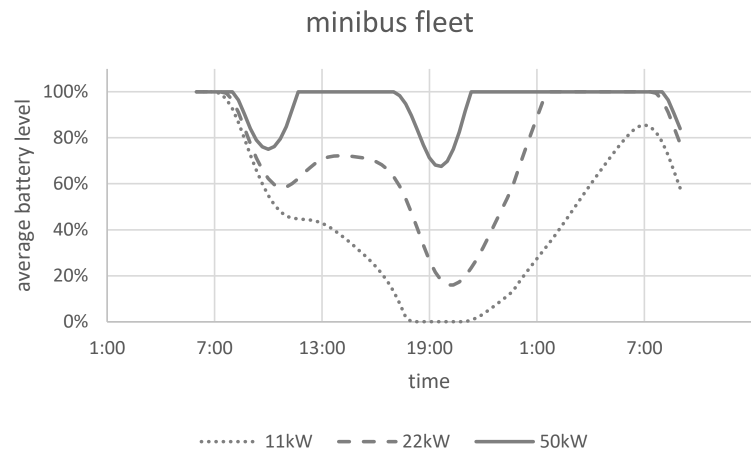


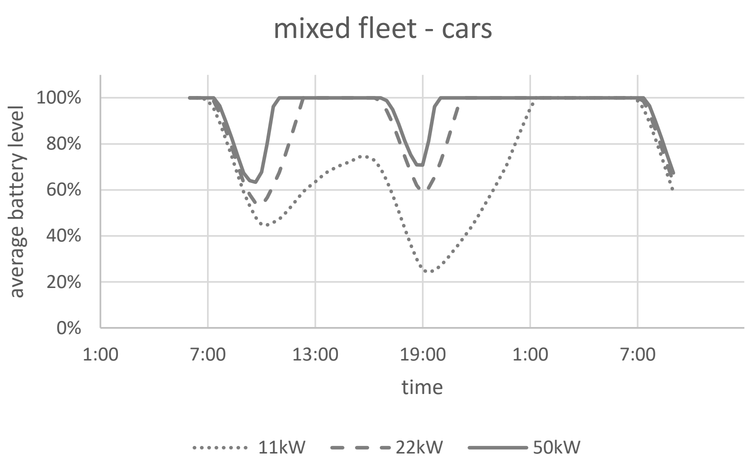
- Low willingness to share leads to losses for the entire region
- And to profit for optimal coverage set of municipalities

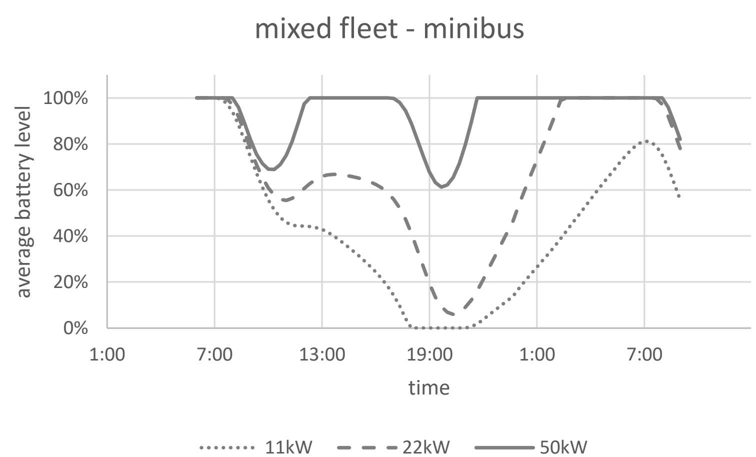
Results – electric charger type

- Important for validation









Closing remarks

- We presented a Flow–based IP model to design interurban SAV systems;
- The model optimizes fleet size and vehicle movements based on profit maximization;
- Adequate for large-scale SAV systems;
- The model was applied to a Portuguese region and the results showed that:

  1) A mixed fleet of cars and minibuses is the best option for profit maximization;

  2) The introduction of the SAV system should be done with sequential expansions to guarantee profit;

  3) Having one passenger per vehicle leads to losses for the entire region;

  4) A 50kw charging power is enough to support the energy needs without afecting vehicle movements.

THANK YOU

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