THE UNIVERSITY OF TEXAS AT AUSTIN
CENTER FOR TRANSPORTATION RESEARCH

Using Automated Vehicles to Replace Buses & Complement Urban Rail Systems

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Source: The Economist

Shared Automated Vehicles (SAVs)

- SAVs can bring **traffic, safety, & environmental** benefits.
- **AVs & automated shuttles** have been successfully tested worldwide.
- **Long term,** SAV costs may be as low as **$0.40 per revenue-mile**.
- Flexible design + a variety of service types.

SAVs can **compete with** public transportation by replacing buses **or complement** urban rail systems

Complement Urban Rail

SAVs for first-mile last-mile to Transit:

- **Faster** speeds (than walking & sometimes biking).
- **No coordination needed** (with neighbors or family members, for pickup & dropoff at stations).
- **Avoid bad weather & carrying items** (e.g., bringing a bike onto train or bus, carrying briefcase & umbrella while walking, in rain or snow).
- **No parking costs** (though SAV idling sites can be important).
- **Energy savings** over conventional vehicles (if use right-sized or all-electric SAVs).
- **Lower cost than ridehailing & taxis + Greater fleet control** (for faster/smarter vehicle-to-rider assignments).

Automated Mobility Districts (AMDs)

- Short-term deployment of AVs is anticipated to be in the form of SAVs in **geofenced urban districts** with **high trip densities**.

AMD = **campus-sized** implementation of CAV technology to realize all benefits of a **fully automated mobility service** within a confined neighborhood.

- **Transit stations** are great use case for AMDs (thanks to high densities of transit **boarding & alighting** throughout the day).

Research Objectives

- **Quantify impacts of deploying SAVs as FMLM connections** to transit in geofenced regions.
- Investigate details of **SAV** fleet operations, in coordination with mode choice + **train schedules**.

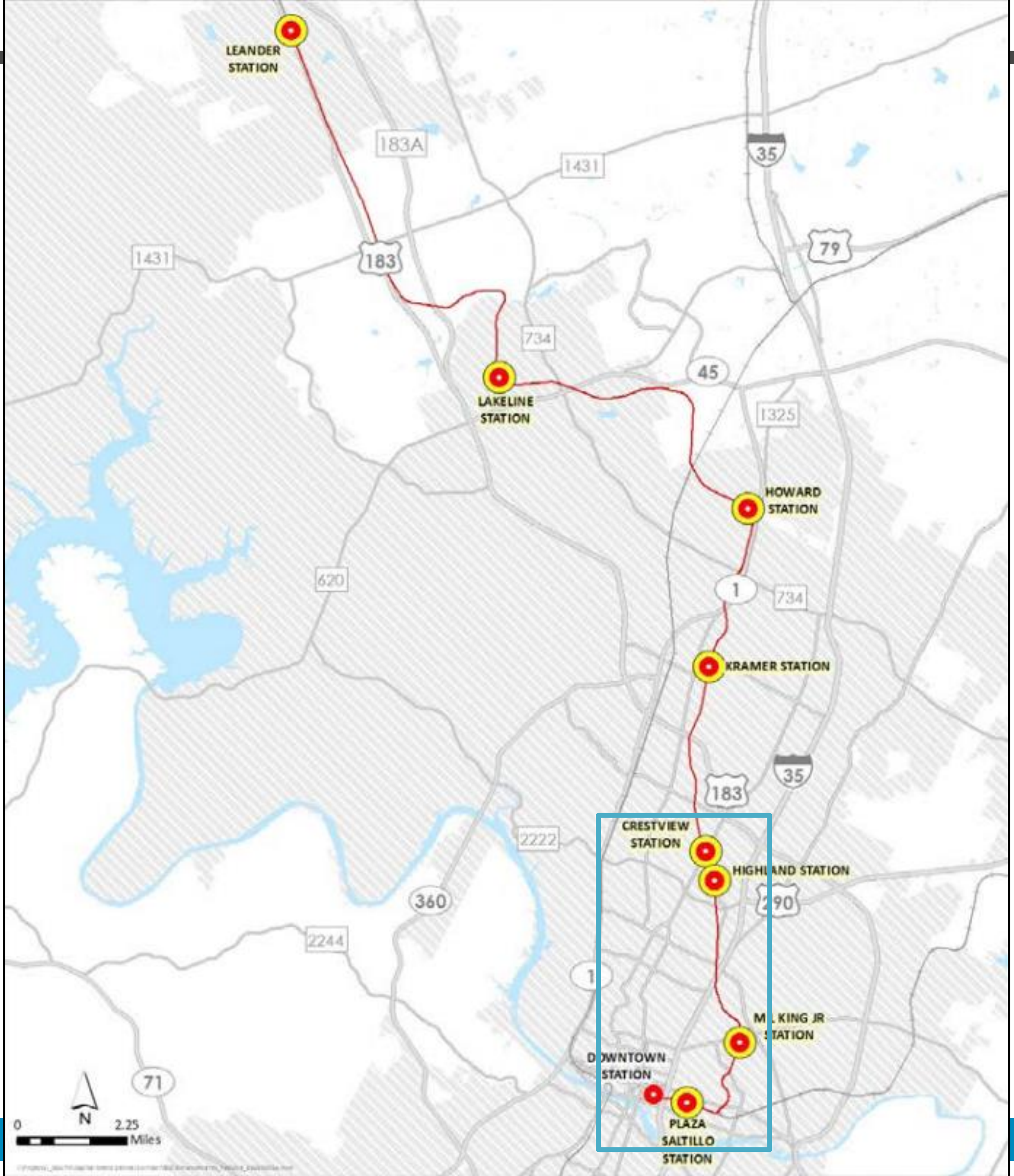
- SUMO = **Simulation of Urban Mobility** = **microscopic** software used to simulate agents (**travelers + SAVs**) over time, across **multiple AMDs** serving **a rail-transit line**.

SUMO
SIMULATION OF URBAN MOBILITY

Huang, Kockelman, Garikapati, Zhu, Young (2021) **Use of Shared Automated Vehicles for First-Mile Last-Mile Service: Micro-Simulation of Rail-Transit Connections in Austin, Texas.** *Transp Research Record, 2675.*

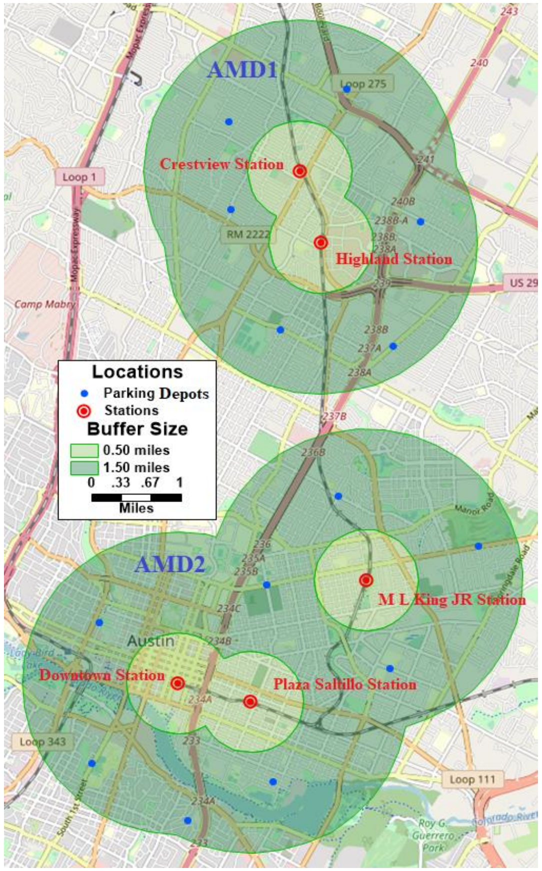
Austin's Red Line Rail

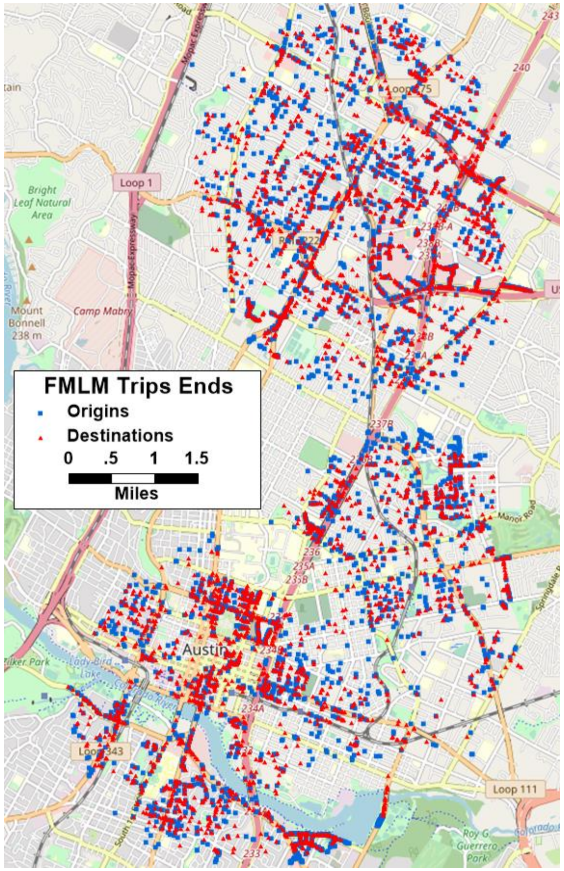
- **32-mile commuter rail** service connecting downtown Austin to Leander City
- 2,552 person-trips/day = average daily ridership
- Expected to reach **10,000 daily riders by 2025** with a **15-minute frequency**
- **FMLM SAVs serve 5** Central Austin **stations:** Crestview, Highland, MLK, Plaza Saltillo & Downtown



Network & Travel Demand

- **Year 2030 forecast** from the region MPO's travel demand model
- **246 traffic analysis zones** extracted from the 6-county region's 2,252 TAZs.





Real-Time Simulation Control

- **Controller** can obtain & react to a **riders'** current **status & location**.
- Every **1 minute**, SAV ride requests are evaluated & **vehicle routing plans** are generated.
- **Dynamic ride-sharing** enabled (so riders can share rides with strangers).
- SAVs can provide FM & LM service in **one routing plan**.

Mode Choice

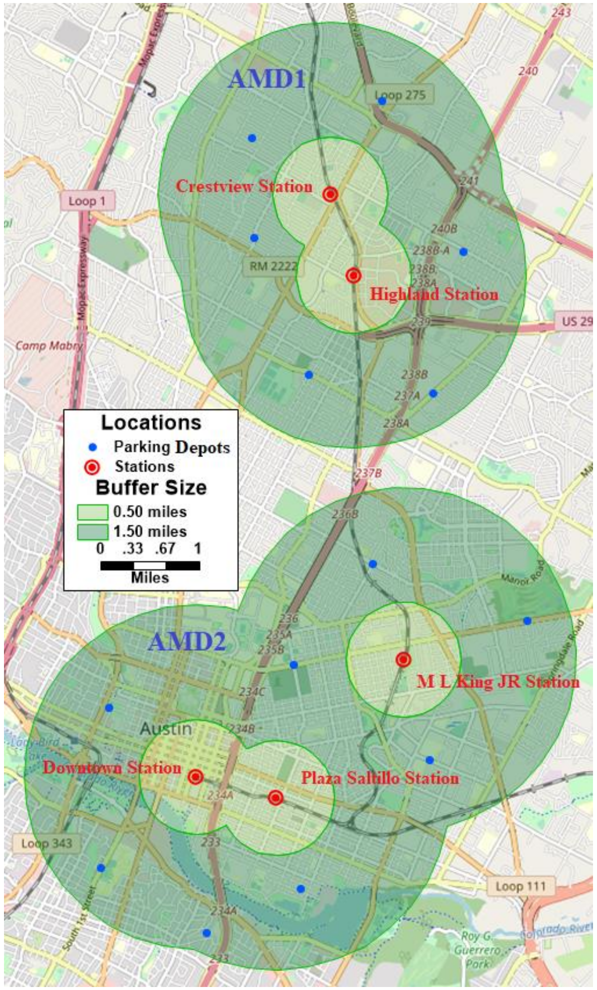
- Rail headways = 15 min
- SAV fares = $1/mile
- 15 SAVs per AMD
- 10% travel demand simulated

- Car VMT **falls 6.4%.**
- **SAV+RideTrain** mode gains **mode share from car**.
- Transit Mode share **rises** from **0.4% to 4.1%.**
- **Occupancy** of SAV = 0.74.
- **Empty SAV VMT** = 36% of total SAV VMT.

SAV Fleet Performance

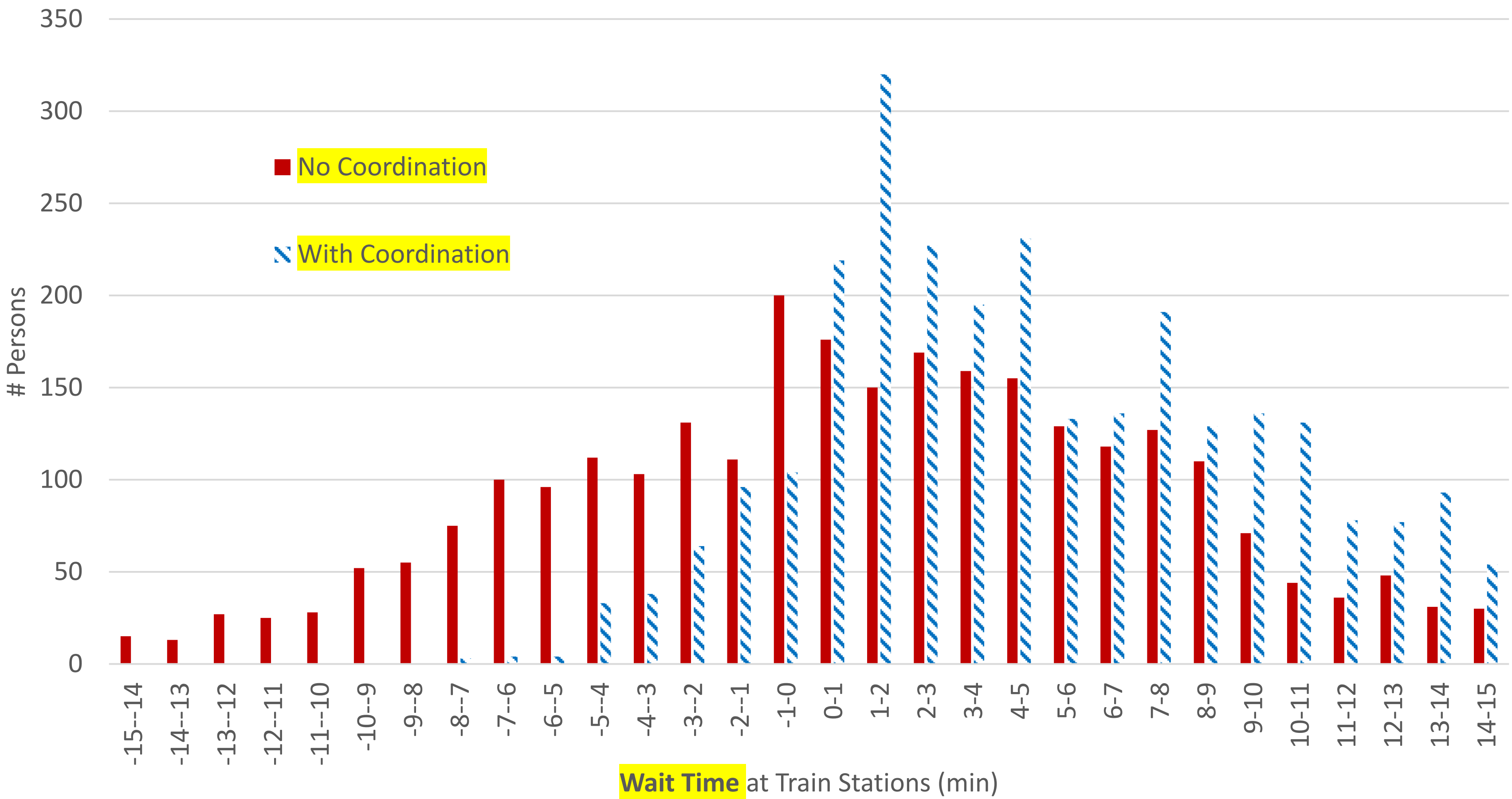
	All 2 AMDs
Shared Vehicle-Miles	31.4%
Shared Person-Trips	90.3%
Average Wait Time	4.61 minutes
Average Ride Distance	2.52 miles
Average Service Duration	15.0 minutes
% Deadheading Distance per Trip	22.3%
% Shared Distance per Trip	27.7%

- **High** shared trips vs. **low** shared miles.
- **1-mile detour** on average.
- SAVs lower total VMT by **3.6%**, if FMLM riders had been traveling by car.



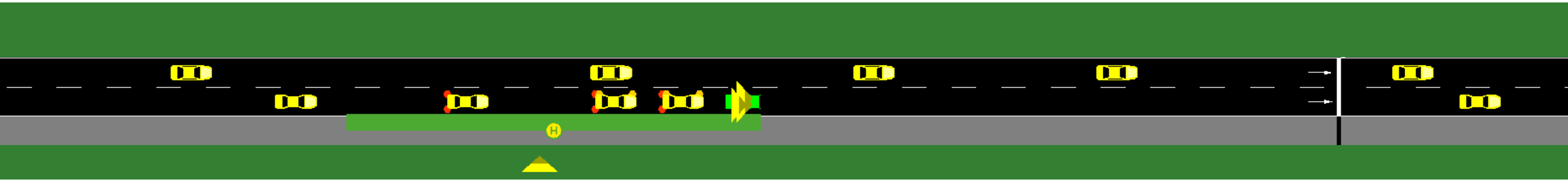
Wait Times at Train Stations

Train Headway = 15 minutes & Negative x-axis value = **Late arrival**



What if Passenger-Miles Traveled shift from Cars to SAVs as a transit service…

- SAV may also offer **fixed-route & fixed-stop transit service.**
- **Total cost per capita** is investigated based on different **SAV penetrations**.
- Human-driven cars & **10-seater SAVs** in a **one-way** 2-lane, 4-mile corridor.
- SAVs **stop** at stations where people are waiting for pickup or wish to alight.
- **Any stopped SAVs wait** for any approaching passenger (i.e., walking up within 20 yards).



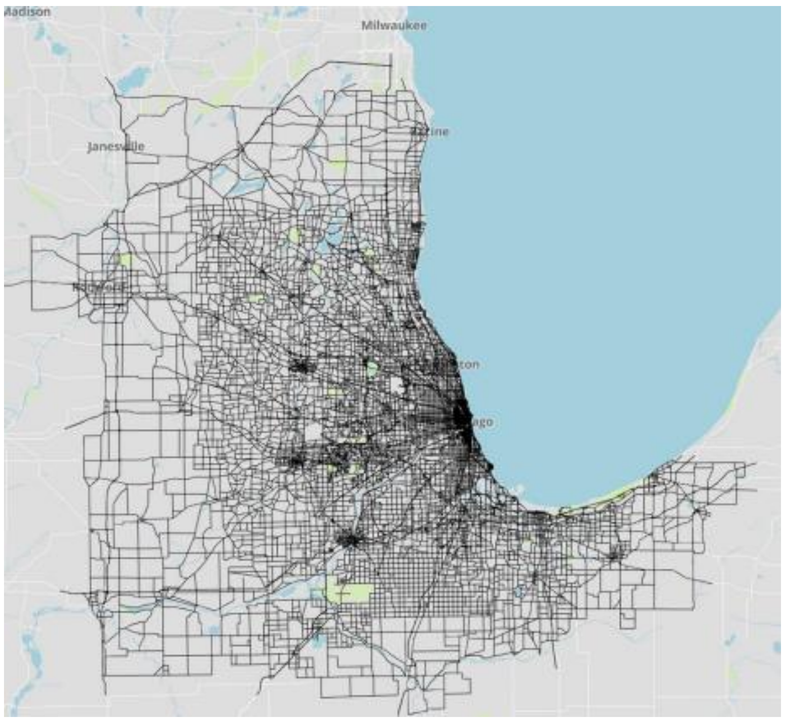
Results

- Total PMT is fixed = **12,000** during 2 hours.
- Car AVO = **1.2** with average VOTT/person = **$12/hour.**
- VOTT of SAV riders = **$30/hr waiting at stops** & **$7.5/hr on board.**
- **Cars** have a total per-mile cost = **$0.58 per mile** + **$3 parking.**
- **SAVs** have a total per-mile cost = **$1.10 per mile.**

SAV PMT Share	Total Cost ($)	Total Cost per PMT ($)
0%	**$ 18,395**	**$ 1.53 / PMT**
5%	$ 19,125	$ 1.59 / PMT
10%	$ 18,876	$ 1.57 / PMT
20%	**$ 18,568**	**$ 1.55 / PMT**
50%	$ 17,414	$ 1.45 / PMT
100%	$ 15,142	$ 1.26 / PMT

Huang, Y. and Kockelman, K.M., 2021. Travel Time Impacts of Using Shared Automated Vehicles along a Fixed-Route Transit Corridor. *Findings*, p.29147.

Deploying SAVs for Various Uses across Large Region



POLARIS for **Chicago simulation**

Door-to-door SAV service **+** **FMLM** service **+** 30-pax **SAVs replace Buses**

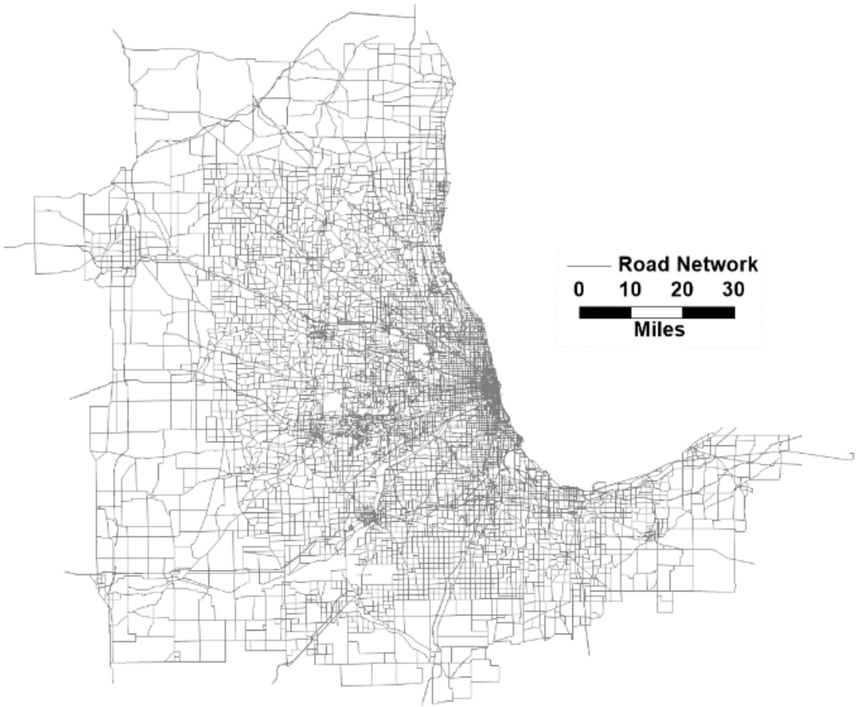
20 counties + **Commuter rail**

Argonne NATIONAL LABORATORY

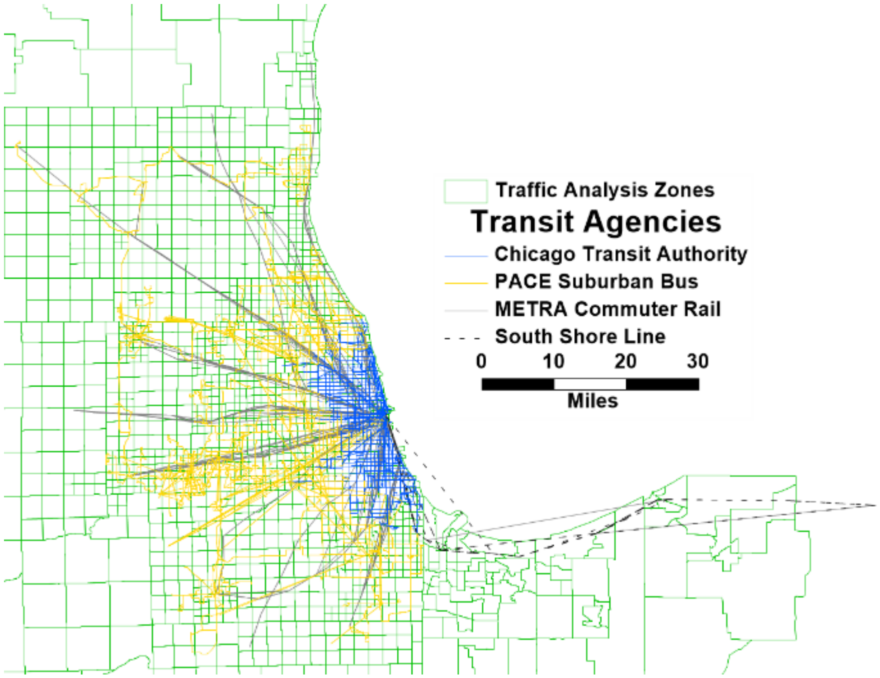
POLARIS Simulation

- **Mesoscopic DTA** for **millions of agents**.
- **FMLM service** to “bus” & rail stations → 2 new mode alternatives.
- **Wait** time + **access & egress travel** time for FMLM service fed back to mode choice model.
- **Multimodal shortest paths** for shortest travel times, between O’s & D’s.

Network



Road network



Transit network

- **20-county** Chicago region
- **1,961** TAZs with ~**32,000** road links
- **349** unique transit lines + **53,763** stops
- **2,100** routes for **28,000** total transit trips over weekday

Simulation Setup

- **5%** Chicago Travel demand
- SAV cost = **$0.50 per mile**
- SAV fleet size = **12,000** assuming **1 SAV for 40 persons**

SAV **D2D** service scenario:

- Household vehicle ownership falls from **0.66 to 0.37 vehicles per capita**.
- Replace Taxi service with low-cost SAV-D2D service.

SAV **D2D** + **FMLM** service scenario:

- Same SAV Fleet size as D2D scenario.

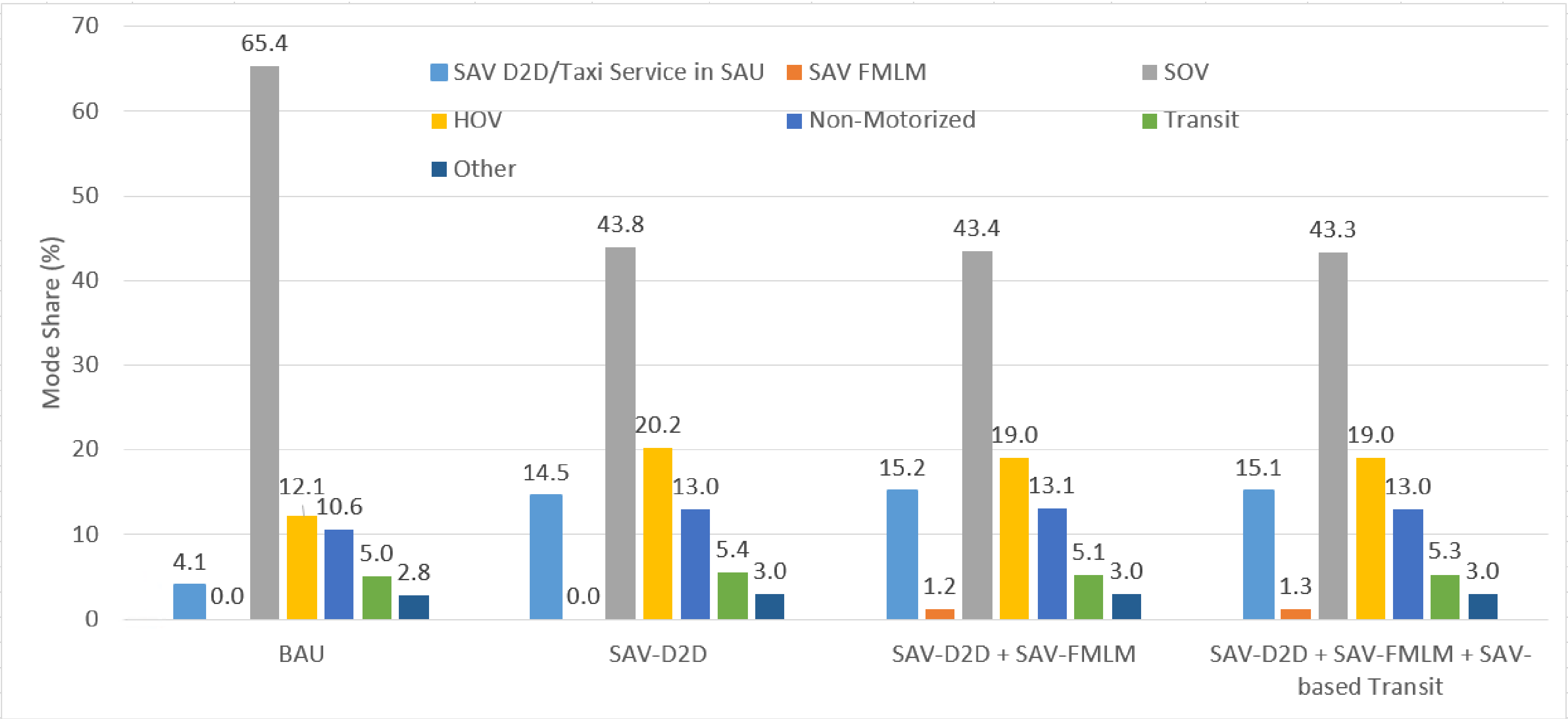
SAV **D2D** + **FMLM** + **SAV-based transit** services scenario:

- SAVs with 15 seats + 15 standing spaces.
- Replaces CTA + PACE bus service.

SAV Fleet Performance of On-demand Service (SAV-D2D + SAV-FMLM)

Scenarios	SAV-D2D	SAV-D2D + SAV-FMLM	SAV-D2D + SAV-FMLM + SAV-based Transit
Avg. Travel Time/person (min)	10.0 min	12.6	12.3
Avg. Wait Time/person (min)	4.9 min	4.6	4.3
# of SAV Requests/day	232,247	260,355	259,685
% Requests Met	99.4	98.8	99.0
AVO by Revenue-trips	1.10	1.13	1.11
AVO by Revenue-miles	1.05	1.05	1.05
Avg. Trips/SAV/day	19.4 trips	23.6	23.5
% eVMT	25%	26%	25%
SAV VMT/person/day	3.03	3.16	3.11
VMT/SAV/day	131.4	136.9	134.9
Hours in Operation/SAV/day	4.2 hrs	4.4	4.3

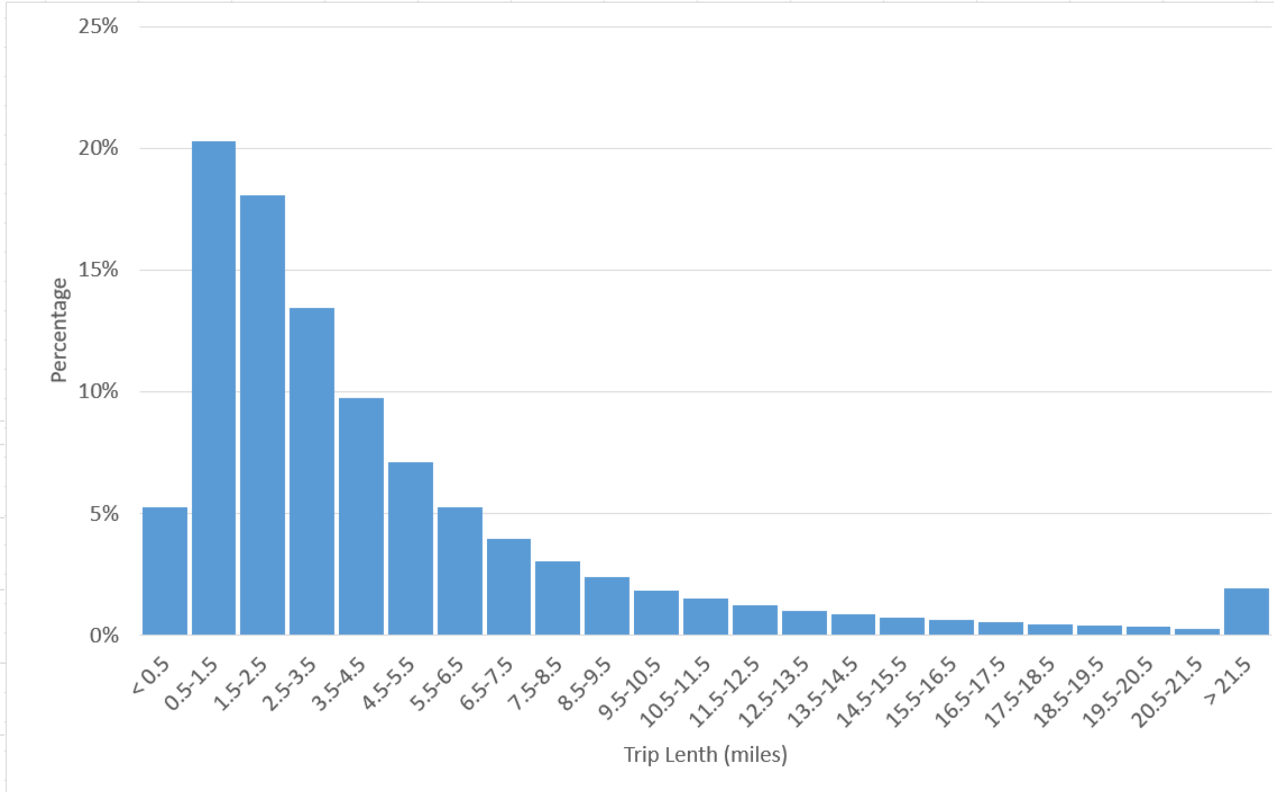
Mode Splits

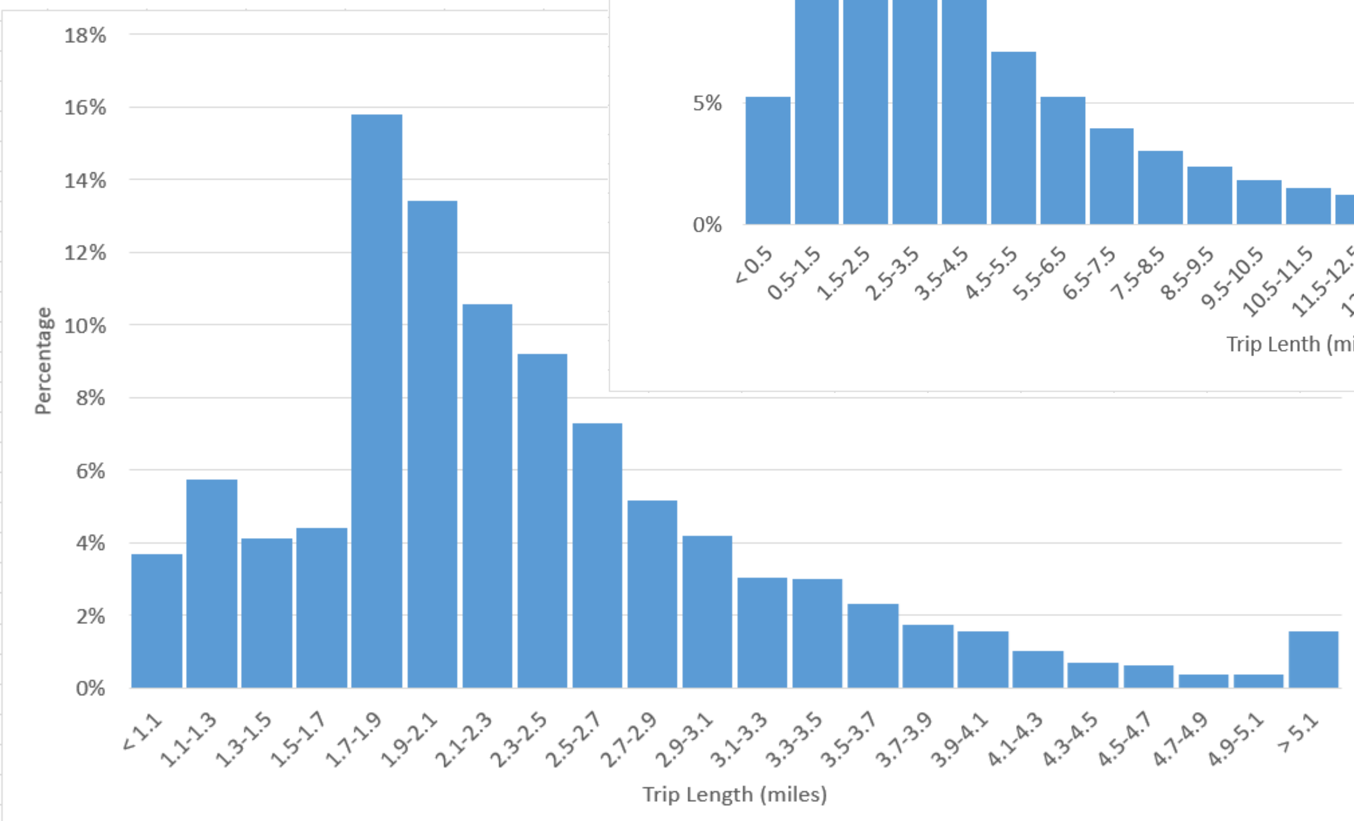


Assuming SAV fares = $0.50/mile

Trip Lengths

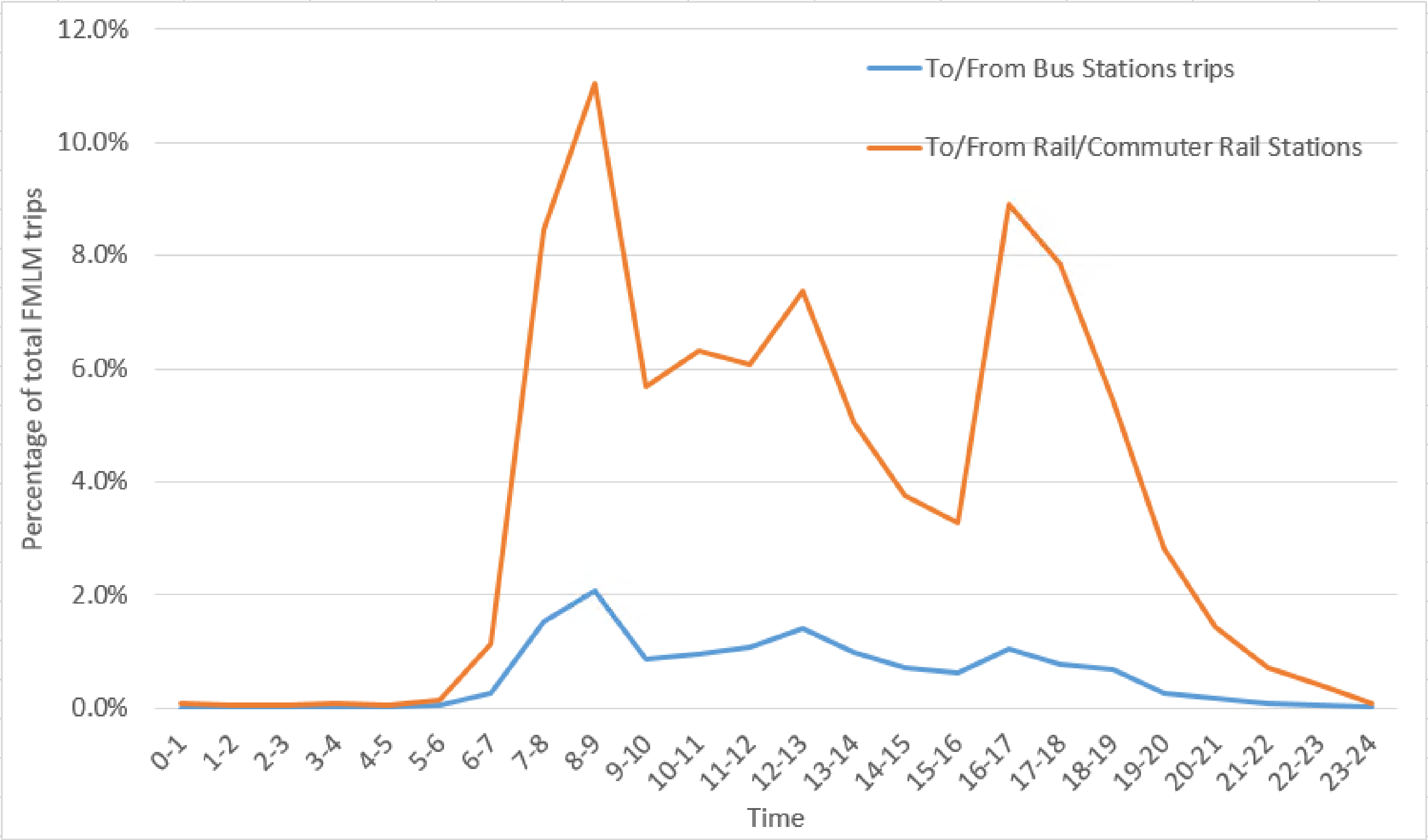
SAV-**D2D** service





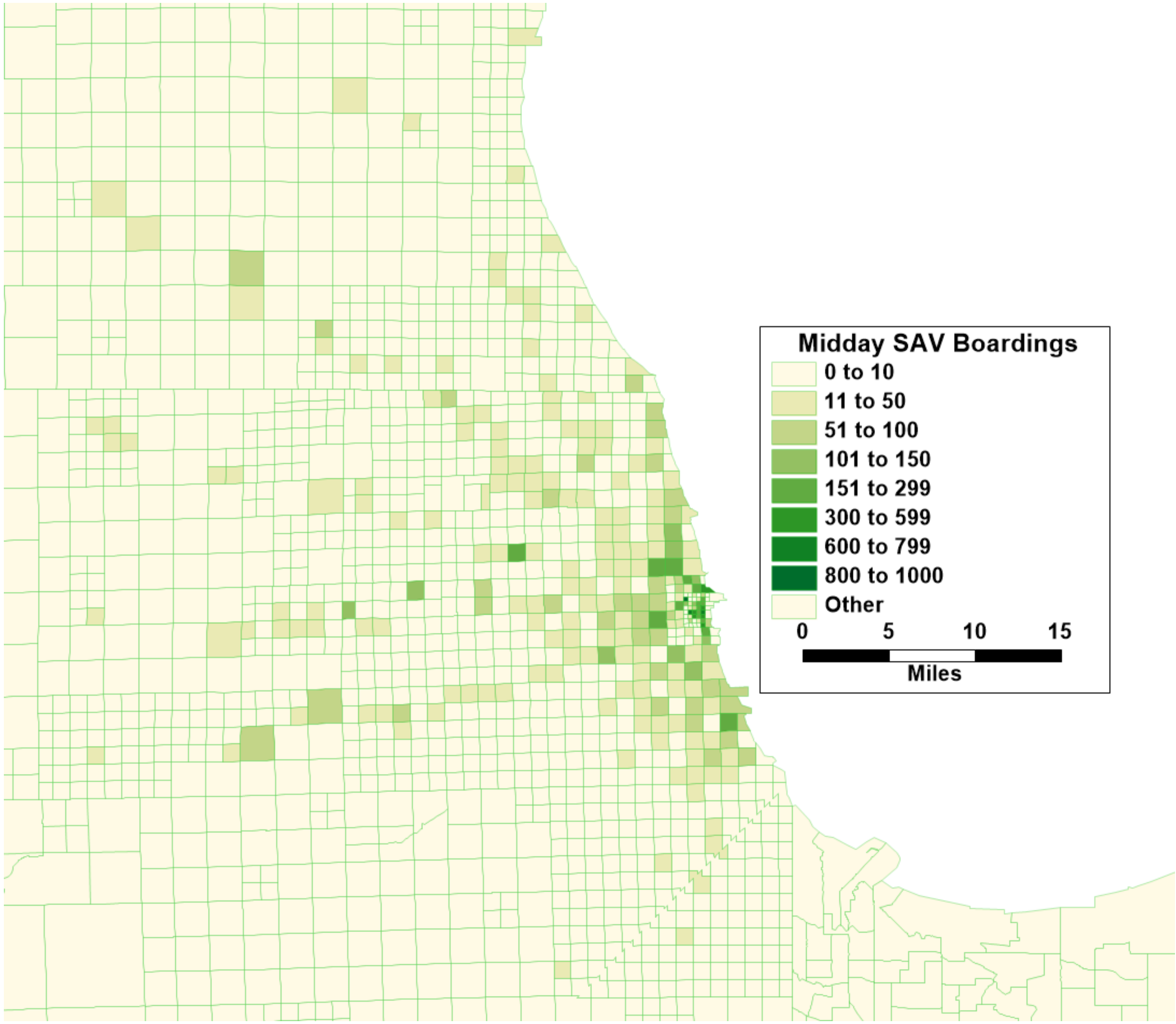
SAV-**FMLM** service

FMLM Trip Count Distribution



- Trips to/from rail lines stations are dominating the FMLM trips, with a ratio of 6:1

SAV Boardings for FMLM service



Conclusion

- SAVs can provide FMLM connectivity to transit stations, with **flexible access/egress decisions** & **coordination with train schedules.**
- **FMLM** service **raises the transit use**, better using utilizing SAV fleet with **small increased VMT** compared to D2D service only.
- The connections to **rail stations** dominates the FMLM trips.
- Roadway system may benefit from SAVs **replacing buses** when SAV PMT Share is **over 20%**.

Questions & Suggestions?

Thanks for your time & support!

Papers available at
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