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ActivitySim Vehicle Type Model and Other Enhancements

Southeast Florida Model User Group Meeting

March 22, 2024

Topics

- ActivitySim project
- Vehicle type model overview and implementation
- Autonomous vehicle extension
- Other recent enhancements
- Phase 9 (2024) scope and future directions

ActivitySim Context

ActivitySim Mission

- Create and maintain advanced, open-source, activity-based travel modeling software based on best software development practices for distribution at no charge to the public.
- Activity-based travel models such as ActivitySim predict the travel-related choices of households and individuals in a region.
  - Activity participation
  - Activity locations
  - Travel mode
  - Time-of-day

ActivitySim Principles

Collaborative	One open common platform / code base that is shared by all users
Cost effective	Reduced development and maintenance costs and economies of scale through pooled funding
Practical	Easy for agencies and modelers of different skill levels to use to produce reasonable and reliable estimates and forecasts
Extensible	Can be customized and extended for new features and region-specific needs
Performant	Makes efficient use of computing resources, including memory, storage, and processors

ActivitySim Agency Partnership

- Agencies contribute annually to pooled fund
- Association of Metropolitan Planning Organizations (AMPO) facilitates coordination and provides administrative support
- All funding agency partners participate in decision-making
- 10 years of successful collaboration
- New agencies are welcome

Vehicle Type Model and Estimation

Vehicle Type Choice Model

- Predicts the types of vehicles that households own
- Model uses
  - Auto operating costs for mode choice
  - Vehicle miles of travel by vehicle type
  - Energy consumption
  - Greenhouse gas emissions
  - Autonomous vehicle impacts
- Policy questions
  - Effects of charging infrastructure on electric vehicle ownership, routing
  - Effects of subsidies on electric vehicle ownership
  - Effects of changes in vehicle technology and fuel price on vehicle ownership

Model Structure and Dimensions

- Body type (5)
  - Car, van, SUV, pickup, and motorcycle
- Fuel type (5)
  - Gas, diesel, hybrid, plug-in hybrid (PEV), and battery-electric vehicle (BEV)
- Vehicle age (20)
  - Up to maximum of 20+ years
- Multinomial Logit model with 500 alternatives
- One vehicle modeled for each owned by a household

Data for Estimation

- 2016-2017 National Household Travel Survey
  - U.S. survey of roughly 130,000 households, 275,000 persons, 247,878 vehicles
  - Household and person attributes (income, size number of children, distance to work for workers)
- U.S. Environmental Protection Agency's (EPA's) fuel economy testing database
  - Fuel economy rating, emissions, electric vehicle range and time to charge
  - Averaged by body type, fuel type, and year
- California Energy Commission (CEC) and Bureau of Transportation Statistics (BTS) data on vehicle price
- US Department of Energy, Alternative Fuels Data Center
  - Total number of charging stations by metropolitan area and state

Estimation Results (1)

- Log of the number of makes and models of each vehicle type available for sale are both positive and highly significant
- Fuel economy and range
  - Households prefer vehicles with better fuel economy
  - For electric vehicles, longer range preferred
  - Households are less likely to own BEV if the range is less than the average round-trip commute distance in the household.
  - The availability of chargers has a positive and significant effect on BEV ownership
- Vehicle price
  - Households are less likely to own vehicles that are more expensive when new
  - Households in lowest income categories about twice as sensitive to price as those in the highest income category, and more likely to own older vehicles.

Estimation Results (2)

- Density
  - Households in denser areas are likely to own smaller vehicles and more hybrids.
  - Electric vehicles are most preferred in suburban densities(more likely to own garage or driveway for home private charging)
- Number of vehicles, vehicle age, and household dynamics
  - If only one vehicle owned, more likely to be newer
  - If more vehicles than it has drivers, more likely to own motorcycles or pickup trucks, and more likely to be older.
  - Households with children tend to own larger vehicles.
  - Work commute length inversely related to vehicle age

Estimation Results (3)

- Combinations of vehicles
  - Unlikely to own both a van and an SUV
  - More likely to own multiple hybrids or an electric vehicle and a hybrid
  - Unlikely to own only vehicles of the same type, especially only pickups or motorcycles
- Alternative-specific constants
  - Specified for each dimension
  - Not specified for combinations of dimension due to likely temporal instability
  - Constants by region of the US, to allow for model transferability across ActivitySim deployments (rural, small metropolitan area, and for each member agency region)

Model Implementation

Vehicle Type and Vehicle Allocation Model Flow

Vehicle Type Model

- Choose a vehicle type for every auto in the household
- Combination of fuel type, body type, and age

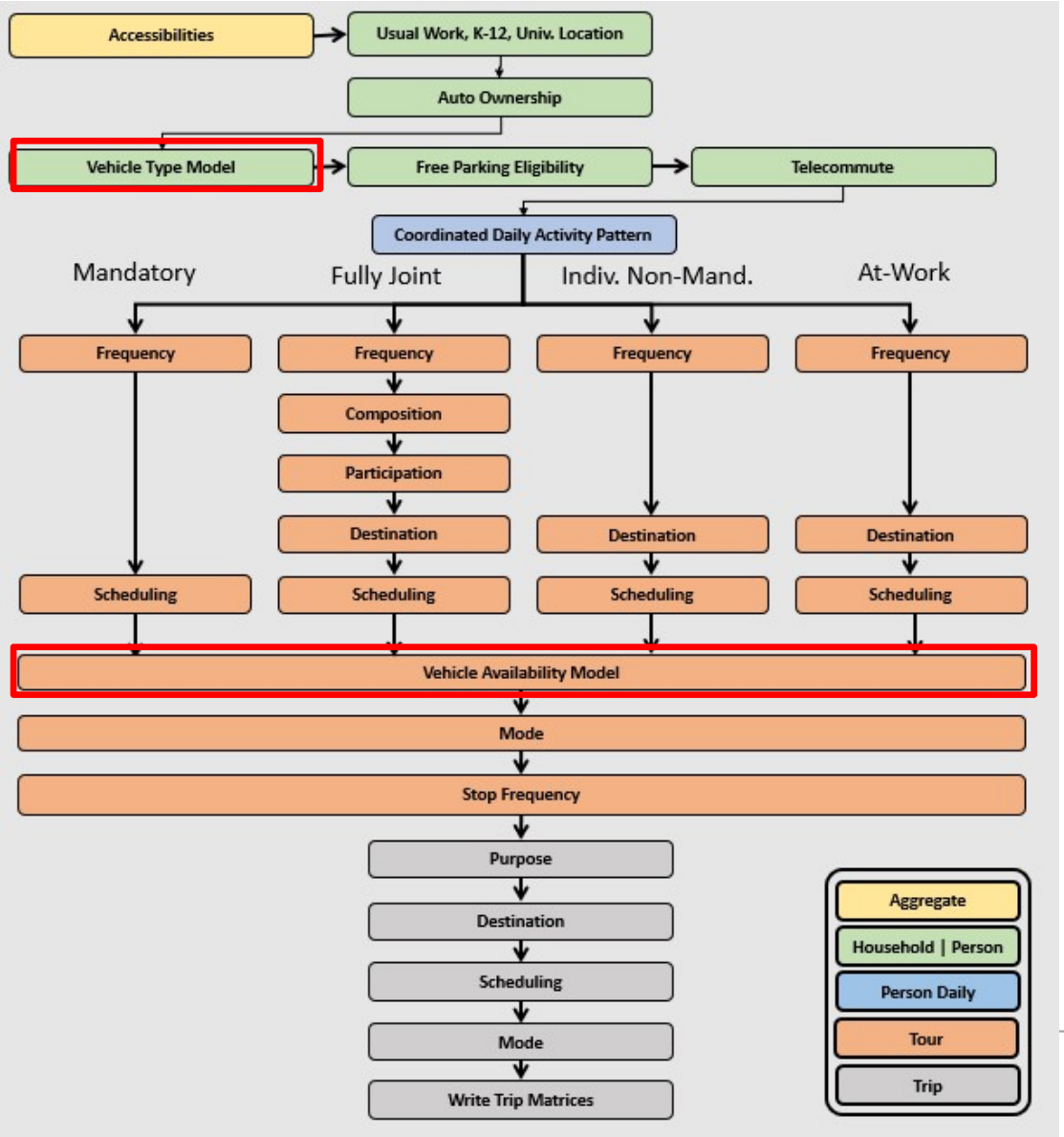
Vehicle Allocation Model

- Match vehicles with tour modes
- Alternatives consist of household vehicles + non-household vehicle option

Auto Operating Costs

- Apply auto operating costs to mode choice
- Mode alternative is given the appropriate occupancy option

Phase 1 Model with vehicle type component



Vehicle Type Model: Vehicle Type Data

	A	B	C	D	E	F	G	H	I
1	body_type	fuel_type	vehicle_year	NumMakes	NumModels	MPG	Range	NewPrice	auto_operating_cost
2	Car	Gas	2017	39	738	24	0	32926.61346	0.13
3	Car	Gas	2016	39	734	23.7	0	33383.61537	0.13
4	Car	Gas	2015	39	740	23.4	0	33369.12233	0.13
5	Car	Gas	2014	41	717	23.2	0	32571.33539	0.13
6	Car	Gas	2013	40	702	23.1	0	32976.62731	0.13
7	Car	Gas	2012	42	668	22.4	0	32959.56219	0.13
8	Car	Gas	2011	42	617	21.7	0	34409.88113	0.14
9	Car	Gas	2010	44	641	21.5	0	35279.71318	0.14
10	Car	Gas	2009	45	637	21	0	35638.52401	0.14
11	Car	Gas	2008	46	649	20.5	0	35745.78309	0.15
12	Car	Gas	2007	43	594	20.3	0	37613.76774	0.15
13	Car	Gas	2006	43	595	20.2	0	38581.65596	0.15
14	Car	Gas	2005	41	661	20.4	0	37537.36453	0.15
15	Car	Gas	2004	43	628	20.6	0	37988.14511	0.15
16	Car	Gas	2003	42	573	20.5	0	37597.37624	0.15
17	Car	Gas	2002	42	543	20.8	0	37380.8733	0.14
18	Car	Gas	2001	39	505	21	0	37361.09207	0.14

Data needs to be supplied for every alternative

Vehicle Type Model: Utility Expressions Subset

Snippet of some terms in the utility expression file

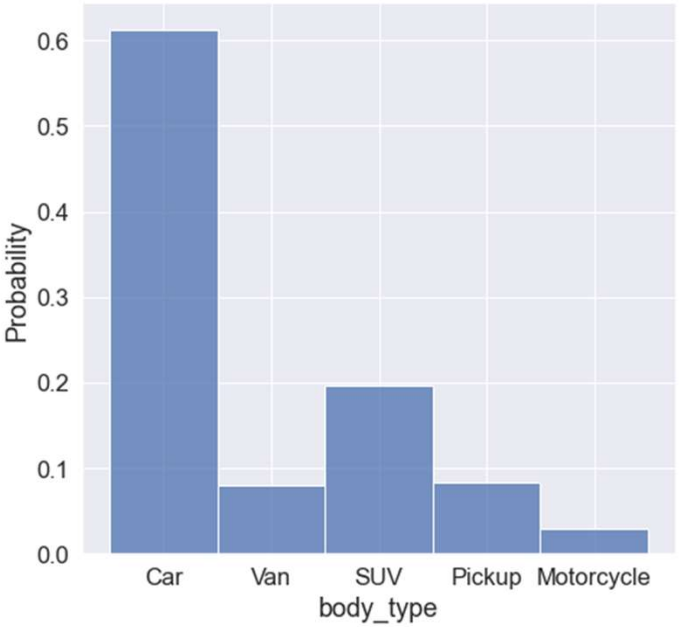
	A	B	C	D
1	Label	Description	Expression	Coefficient
2	util_ln_nmods	number of models available	@np.log(1 + df.NumModels)	coef_ln_nmods
3	util_ln_nmakes	number of makes available	@np.log(1 + df.NumMakes)	coef_ln_nmakes
4	util_mpg	miles per gallon (or equivalent)	@df.MPG	coef_mpg
5	util_crange	Range for BEV (mi)	@df.Range	coef_crange
6	util_crangeltwk	range less than average round trip distance to work	@np.where((df.Range < df.avg_hh_dist_to_work * 2) & (df.fuel_type=='BEV'), 1, 0)	coef_crangeltwk
7	util_ln_chpc_ev	ln(1+number of chargers per capita in MSA/state)	@np.log(1+CHARGERS_PER_CAP)	coef_ln_chpc_ev
8	util_cprice0	New Purchase Price (2017$) Segmented by Income	((income < 25000) & (income > -1)) * NewPrice	coef_cprice0
9	util_cprice25	New Purchase Price (2017$) Segmented by Income	((income < 50000) & (income >= 25000)) * NewPrice	coef_cprice25
10	util_cprice50	New Purchase Price (2017$) Segmented by Income	((income < 100000) & (income >=50000)) * NewPrice	coef_cprice50
11	util_van_van	Household already owns a Van -- Van	(num_hh_Van > 0) & (body_type == 'Van')	coef_van_van
12	util_van_suv	Household already owns a Van -- SUV	(num_hh_Van > 0) & (body_type == 'SUV')	coef_van_suv
13	util_van_pu	Household already owns a Van -- Pickup	(num_hh_Van > 0) & (body_type == 'Pickup')	coef_van_pu
14	util_van_mc	Household already owns a Van -- Motorcycle	(num_hh_Van > 0) & (body_type == 'Motorcycle')	coef_van_mc
15	util_van_suv	Household already owns an SUV -- Van (symmetrical with above)	(num_hh_SUV > 0) & (body_type == 'Van')	coef_van_suv
16	util_van	Van ASC	(body_type == 'Van')	coef_van
17	util_suv	SUV ASC	(body_type == 'SUV')	coef_suv
18	util_sfo_van	SF and San Jose - Van	@(CBSA == 'SFO') * (df.body_type == 'Van')	coef_sfo_van
19	util_sfo_suv	SF and San Jose - SUV	@(CBSA == 'SFO') * (df.body_type == 'SUV')	coef_sfo_suv
20	util_sfo_pu	SF and San Jose - Pickup	@(CBSA == 'SFO') * (df.body_type == 'Pickup')	coef_sfo_pu

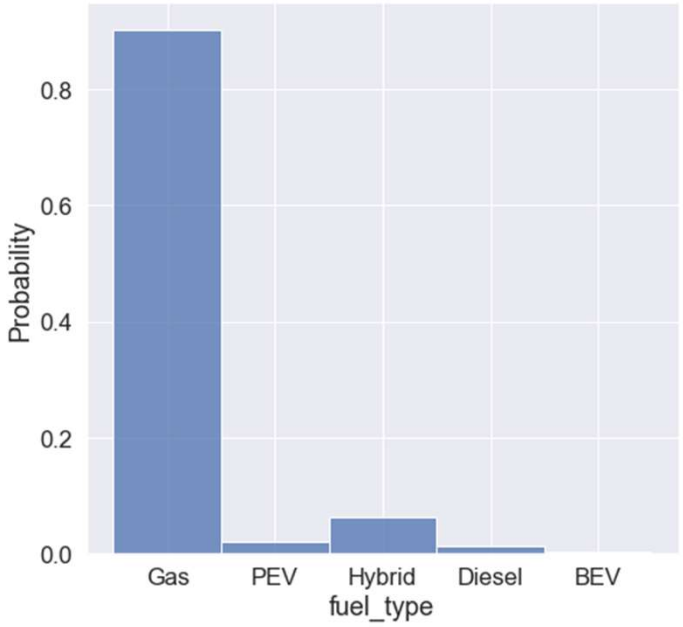
Vehicle Type Model: Output

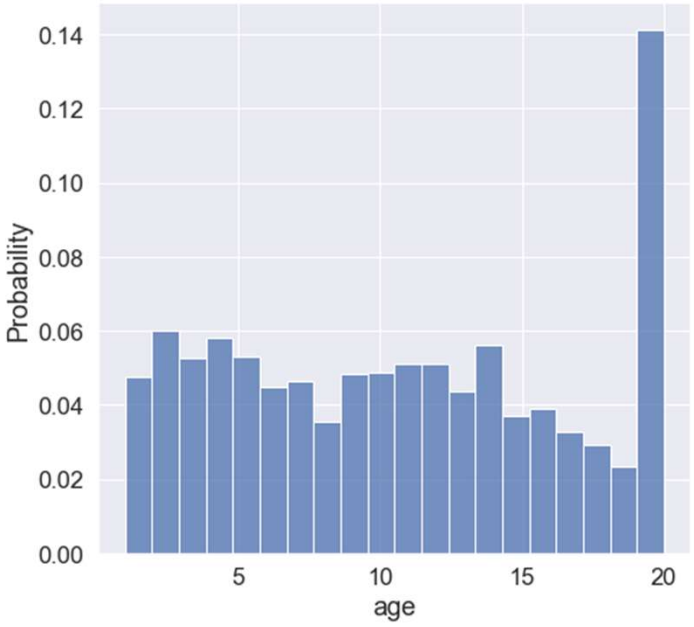
final_vehicles.csv

	A	B	C	D	E	F	G
1	vehicle_id	household_id	vehicle_num	vehicle_type	auto_operating_cost	Range	MPG
2	9828751	982875	1	Car_12_Gas	0.15	0	20.2
3	13120521	1312052	1	Car_2_Gas	0.13	0	23.7
4	13120522	1312052	2	Car_20_Gas	0.14	0	21.3
5	17402091	1740209	1	Van_4_PEV	0.1	0	0
6	17402092	1740209	2	SUV_14_Gas	0.18	0	16.6
7	13190021	1319002	1	SUV_20_Gas	0.17	0	17.4
8	13190022	1319002	2	Pickup_2_Gas	0.16	0	18.5
9	15274261	1527426	1	Car_3_Hybrid	0.08	0	35.5
10	15274262	1527426	2	Car_20_Gas	0.14	0	21.3
11	15274263	1527426	3	Car_11_Gas	0.15	0	20.3
12	7134881	713488	1	SUV_20_Gas	0.17	0	17.4
13	7134882	713488	2	Car_19_Gas	0.14	0	21.2
14	23169201	2316920	1	Car_19_Gas	0.14	0	21.2
15	23169202	2316920	2	Car_1_Gas	0.13	0	24
16	23169203	2316920	3	Car_13_Gas	0.15	0	20.4
17	9213581	921358	1	Car_13_Gas	0.15	0	20.4
18	9213582	921358	2	Car_8_Gas	0.14	0	21.5
19	19624501	1962450	1	Car_5_Gas	0.13	0	23.1
20	19624502	1962450	2	SUV_4_Gas	0.15	0	20.3
21	19624503	1962450	3	Van_13_Gas	0.18	0	16.4

Vehicle Type Model: Output Distributions







Vehicle Allocation Model

Want to select a vehicle that will be used for each tour.

Runs before tour mode choice.

- Setup the example to have 5 alternatives:
  - 4 possible household vehicles (max from auto ownership model)
  - 1 for a non-household vehicle
  - Can be extended if auto ownership model is extended by just adding an alternative column to spec
- Need to run the model once for each occupancy level:
  - Have occupancy values of 1, 2, and 3.5 for sov, shared-2, and shared-3+ modes (configurable setting)
  - tour file is output with one vehicle allocated for each occupancy level

Vehicle Allocation Model: Utility Expressions Subset

	A	B	C	D	E	F	G	H
1	Label	Description	Expression	veh_num1	veh_num2	veh_num3	veh_num4	non_hh_veh
2	#	Availability Conditions						
3	util_alt1_unavail	Household does not own vehicle	veh_num1.isna() | (veh_num1 == '')	coef_unavail	0	0	0	0
4	util_alt2_unavail	Household does not own vehicle	veh_num2.isna() | (veh_num2 == '')	0	coef_unavail	0	0	0
5	util_alt3_unavail	Household does not own vehicle	veh_num3.isna() | (veh_num3 == '')	0	0	coef_unavail	0	0
6	util_alt4_unavail	Household does not own vehicle	veh_num4.isna() | (veh_num4 == '')	0	0	0	coef_unavail	0
7	#	BEV Range						
8	util_dstgtrng1	Round trip tour distance > BEV range	@np.where((df.tot_tour_dist > df.Range_1) & (df.fuel_type_1 == 'BEV'), 1, 0)	coef_dstgtrng	0	0	0	0
9	util_dstgtrng2	Round trip tour distance > BEV range	@np.where((df.tot_tour_dist > df.Range_2) & (df.fuel_type_2 == 'BEV'), 1, 0)	0	coef_dstgtrng	0	0	0
10	util_dstgtrng3	Round trip tour distance > BEV range	@np.where((df.tot_tour_dist > df.Range_3) & (df.fuel_type_3 == 'BEV'), 1, 0)	0	0	coef_dstgtrng	0	0
11	util_dstgtrng4	Round trip tour distance > BEV range	@np.where((df.tot_tour_dist > df.Range_4) & (df.fuel_type_4 == 'BEV'), 1, 0)	0	0	0	coef_dstgtrng	0
12	#	Vehicles & Driver interactions						
13	util_vehltdr_nh	Vehicles < Drivers -- Non-Household Vehicle	hh_veh_lt_drivers	0	0	0	0	coef_vehltdr_nh
14	util_vehltdr_nh	Vehicles > Drivers -- Non-Household Vehicle	hh_veh_gt_drivers	0	0	0	0	coef_vehgtdr_nh
15	util_vehltdr_van1	Vehicles > Drivers -- Van alt 1	hh_veh_gt_drivers * (body_type_1 == 'Van')	coef_vehltdr_van	0	0	0	0
16	util_vehltdr_van2	Vehicles > Drivers -- Van alt 2	hh_veh_gt_drivers * (body_type_2 == 'Van')	0	coef_vehltdr_van	0	0	0
17	util_vehltdr_van3	Vehicles > Drivers -- Van alt 3	hh_veh_gt_drivers * (body_type_3 == 'Van')	0	0	coef_vehltdr_van	0	0
18	util_vehltdr_van4	Vehicles > Drivers -- Van alt 4	hh_veh_gt_drivers * (body_type_4 == 'Van')	0	0	0	coef_vehltdr_van	0
19	#	Occupancy interactions						
20	util_maxocc_van1	Maximum Occupancy -- Van alt 1	@occup * (df.body_type_1 == 'Van')	coef_maxocc_van	0	0	0	0
21	util_maxocc_van2	Maximum Occupancy -- Van alt 2	@occup * (df.body_type_2 == 'Van')	0	coef_maxocc_van	0	0	0
22	util_maxocc_van3	Maximum Occupancy -- Van alt 3	@occup * (df.body_type_3 == 'Van')	0	0	coef_maxocc_van	0	0
23	#	Alternative Specific Constants						
24	util_non_hh	Non-Household Vehicle Constant	1	0	0	0	0	coef_non_hh
25	util_van1	Van ASC alt 1	(body_type_1 == 'Van')	coef_van	0	0	0	0
26	util_van2	Van ASC alt 2	(body_type_2 == 'Van')	0	coef_van	0	0	0
27	util_van3	Van ASC alt 3	(body_type_3 == 'Van')	0	0	coef_van	0	0
28	util_van4	Van ASC alt 4	(body_type_4 == 'Van')	0	0	0	coef_van	0
29	util_suv1	SUV ASC alt 1	(body_type_1 == 'SUV')	coef_suv	0	0	0	0

Tour Mode Choice Modifications

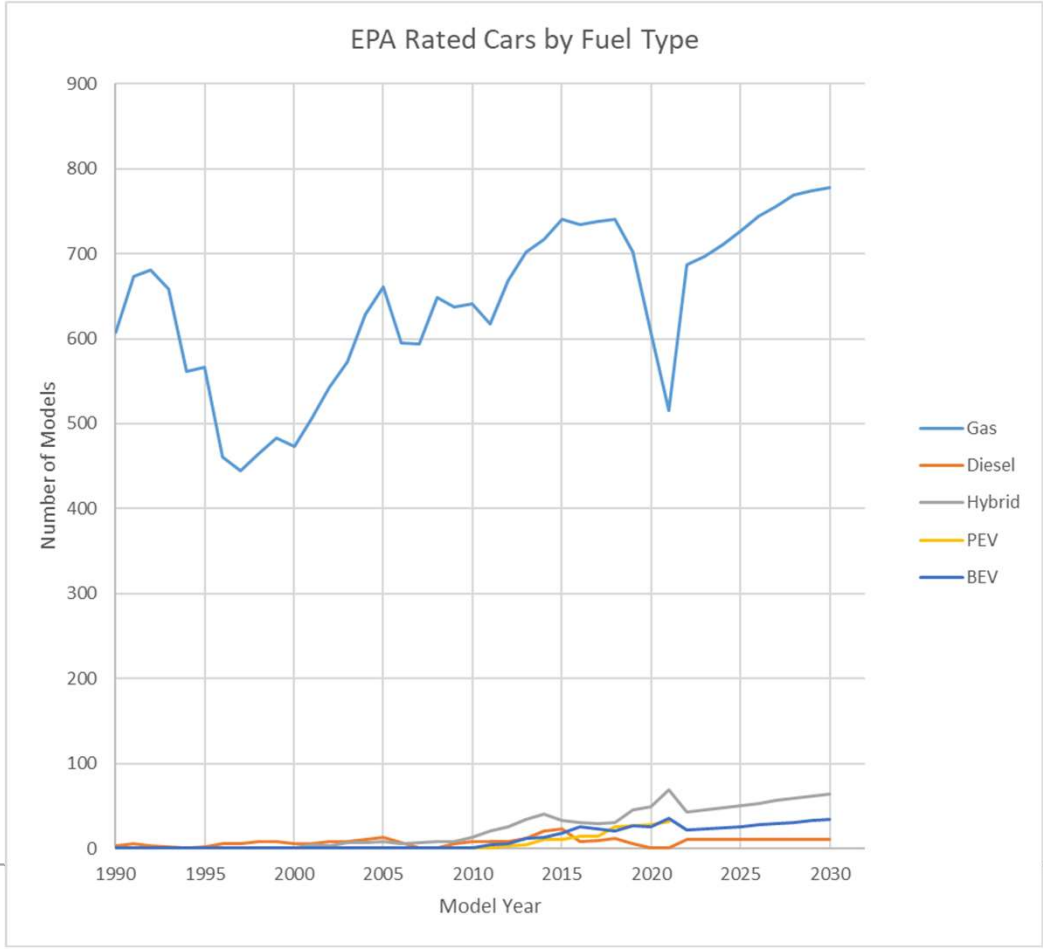
- Preprocessor selects the auto operating costs from the vehicles table for each occupancy level
- Correct auto operating cost is used for each mode
  - SOV, drive transit → occupancy 1
  - SR2 → occupancy 2
  - SR3p → occupancy 3.5
  - TNC, non-motorized → N/A
- The selected vehicle is added as a new column after tour mode choice is run
- Atwork subtours use the auto operating costs of the parent tour vehicle
- Non-household vehicles use the previous *costPerMile* constant

final_tours.csv

	A	S	T	U	V	W
1	tour_id	vehicle_occup_1	vehicle_occup_2	vehicle_occup_3.5	tour_mode	selected_vehicle
2	3827799	non_hh_veh	non_hh_veh	non_hh_veh	WALK_HVY	
3	3867733	Car_9_Gas	Car_9_Gas	Car_9_Gas	DRIVEALONEFREE	Car_9_Gas
4	3875277	non_hh_veh	non_hh_veh	non_hh_veh	WALK_HVY	
5	4162195	Car_12_Gas	Car_12_Gas	Car_12_Gas	DRIVEALONEFREE	Car_12_Gas
6	5616465	Car_16_Gas	Car_16_Gas	Car_16_Gas	DRIVEALONEFREE	Car_16_Gas
7	16038903	Car_20_Gas	Car_20_Gas	Car_20_Gas	SHARED3FREE	Car_20_Gas
8	36354780	SUV_15_Gas	Pickup_20_Gas	SUV_15_Gas	SHARED2FREE	Pickup_20_Gas
9	36354781	SUV_15_Gas	Pickup_20_Gas	SUV_15_Gas	DRIVEALONEFREE	SUV_15_Gas
10	36354813	SUV_15_Gas	SUV_15_Gas	SUV_15_Gas	DRIVEALONEFREE	SUV_15_Gas
11	36354854	SUV_15_Gas	SUV_15_Gas	SUV_15_Gas	SHARED3FREE	SUV_15_Gas
12	36354855	Pickup_20_Gas	SUV_15_Gas	SUV_15_Gas	SHARED2FREE	SUV_15_Gas
13	48309478	Car_14_Gas	SUV_15_Gas	SUV_15_Gas	DRIVEALONEFREE	Car_14_Gas
14	48309519	Car_14_Gas	SUV_15_Gas	SUV_15_Gas	DRIVEALONEFREE	Car_14_Gas
15	48309560	Car_14_Gas	SUV_15_Gas	SUV_15_Gas	SHARED2FREE	SUV_15_Gas
16	48309593	SUV_18_Gas	Car_14_Gas	SUV_15_Gas	SHARED3FREE	SUV_15_Gas
17	48309594	Car_14_Gas	SUV_15_Gas	SUV_15_Gas	SHARED3FREE	SUV_15_Gas
18	60437360	Car_12_Gas	Car_12_Gas	Car_12_Gas	DRIVEALONEFREE	Car_12_Gas
19	71860247	Car_13_Gas	Car_13_Gas	Car_8_Gas	WALK	
20	73330466	SUV_8_Gas	Car_4_Gas	Car_4_Gas	DRIVEALONEFREE	SUV_8_Gas
21	73597909	SUV_9_Gas	SUV_9_Gas	SUV_9_Gas	DRIVEALONEFREE	SUV_9_Gas

Forecasting Future Vehicle Types

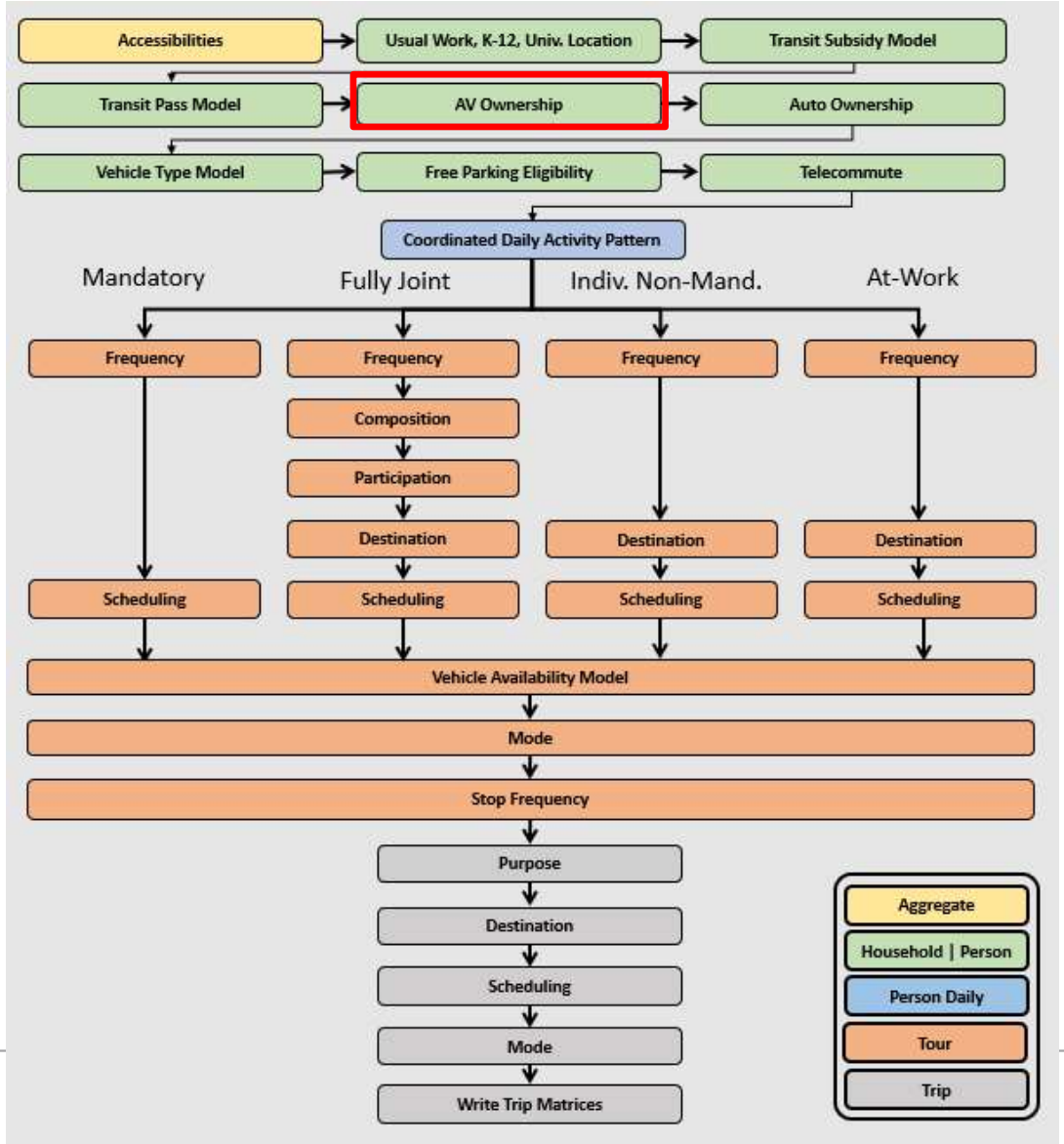
- We developed a tool to forecast future makes and models of vehicles by body type and fuel type and their attributes
- The user specifies the starting and ending value for each attribute and a distribution to use to interpolate values by year



ActivitySim With AV Extension

Extensions for AVs

- AV ownership model before auto ownership to predict whether *at least one AV* is owned by household
- If an AV is owned, coefficients applied in mode choice to reflect *lower probability of owning multiple vehicles* (and 0 probability for no autos)
- Vehicle type choice model extended to consider AV as an additional dimension
- If an AV is owned, first vehicle sampled in vehicle type choice model *must* be an AV



Extend Vehicle Table For Future Years

BodyType	FuelType	ModelYear	BT-FT-Year	NumMakes	NumModels	MPG	Range	charge240	co2gpm	NewPurchasePrice2017USD	Depreciated Value (Year Specific)	AV
Car	PEV	2020	Car-PEV-2020	13	28	30.5	0.0	3.4	160.4	0.0	0.0	0
Car	PEV	2021	Car-PEV-2021	12	32	27.6	0.0	3.7	168.0	0.0	0.0	0
Car	PEV	2022	Car-PEV-2022	9	18	34.6						0
Car	PEV	2023	Car-PEV-2023	10	20	36.7						0
Car	PEV	2024	Car-PEV-2024	11	21	38.8						0
Car	PEV	2025	Car-PEV-2025	11	22	41.0						0
Car	PEV	2026	Car-PEV-2026	12	24	43.2						0
Car	PEV	2027	Car-PEV-2027	13	25	45.5						0
Car	PEV	2028	Car-PEV-2028	14	26	47.7						0
Car	PEV	2029	Car-PEV-2029	14	28	50.0						0
Car	PEV	2030	Car-PEV-2030	15	29	52.3						0
Car_AV	PEV	2020	Car_AV-PEV-2020	13	28	30.5	0.0	3.4	160.4	0.0	0.0	1
Car_AV	PEV	2021	Car_AV-PEV-2021	12	32	27.6	0.0	3.7	168.0	0.0	0.0	1
Car_AV	PEV	2022	Car_AV-PEV-2022	9	18	34.6						1
Car_AV	PEV	2023	Car_AV-PEV-2023	10	20	36.7						1
Car_AV	PEV	2024	Car_AV-PEV-2024	11	21	38.8						1
Car_AV	PEV	2025	Car_AV-PEV-2025	11	22	41.0						1
Car_AV	PEV	2026	Car_AV-PEV-2026	12	24	43.2						1
Car_AV	PEV	2027	Car_AV-PEV-2027	13	25	45.5						1
Car_AV	PEV	2028	Car_AV-PEV-2028	14	26	47.7						1
Car_AV	PEV	2029	Car_AV-PEV-2029	14	28	50.0						1
Car_AV	PEV	2030	Car_AV-PEV-2030	15	29	52.3						1

New AV Body Types

- Body type and Fuel type attributes must be defined for future years (up to max forecast year)
- AV-Body Type combinations must be added, with indicator field

AV Ownership Model

AV ownership model informed by stated preference model

Variable	Coefficient
AV_Constant	Calibrated for different penetration Rates
AV_HHIncomeUnder50KCoefficient	-1.0
AV_HHIncomeOver100KCoefficient	1.0
AV_HHHeadUnder35Coefficient	0.5
AV_HHHeadOver65Coefficient	-1.0
AV_CoefficientPerHourCommuteTime	0.25

AV ownership used to influence number of cars owned in the auto ownership model

	Parameters				
Variable	Cars 0	Cars 1	Cars 2	Cars 3	Cars 4+
util_asc		1.17	-0.709	-2.88	-4.57
util_auto_time_saving_per_worker		0.837	0.957	0.957	0.957
util_children_16_17_per_driver		0.00	-2.42	-4.18	-5.50
util_density		-0.00730	-0.00730	-0.00730	-0.00730
…		…	…	…	…
util_AV_owned	-999	0	-0.22314	-0.69315	-999

Or turn off?

AV influence on mode choice

- If an AV is selected as the vehicle choice for tour mode choice, a set of "modifier" parameters will be turned on in the pre-processor
  - In-vehicle time perception for auto (0.8, due to increased productivity in self-driving vehicles)
  - Parking cost (~0, due to sending self-driving car to remote parking or home)
  - Terminal time (~0, due to curbside drop-off and pick-up)
- AV household trip allocation model
  - Developed for San Diego Association of Governments
  - Simulates AV car sharing and vehicle repositioning for trips made by members of an AV-owning household
  - Includes remote parking and 'go home and wait' options

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- Greg Erhardt and Michelle Imarah, Department of Engineering, University of Kentucky
- Mark Bradley, Blue Door Consulting
- Mark Moran and Feng Xie, Metropolitan Washington Council of Governments
- Joe Castiglione, Alex Bettinardi, and the ActivitySim Consortium

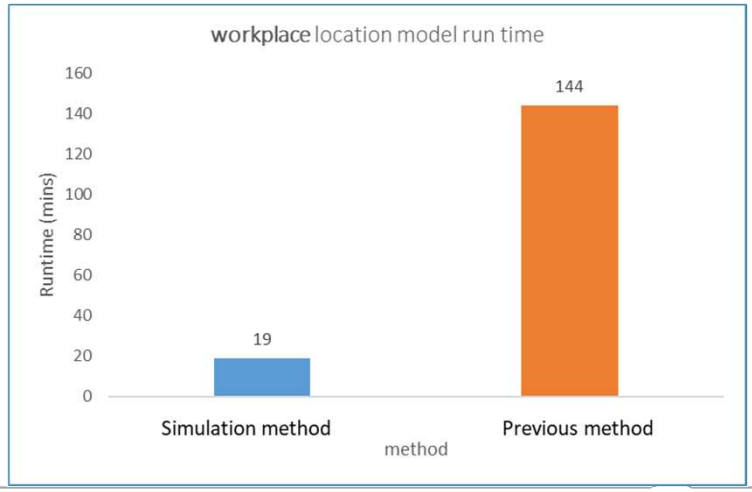
Other Recent and Ongoing Enhancements

Other recent and ongoing work

- School pickup/dropoff model
- Simulation-based work and school constraints
- Input checker to reduce runtime errors due to input data problems
- Pre-compiler (Numba/Sharrow) for performance
- Data types and memory usage improvements

Agency-led developments

- Enhancements for university travel (SEMCOG)
- Explicit internal-external travel (SANDAG)
- Airport ground access model (SANDAG)
- Overnight visitors model (SANDAG)



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