Shared Autonomous Electric Mobility:

Opportunities & Challenges

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CONNECTED AND AUTOMATED VEHICLES 2019
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SCHOOL of ENGINEERING & APPLIED SCIENCE

Why Shared Autonomous Electric Vehicles (SAEVs)?

Autonomous

Electric

Alleviates "range anxiety."

Automated charging/fueling is easier to achieve w/ electric vehicles

Eliminates driver labor cost. Enables strategic relocation (avoiding spatial mismatch of demand & supply).

High cost of automation technology incentivizes shared use.

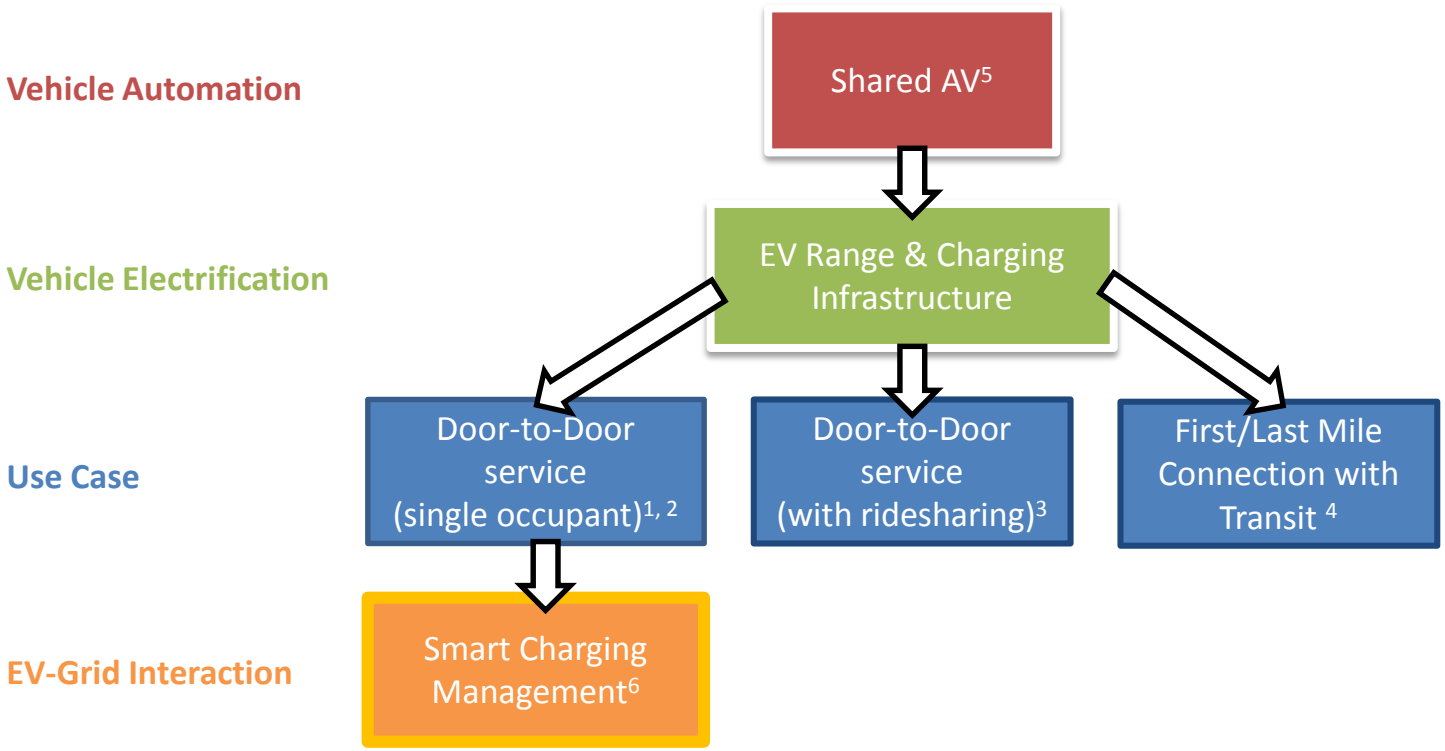
Accelerates EV adoption to meet urban air quality & transport emissions goals.

Fewer components lead to reduced maintenance (compared to internal combustion engine vehicles).

Shared

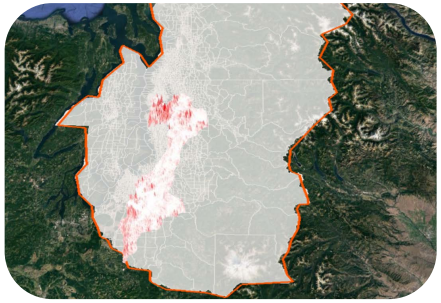
Shared Autonomous Electric Vehicle

Chen Research Group



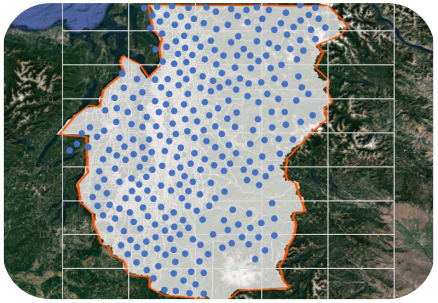
1. Chen, T.D, K. M. Kockelman & J.P. Hanna (2016) "Operations of a Shared, Autonomous, Electric Vehicle Fleet: Implications of Vehicle & Charging Infrastructure Decisions." *Transportation Research Part A: Policy and Practice* 94: 243-254.
2. Chen, T. D. & K.M. Kockelman (2016) "Management of a Shared Autonomous Electric Vehicle Fleet: Implications of Pricing Schemes." *Transportation Research Record* 2572: 37-46.
3. Farhan, J. & T.D. Chen (2018) "Impact of Ridesharing on Operational Efficiency of Shared Autonomous Electric Vehicle Fleet." *Transportation Research Part C: Emerging Technologies* 93: 310-321.
4. Farhan, J., T.D. Chen & Z. Zhang (2018) "Leveraging Shared Autonomous Electric Vehicles for First- and Last-Mile Mobility." Proceedings of the 97th Annual Meeting of the Transportation Research Board, January 2018, Washington, DC.
5. Hanna, J.P., M. Albert, T.D. Chen & P. Stone. (2016) "Minimum Cost Matching for Autonomous Carsharing." *International Federation of Automatic Control Papers On Line* 49-15: 254-259.
6. Zhang, Z. & T.D. Chen, "Smart Charging Management for Shared Autonomous Electric Vehicle Fleet: A Puget Sound Case Study," presented at the 98th Annual Meeting of the Transportation Research Board, January 2019, Washington, DC.

SAEV Modeling Framework



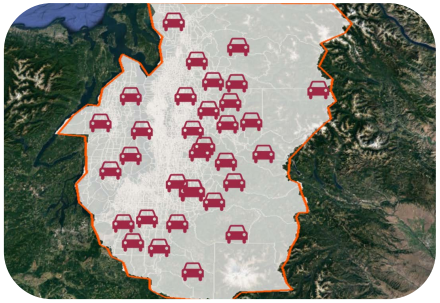
Trip Generation

- Use local travel demand model data to generate trips to simulate origin-destination travel demand



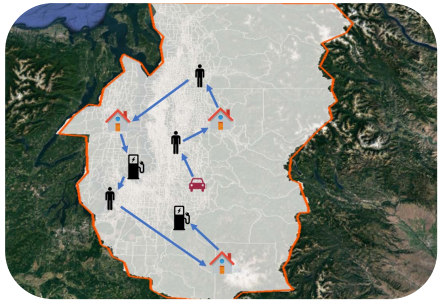
Charging Station Generation

- Charging station site selection to ensure sufficient infrastructure coverage



SAEV Fleet Generation

- Determine the necessary fleet size to serve travel demand

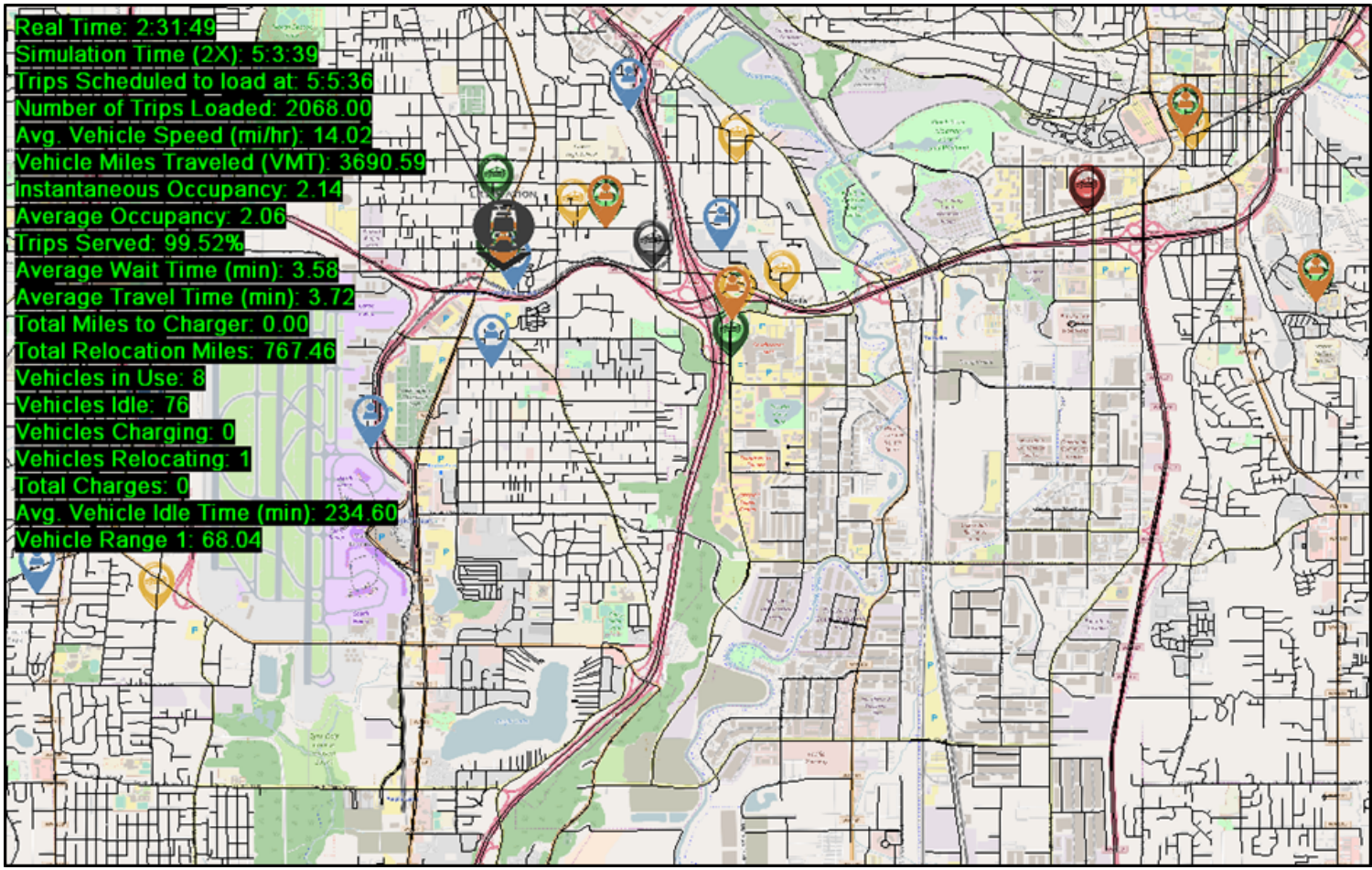


Operation

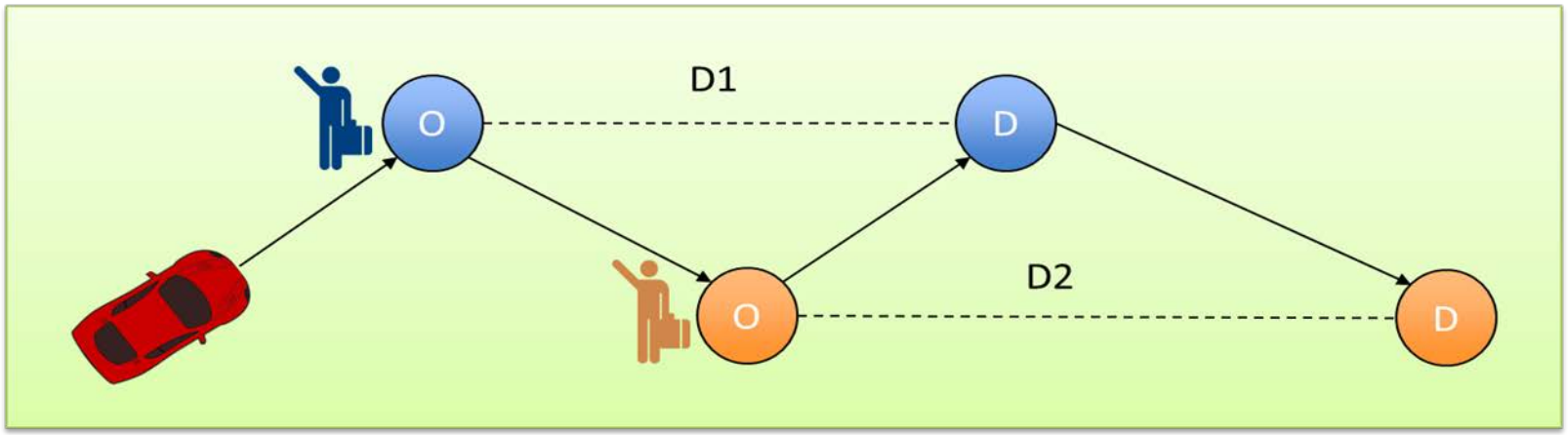
- Continuous daily operation based on the station and fleet configuration

SAEV Simulator Implementation

- Available vehicles
- Vehicles at capacity
- Relocating vehicles
- Trip origins
- Trip destinations



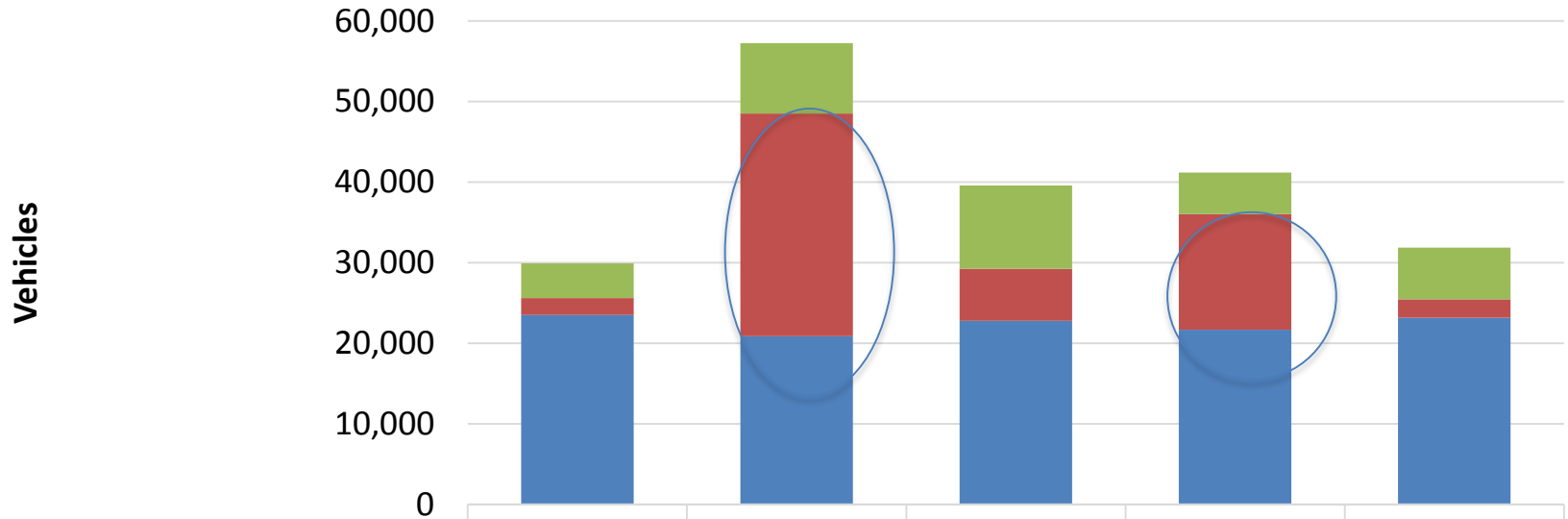
SAEV Use Case: Door-to-Door Service



Case studies in Austin, Texas

Door-to-Door SAEV Service (Single Occupant):

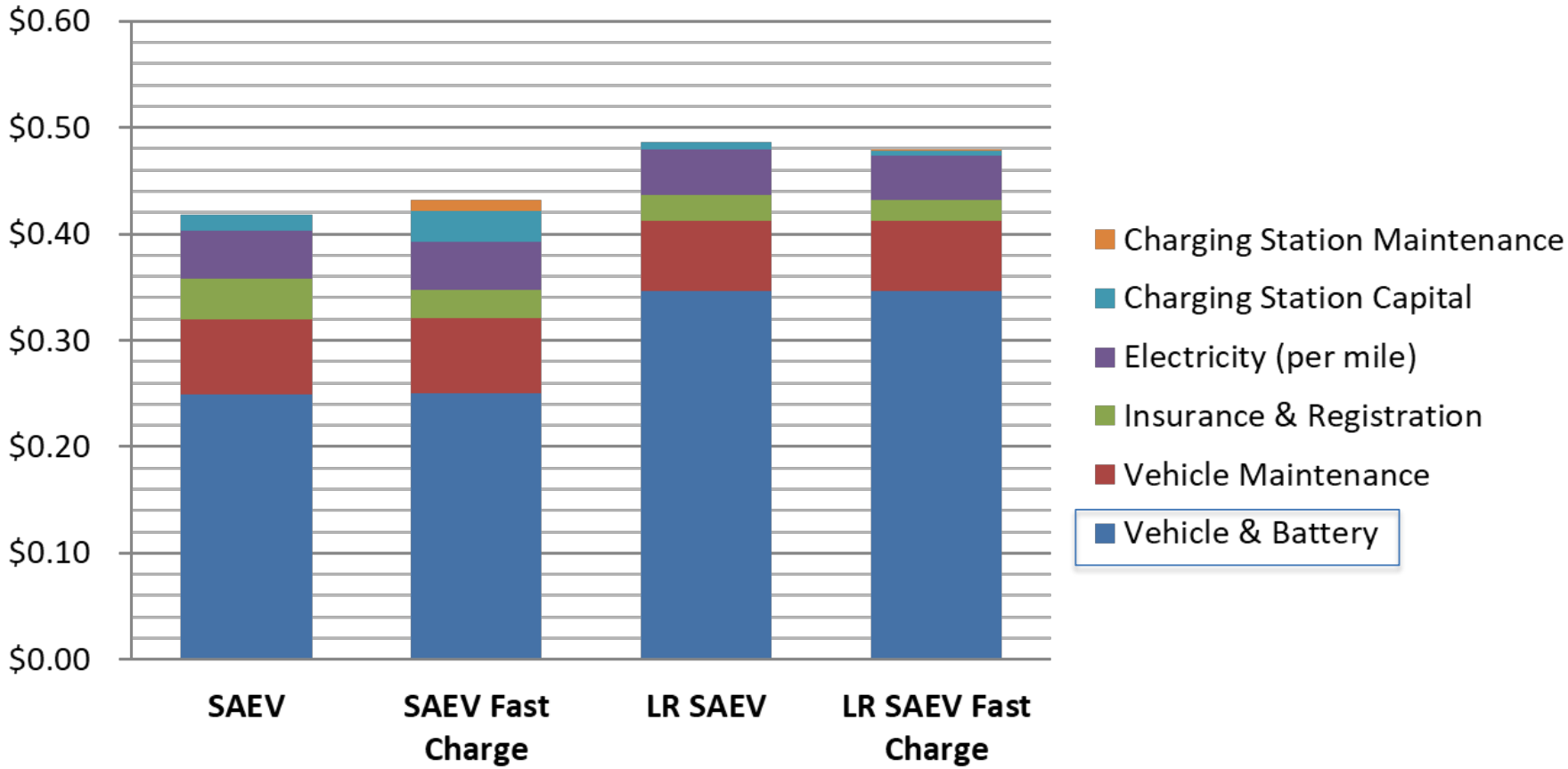
Fleet Size by Vehicle & Charging Infrastructure



	SAV	SAEV	SAEV Fast Charge	LR SAEV	LR SAEV Fast Charge
Unused/Relocating Vehicles	4339	8741	10359	5145	6408
Charging Vehicles	2085	27668	6459	14340	2288
In Use Vehicles	23515	20869	22774	21693	23162

- **Fast charging** infrastructure & longer **EV range** reduces required fleet size.
- Each SAEV can **serve 11 to 21 trips per day**, equivalent to **replacing 3.7 to 6.8 privately owned vehicles**. (SAVs serve, on average, 22 trips/day)
- **"Empty" VMT** constitutes **7 to 14%** of all miles traveled.

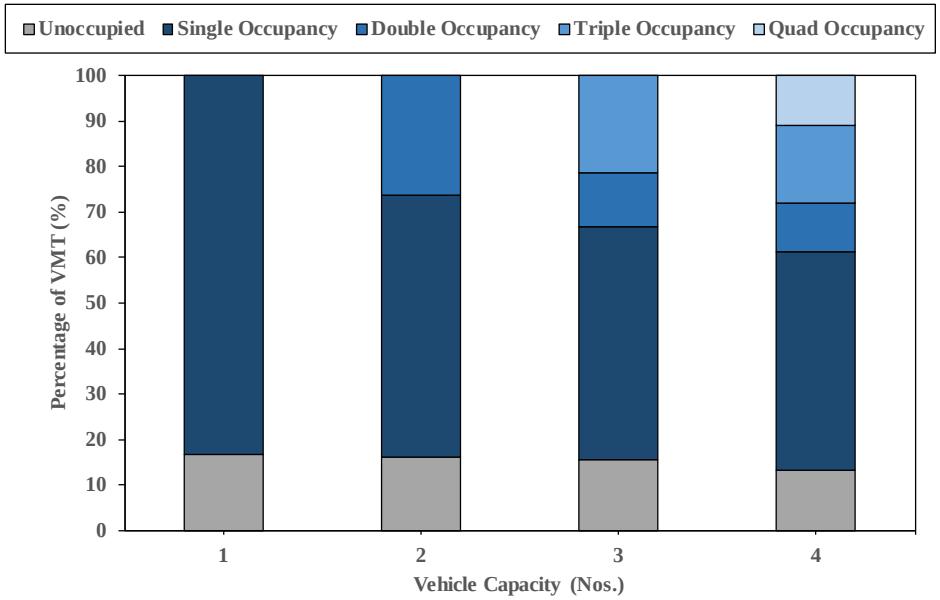
Door-to-Door SAEV Service (Single Occupant): Operational Cost Per Occupied-Mile Traveled



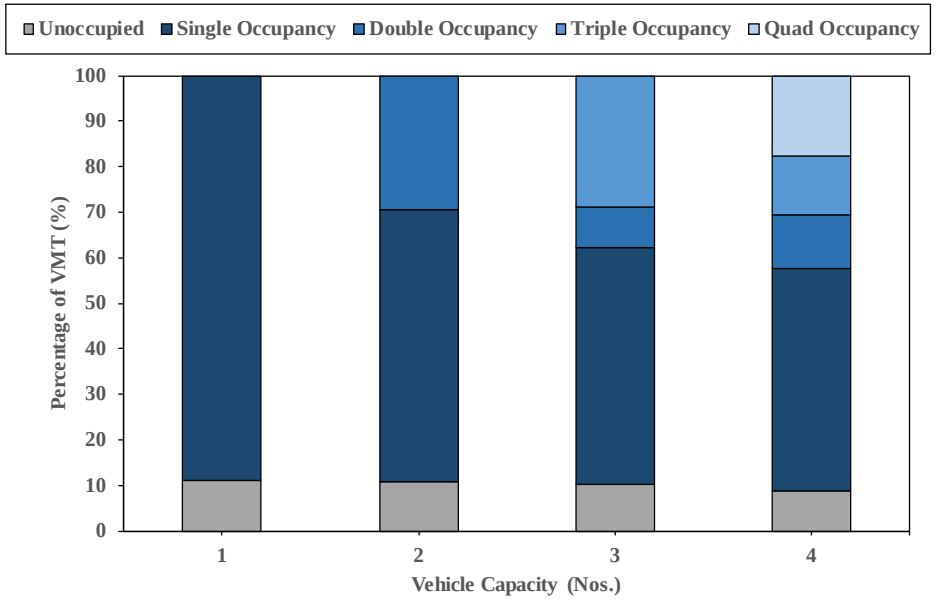
- **SR SAEVs with Level II charging** are cheapest to operate on a per-mile basis, even if this configuration incurs **highest % "empty" VMT** (increases congestion) and **require biggest fleet** (requires more land for charging spots).

SAEV Door-to-Door Service with Dynamic Ridesharing

SR SAEV



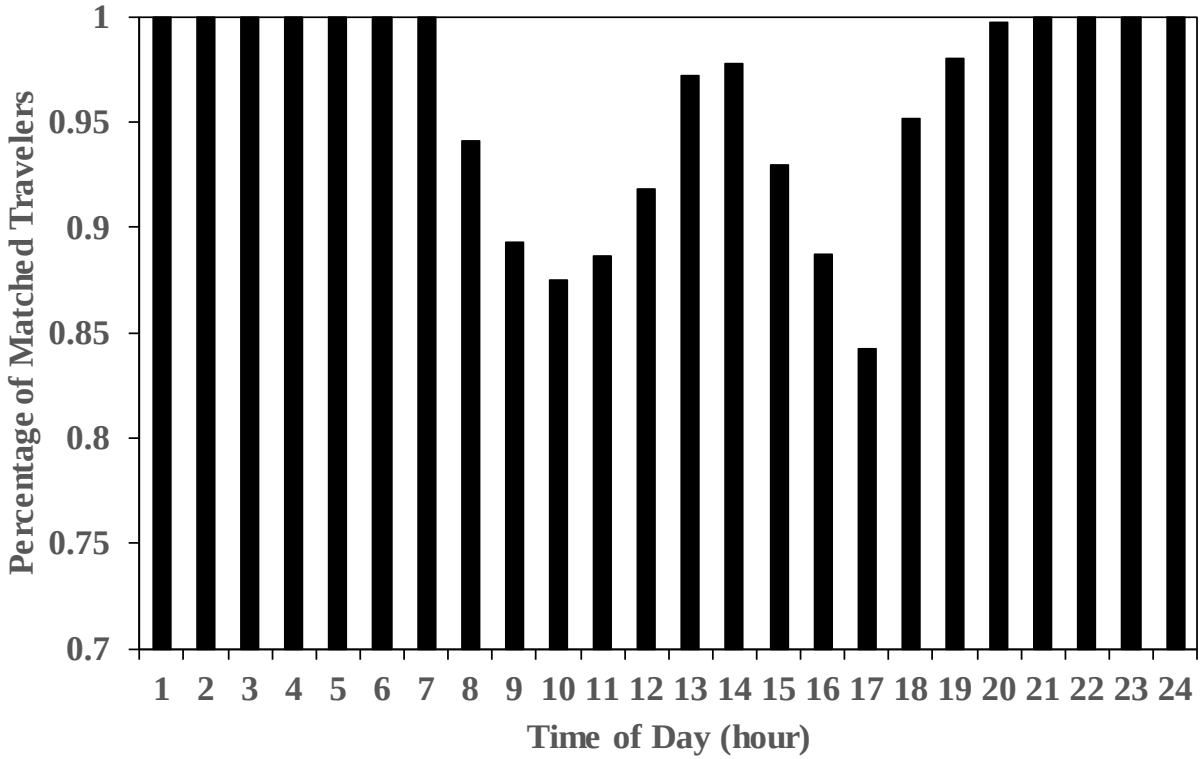
LR SAEV



- **"Empty" VMT** comprises **9-16%** of total VMT for SAEV with ridesharing.
- Assuming all travelers are willing to participate in ridesharing, about **35% of all VMT** include at **least two passengers**.
- One **SAEV with dynamic ridesharing** can **replace 8 to 13 privately owned vehicles.**

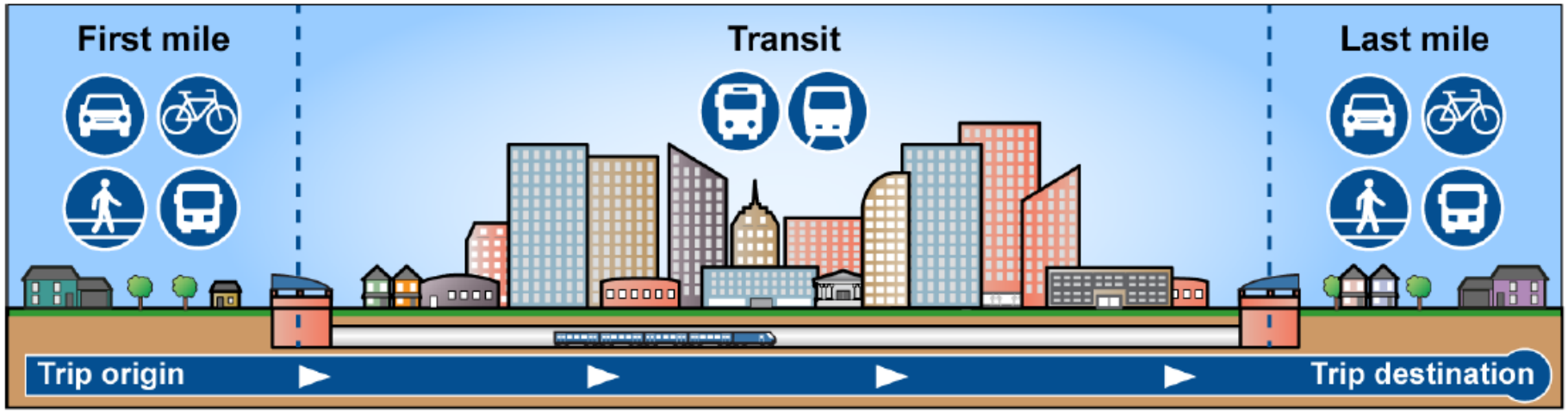
SAEV Door-to-Door Service w/ Dynamic Ridesharing

- Though the total % of trips served exceeds 96% in all scenarios, the **likelihood of matching a vehicle with a passenger varies by time of day**. During peak hours, matching rates can be as low as 85%.



Likelihood of Finding a SAEV by Time of Day (SR SAEV)

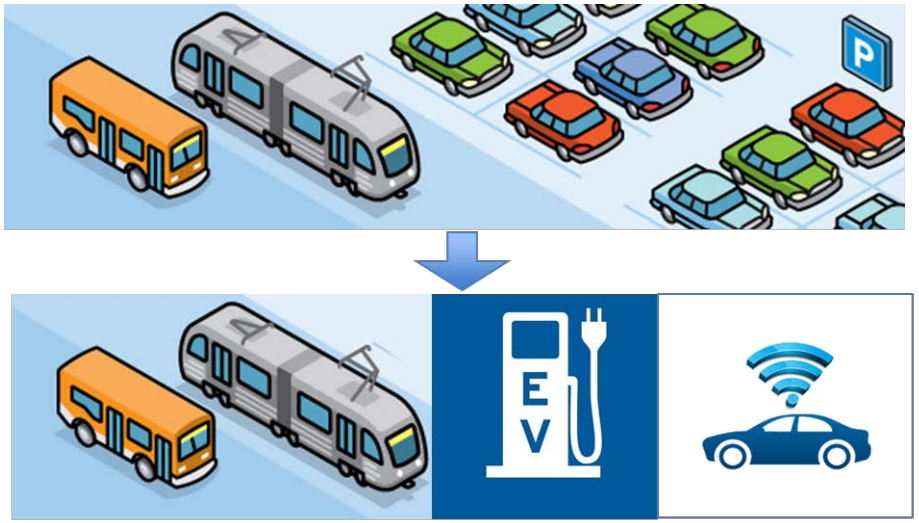
SAEV Use Case: First/Last Mile Connection



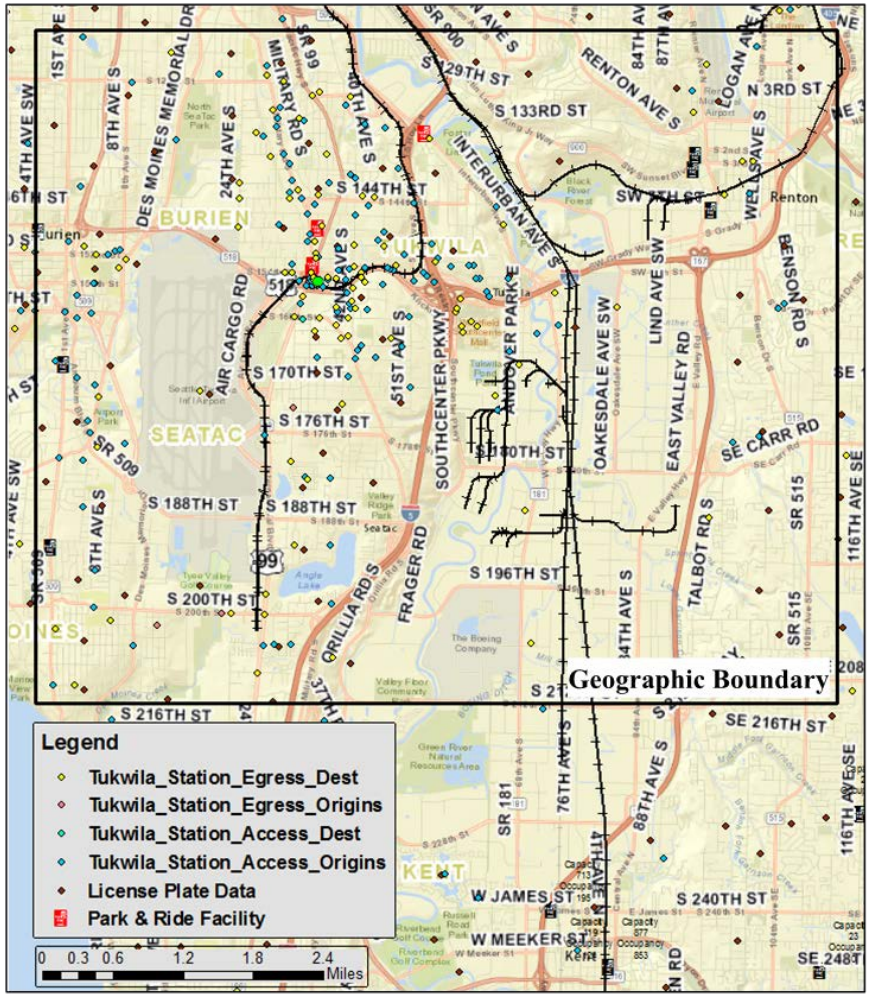
Case study in Seattle, Washington

SAEVs for First/Last Mile Connection

- SAEVs can help **decrease the demand for scarce parking spots** at Park & Rides, and reduce the parking infrastructure requirements on valuable real estate.



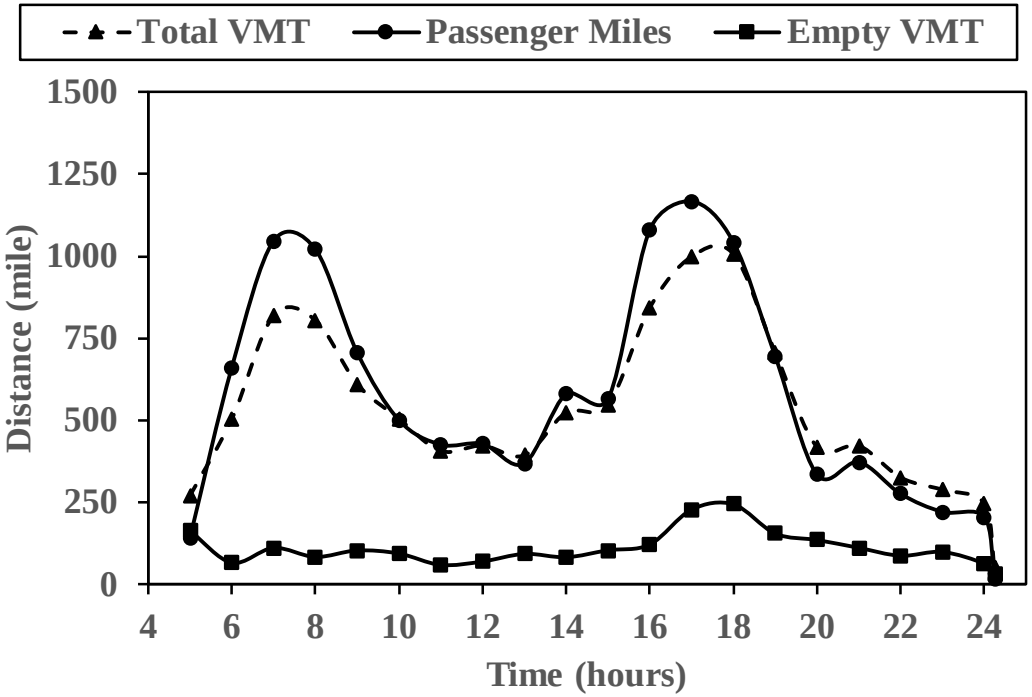
Park and Ride Lot replaced by Charging Station



Case study at Tukwila Light Rail Station in Seattle, Washington

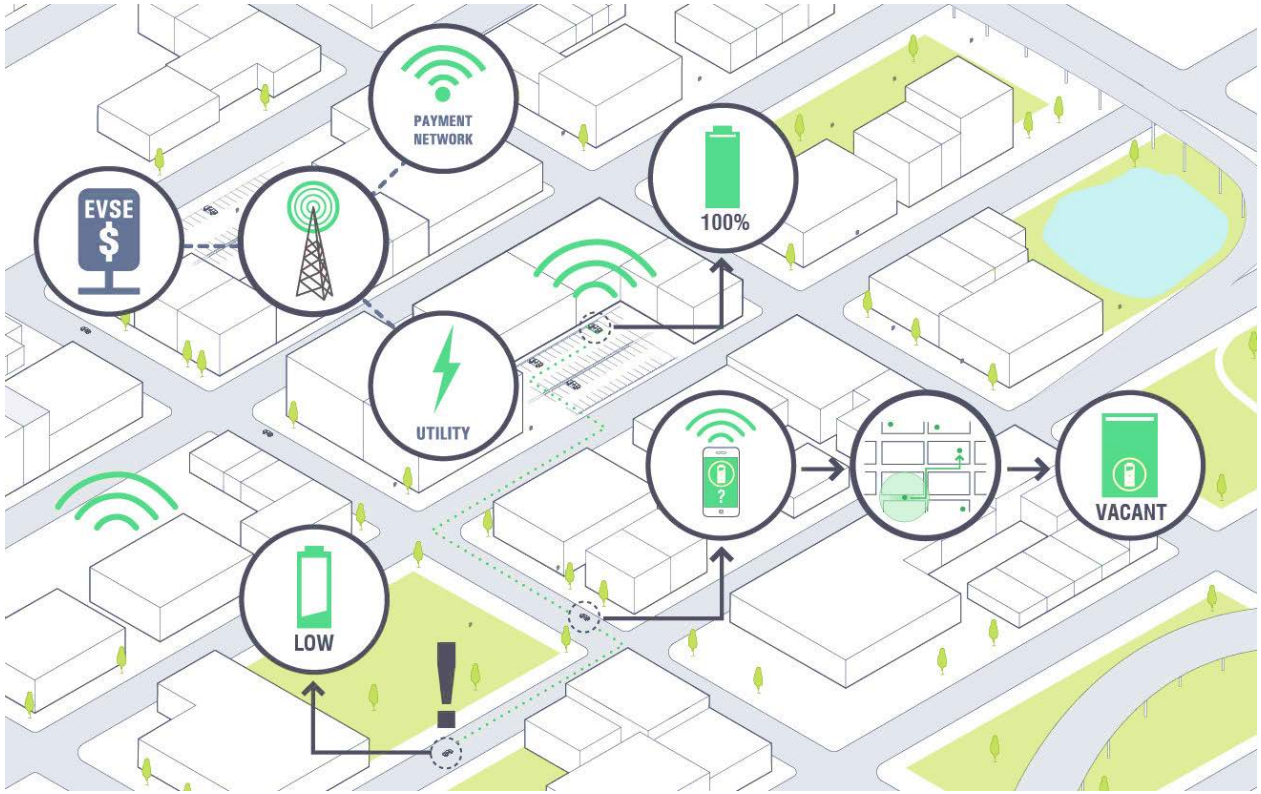
- 2016 survey of rider origin-destinations
- Hourly boarding & alighting data

SAEVs for First/Last Mile Connection



- **Enabling ridesharing** in SAEVs for first/last mile mobility **reduce system-wide VMT by 37%** (compared to single occupancy).
- If all travelers participate in ridesharing, **40-45% of all VMT** include at **least two passengers**, and ridematch rate is higher during AM & PM peaks.
- **"Empty" VMT remains around 20% with ridesharing** in all vehicle & charging infrastructure scenarios.
- One **SAEV with dynamic ridesharing** can **replace 20 to 34 "park & ride" vehicles.**

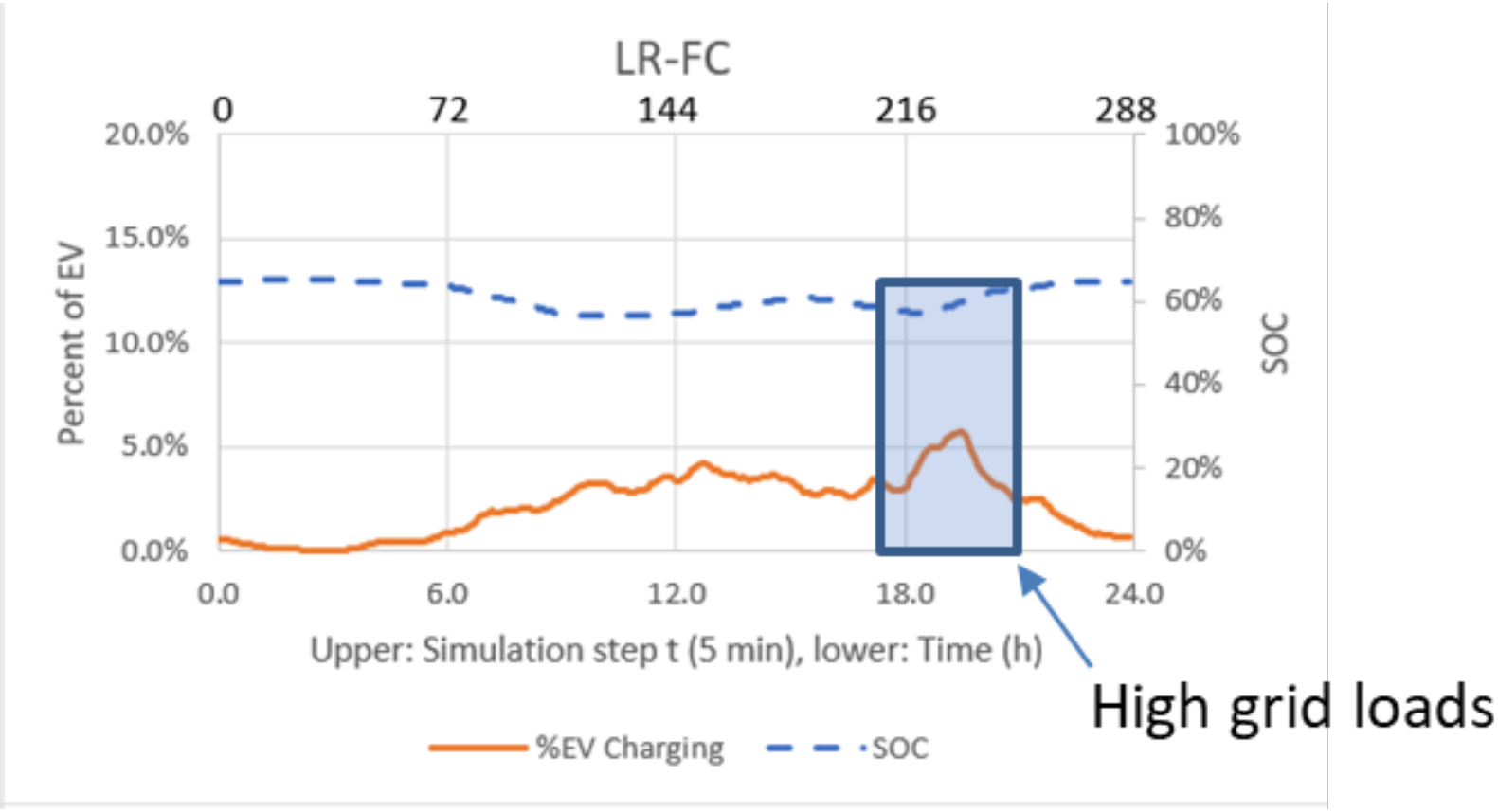
SAEV-Grid Interaction



Case study in Seattle, Washington

SAEV-Grid Interaction

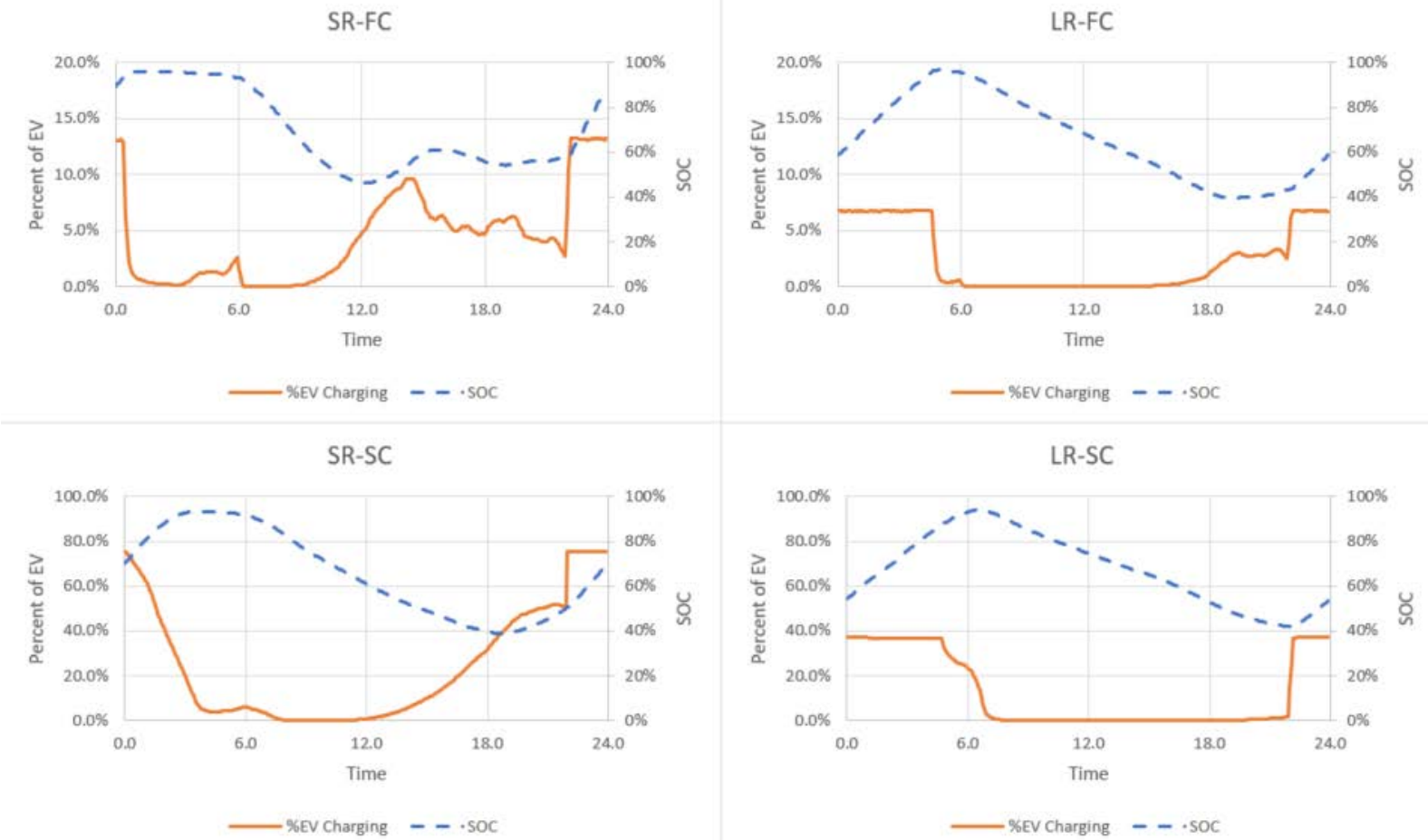
Unmanaged SAEV Charging



Charging "as needed" minimizes SAEV "empty" travel distance for charging, but exhibits **peak charging periods** which coincide with **existing peak hours of electricity use**.

SAEV-Grid Interaction

SAEV Smart Charging under TOU Pricing



With increased battery capacity, **LR vehicles** exhibit superior ability to **avoid charging on-peak**. Compared to unmanaged charging, electricity costs can reduce 10% (SR SAEVs) to 34% (LR SAEVs).

SAEVs: Key Takeaways

- When ridesharing is considered, SAEVs are more efficient at serving first/last mile connection trips than door-to-door trips (higher average occupancy, better ridematch rates during peak hours).
  - How will we encourage disruptive mobility as part of a multimodal trip rather than a new replacement mode?
- "Empty" VMT as a singular measure is not indicative of service efficiency. Service configurations & use cases with higher "empty" VMT can mean higher average vehicle occupancy across all VMT.
  - Don't let the bad publicity of the empty autonomous car get in the way of the real focus: higher average occupancy.
- Charging station capacity can be reduced with longer range vehicles, fast charging infrastructure, and higher ridematch rates.
  - But shorter range vehicles & Level II charging infrastructure are cheaper for the fleet operator to acquire & implement.
- Battery capacity plays an essential role in SAEV-grid interactions. Larger batteries enable SAEVs to act simultaneously as mobile energy user & storage. But with current battery costs & static electricity pricing, fleet operators are not incentivized to adopt LR vehicles.
  - Electricity pricing structures should considered in the conversation about disruptive mobility.

Thank you for your time!

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