A Decision Support Tool for Planning Neighborhood-Scale Deployment of Low-Speed Shared Automated Shuttles

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Background

Connected, automated, and electric vehicles (CAEV) and **Mobility-as-a-Service (MaaS)**

In the short term, many cities are testing **low-speed automated electric shuttles** as a shared on-demand mobility service in **geo-fenced regions**.

Automated Mobility District (AMD)

Transportation planners rely on **travel demand simulation and models** to understand the mobility and energy impacts

Existing models lack the capabilities to model emerging mobility technologies such as **on-demand shared mobility**

AMD simulation toolkit is desired

What is an Automated Mobility District?

An AMD is a campus-sized implementation of Connected and automated vehicle (CAV) technology to realize all the benefits of a fully electric automated mobility service within a confined region or district.

Real-World AMD Demonstrations

Find out when driverless vehicles will be hitting the streets of this North Texas city

BY BILL HANNA
JUNE 13, 2018 06:00 AM, UPDATED JUNE 13, 2018 12:57 PM

Self-driving shuttles to start circling Scioto Mile soon

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DEEP DIVE

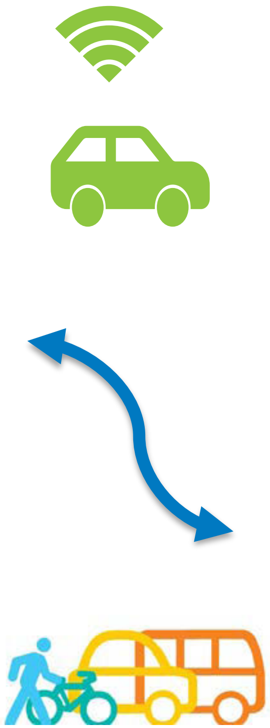
How autonomous shuttles are changing city transportation

Current	Upcoming
Denver, CO	New York City, NY
Houston, TX	Rhode Island
Arlington, TX	Austin, TX
Las Vegas, NV	Reston, VA
Jacksonville, FL	Battle Creek, MD
Columbus, OH	Columbus – Linden, OH
Ann Arbor, MI	Sacramento State University, CA
Bishop Ranch, CA	Dublin, CA
Gainesville, FL	Rivium Park, Netherlands
Babcock Ranch, FL	

Automated Mobility Districts

Characteristics

- Fully automated and driverless cars
- Service constrained to an area with high trip demand
- Mix of on-demand and fixed-route services
- Multi-modal access within/at the perimeter



Operational Challenges

- Customer demand (adoption rate)
- Fleet size
- Operational configuration:

  Fixed route vs. on-demand
- Battery capacity
- Mobility/energy impacts

Current State of AMD Modeling

Where We Are

Existing tools primarily emphasize:

- The road network, with minimal to **no consideration for pedestrian/bike/transit**
- Privately owned vehicles, but **do not model shared mobility**
- Solutions not customized to guide **early-stage deployments**

Where We Want To Be

Need modeling tools that:

- Capture **private as well as shared economies** in vehicles
- Are built based on **data from field deployments** of emerging transportation technology
- Can **quantify energy as well as mobility benefits**

AMD Simulation Toolkit: Model Flow

Travel Demand

- Origin–destination data from regional travel demand model
- Local surveys or counts
- Induced travel demand
- Passenger travel behavior, adoption rates

SUMO

(Mobility Analysis)

- SUMO — Simulator of Urban Mobility
- Carries out the network simulation of vehicles
- SUMO will output travel trajectories

FASTSim

(Energy Analysis)

- FASTSim — Future Automotive Systems Technology Simulator
- FASTSim will output vehicle energy consumption

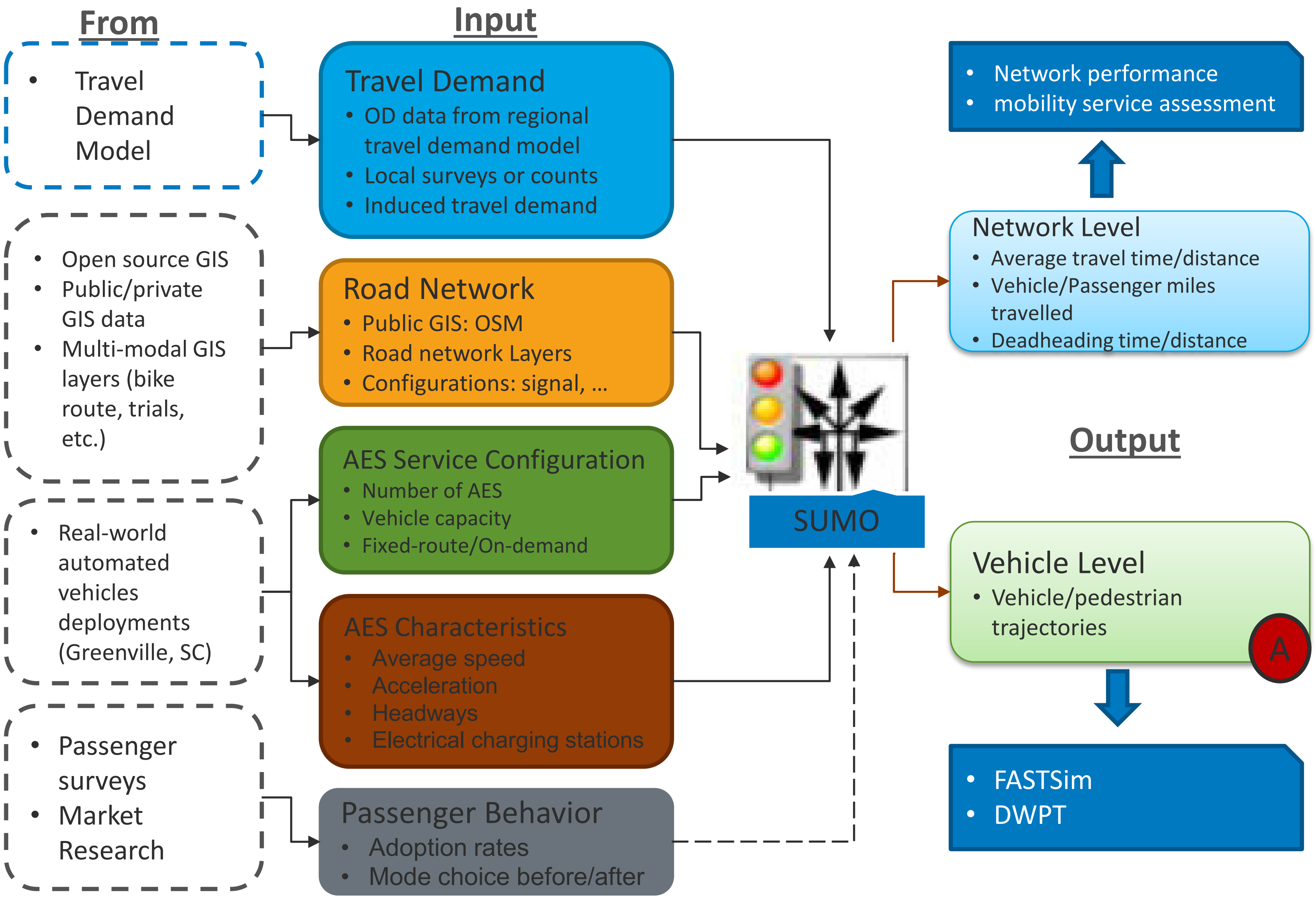
Mode Choice Modeling

- Initially tagged to be developed based on user surveys from Greenville
- Resorting to a model based on existing literature owing to lack of data from Greenville

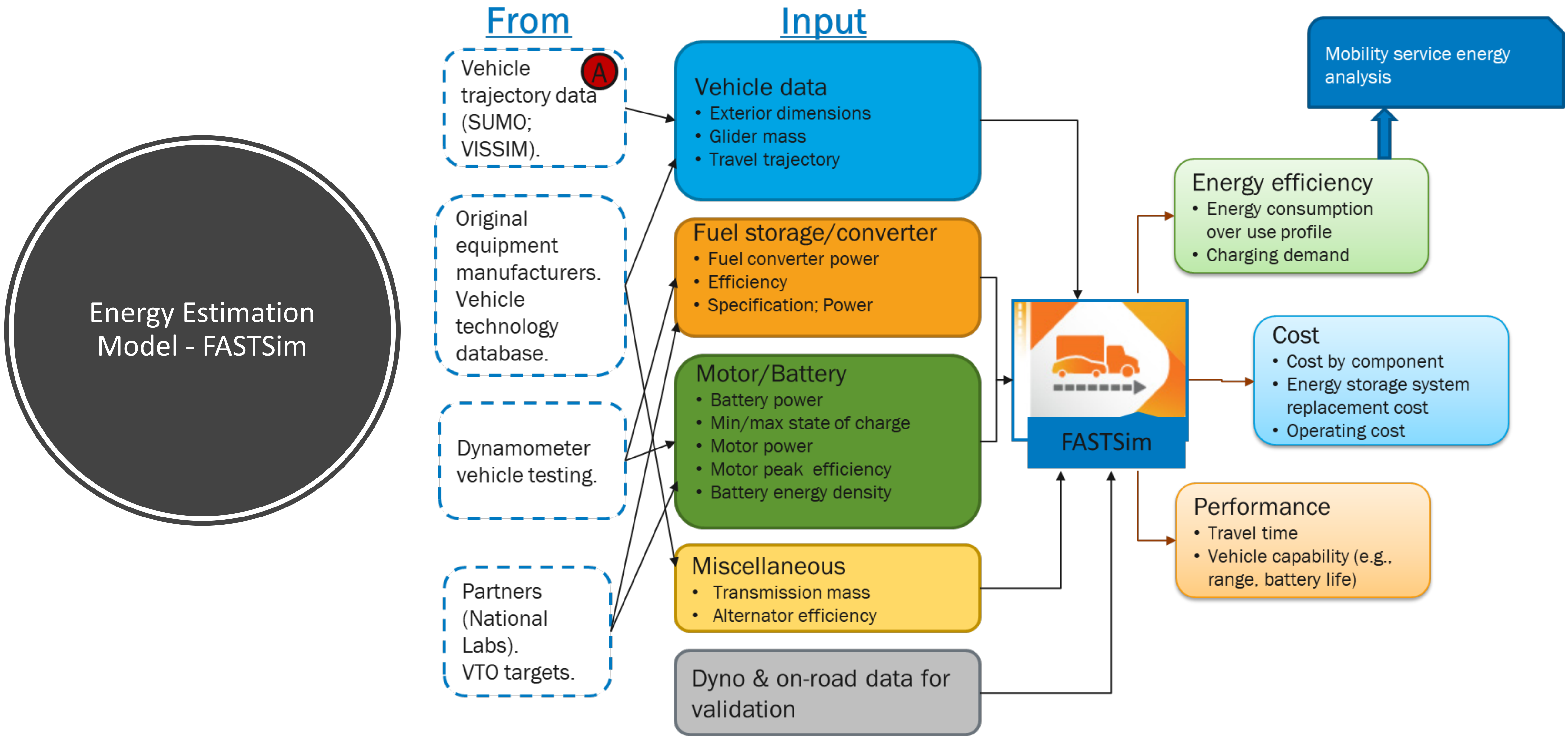
Optimization Module

- Fleet size: How many electric shuttle units will be required?
- Routes: What are the optimal routes that minimize travel time and energy consumption?
- How do we find solutions that meet customers' expected waiting time and overall trip duration?

INPUTS/OUTPUTS FOR SUMO



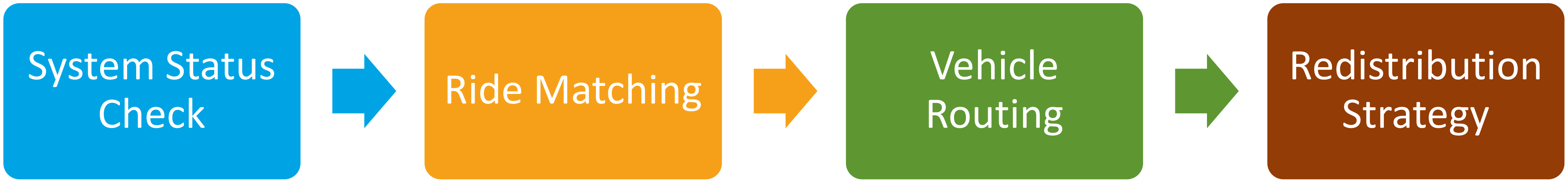
AES: automated electric shuttle; GIS: geographic information system



- *2016 Toyota Camry* is selected to represent gasoline shared and automated vehicles (SAV) and all regular cars
- *2getthere's GRT* (group rapid transit) vehicles for shared and automated electric shuttles

AMD SUMO Simulation

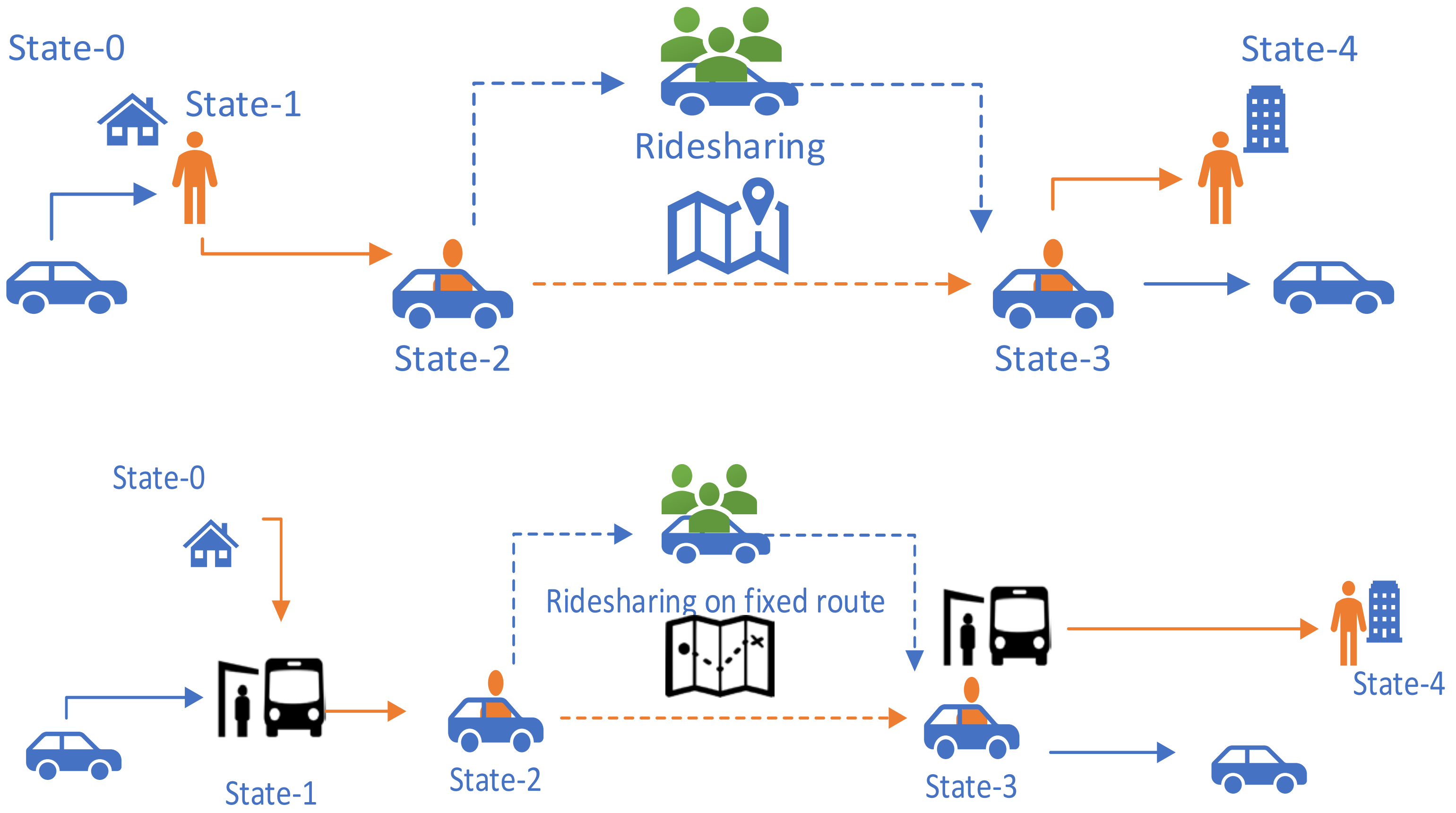
Vehicle Ridesharing Service



1. **System Status Check**
   Gathering information on current location and travel data of passengers as well as SAVs
2. **Ride Matching**
   Matching passengers to available SAVs
3. **Vehicle Routing**
   Calculating an SAV routing strategy
4. **Redistribution Strategy**
   Relocating SAVs for incoming trip requests

AMD SUMO Simulation

Passenger Behavior States



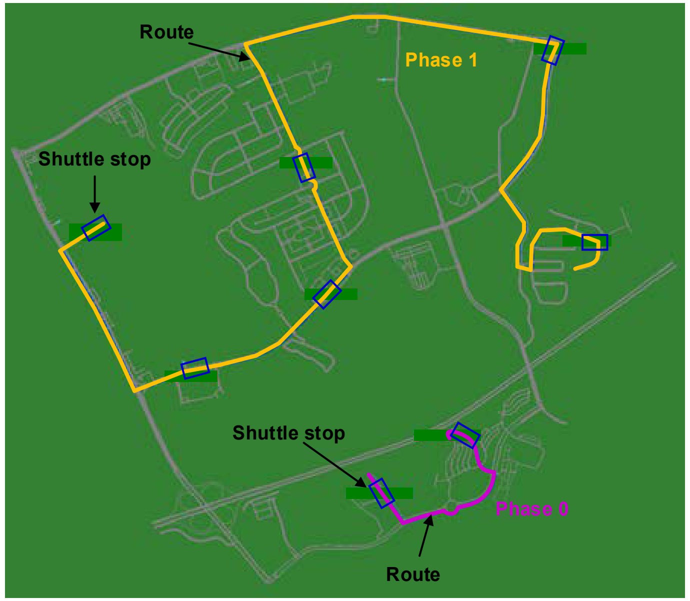
States of passengers

0 - Initialization
1 - Arrive at pickup location and wait
2 - Get onboard
3 - Arrive at drop-off location and alight
4 - Arrive at destination and stop

Case Study: Greenville, South Carolina

- Location: Greenville, South Carolina
- Analysis period: morning peak hours (6 a.m. – 9 a.m.)
- The time-dependent demand distribution: Total 308 trips
- Four modes:
  - CAR: regular car
  - WAK: pedestrian
  - DTD: on-demand door-to-door ridesharing
  - FXR: on-demand fixed-route ridesharing
- AES configuration:
  - SAV Capacity: four passengers
  - Total 10 SAVs: six for FXR mode and four for DTD

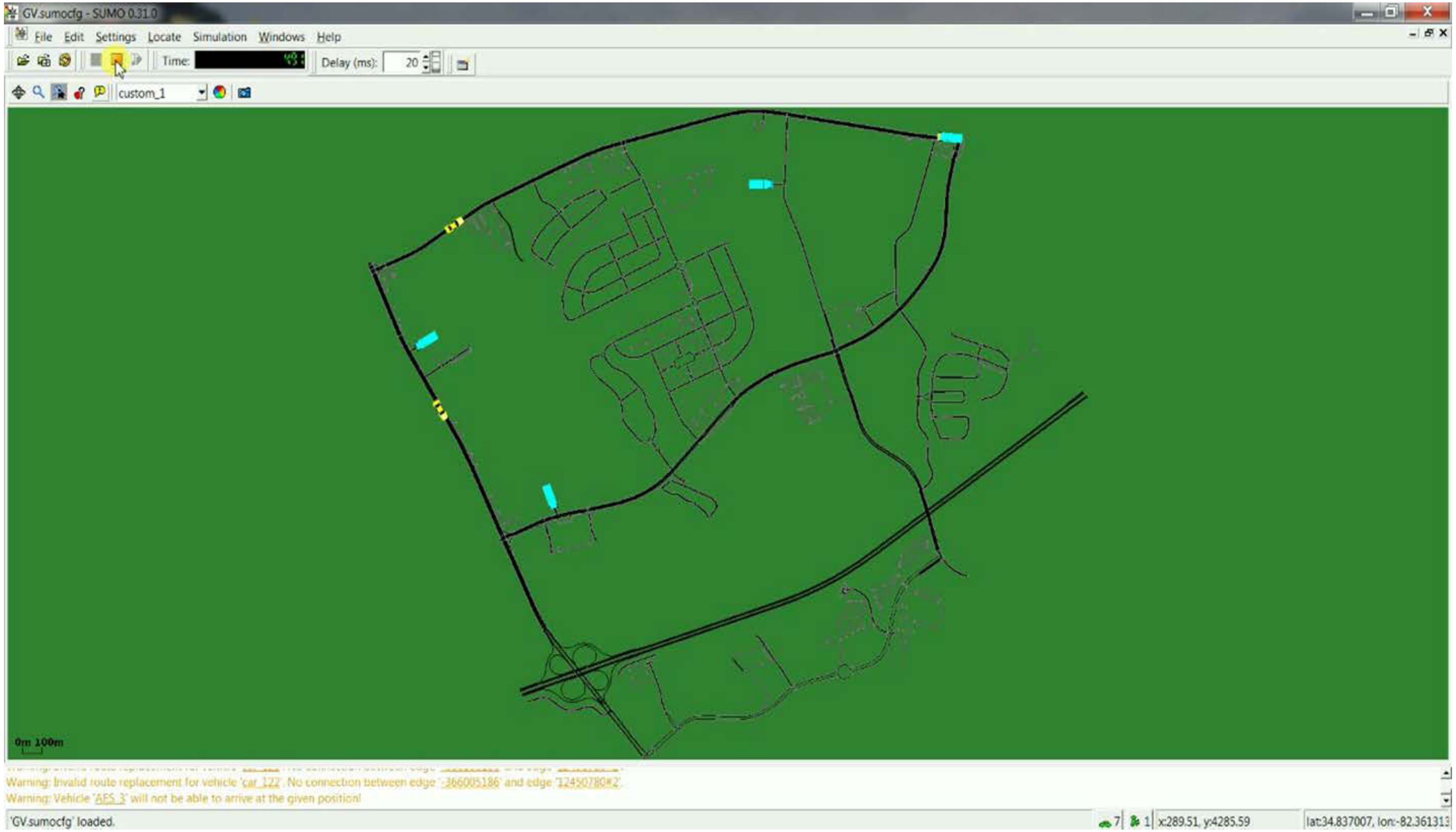
Greenville, South Carolina, network has 554 nodes and 1,340 edges



Network in SUMO and two fixed routes

- In 2017, Greenville, SC won a **Federal Highway Administration grant award** to deploy automated taxis (A-Taxis) in three neighborhoods in the Greenville county.
- In **phase 0**, SAVs were envisioned to be deployed at the Clemson University International Center for Automotive Research (CU-ICAR) facility. In **phase 1**, SAV deployment was planned in the nearby Verdae District, which is a mixed-use urban development

AMD Simulation Sample



Scenario Study and Analysis

Baseline

- Scenario 0: with CAR and WAK modes only

DTD mode only

- Scenarios 1 – 3: 10% increments shifting from CAR mode

FXR mode only

- Scenarios 4 – 6: 10% increments shifting from CAR mode

DTD and FXR modes

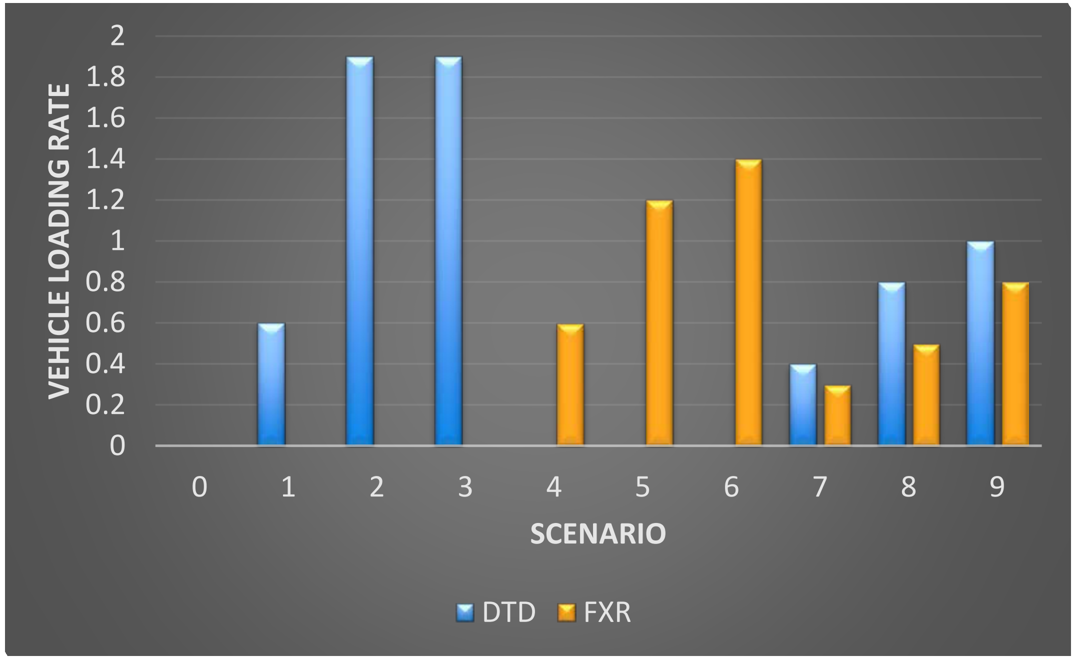
- Scenarios 7 – 9: 10% increments (5% of DTD, 5% of FXR)

	Mode Share Ratio			
Scenario ID	**CAR**	**WAK**	**DTD**	**FXR**
0	0.8	0.2	0	0
1	0.7	0.2	0.1	0
2	0.6	0.2	0.2	0
3	0.5	0.2	0.3	0
4	0.7	0.2	0	0.1
5	0.6	0.2	0	0.2
6	0.5	0.2	0	0.3
7	0.7	0.2	0.05	0.05
8	0.6	0.2	0.1	0.1
9	0.5	0.2	0.15	0.15

Service Performance Metrics

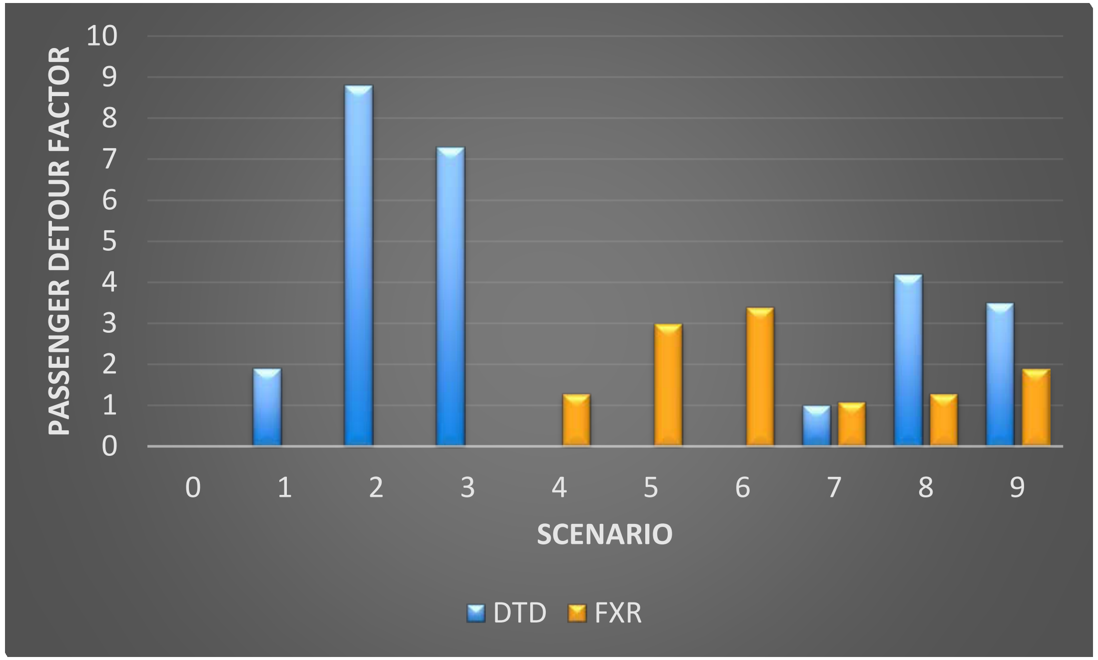
Metric	Unit	Description
VMT	miles	Vehicle miles traveled
VDH	miles	Vehicle deadheading miles traveled (distance traveled with no passenger on board)
VTT	seconds	Vehicle travel time
VLR	# of passengers per mile	Vehicle loading rate: distance weighted number of passengers onboard divided by the vehicle distance traveled for all SAVs
VEC	gallons or kilowatt-hours	Vehicle energy consumption in fuel (gallons) or electricity (kilowatt-hours)
PDF	-	Passenger detour factor: trip distance of ridesharing modes divided by trip distance of regular car mode (time-dependent shortest path)
PWT	seconds	Passenger waiting time

Service Performance Metrics

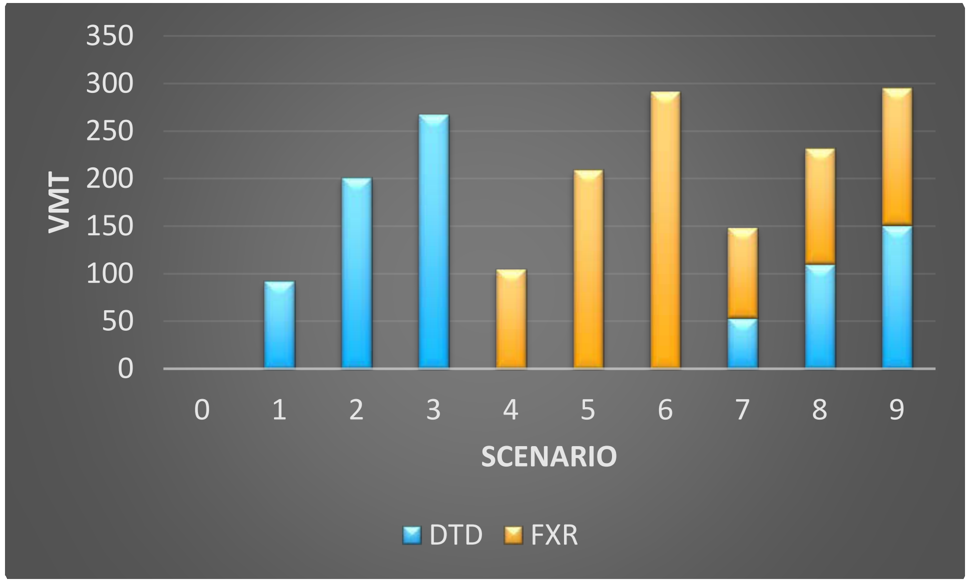


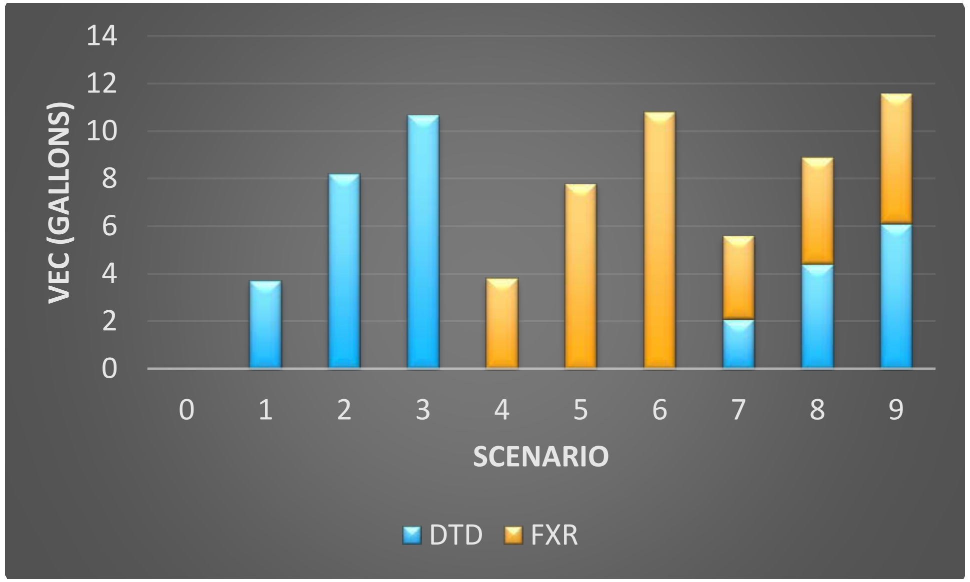
Vehicle loading rate: distance weighted number of passengers on board divided by the vehicle distance traveled for all SAVs; DTD outperforms FXR.

Passenger detour factor: trip distance of ridesharing modes divided by trip distance of regular car mode (time-dependent shortest path).



Service Performance Metrics





Vehicle miles traveled (VMT): VMT increases as number of SAVs increases.

- When both modes are deployed, there are more SAVs operating in the system, leading to higher system-level VMT.

Vehicle energy consumption (VEC): In fuel (gallons) or electricity (kilowatt-hours); similar pattern as VMT

- Scenario 0 has VEC of 17.4 gallons for CAR mode only
- If all SAVs are electric vehicles, the fuel saving ranges from 11% to 38%.

Simulation Results

- The intent of this simulation tool is to help test a variety of deployment scenarios to see what works and what doesn’t before actual field deployment for SAVs.

Network-level VMT, VTT, and VEC keep increasing as the SAV share goes up

DTD outperforms FXR mode with lower VDH and higher VLR

DTD mode falls inferior to FXR mode in passenger detour factor (PDF) and passenger wait time (PWT)

Under same mode adoption ratios, deployment of both FXR and DTD modes leads to higher VMT, VTT, and VEC compared to deploying only one mode.

Next Steps

- Incorporation of additional "**mobility on-demand**" modes and mode choice model
  - Shared bikes, e-scooters, SAVs for **first/last mile connections**
- Integrating the toolkit into a **regional travel demand model**
- Utilizing the toolkit in the context of **real-world AMD deployment**
  - Collecting travel behavior and vehicle dynamics data from these deployments
- More sophisticated routing algorithms and an endogenous mode choice model

Thank you

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Mode Choice Modeling

- Modes considered in Greenville AMD simulation

  1) Auto, 2) Walk, 3) AES, 4) Fixed Route

- General form of mode choice model

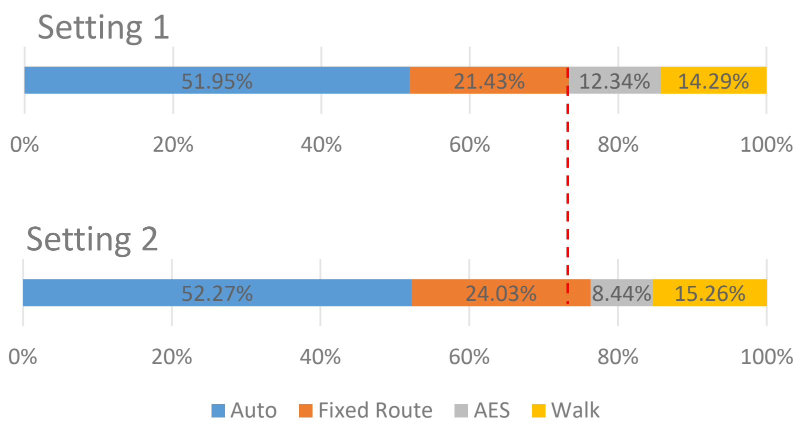
$$V_i = \alpha + \sum_{j=1}^{J} \beta_j x_j$$

Where
$i \in$ {Auto, Walk, AES, Fixed Route}
α is the constant value
x_j is j^{th} mode choice attribute
β_j is coeff. of attribute x_j

- Potential attributes of mode choice model
  - *In-vehicle travel time (IVTT)*
  - *Out-of-vehicle travel time (OVTT)*
  - *Value of travel distance*
  - *Fixed cost (fare)*
  - *Other costs, e.g., parking cost*

Example including IVTT and OVTT

	Value of IVTT ($/h)	Value of OVTT ($/h)
Car	10	0
Fixed Route	17	34
Walk	10	34
AES in Setting 1	**10**	34
AES in Setting 2	**17**	34



- Mode shift observed when value of IVTT changed
- More tests on other attributes in progress