INTEGRATING AUTONOMOUS CARS & TRUCKS INTO TXDOT'S STATEWIDE ANALYSIS MODEL

TxDOT Research Project 5-7081

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Motivation

- AVs **will make driving easier** & thus **increase TX & US VMT** – everything else constant.

- AVs **may reduce crashes** per VMT **by 80%, double access** for elderly & impaired, & perhaps help lower **emissions**.

- **ATrucks** lower operator burden, thereby **extending** trucks' operating **hours & distances,** making them more competitive.

- **This work** extends **TxDOT's SAModel** to include private AVs, shared AVs (SAVs), & ATrucks. Results include **6 distinct AV scenarios** in Year **2040** model.

SAM Details

- SAM = **multi-modal travel model** maintained by **TxDOT** & developed by **Alliance Transportation group**.

- Latest version: SAM-V4, operating on **TransCAD 8.0** 64-bit platform.

- Analysis conducted on **typical weekday** using SAM's weekday module focusing on travel predictions & scenarios for the **year 2040.**

- Texas network has 228,562 links & **6,860 TAZs**.
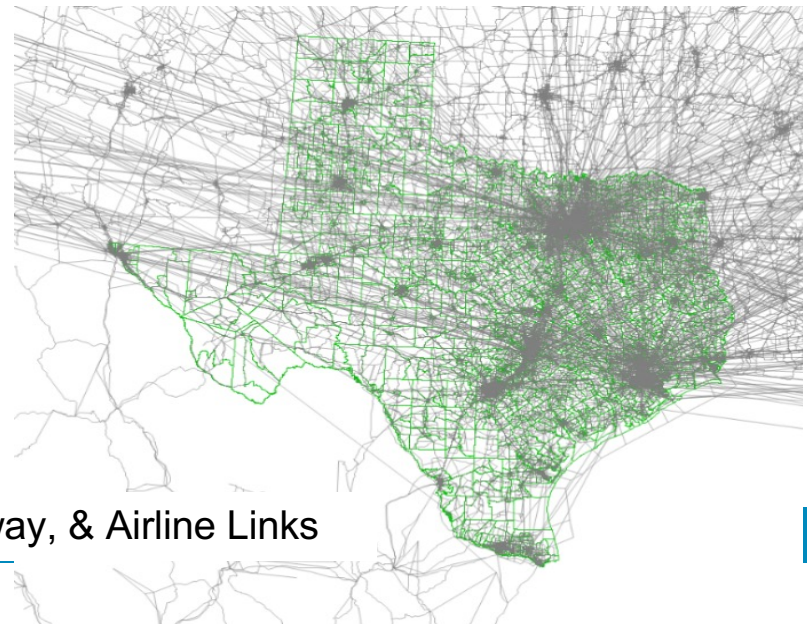
Highway, Railway, & Airline Links

SAM Structure

- **4-step Passenger + Freight models** for Trip Generation &p Distribution, Mode Choice, & Traffic Assignment

- **Passenger "car" + Freight truck trips** are **combined in assignment step** to load onto (& congest) Texas highway network.

- **4 Times of Day**: 6-8 am (**AM**) 8 am-2 pm (**MD**), 2-6 pm (**PM**) & 6 pm-6 am (**NT**)
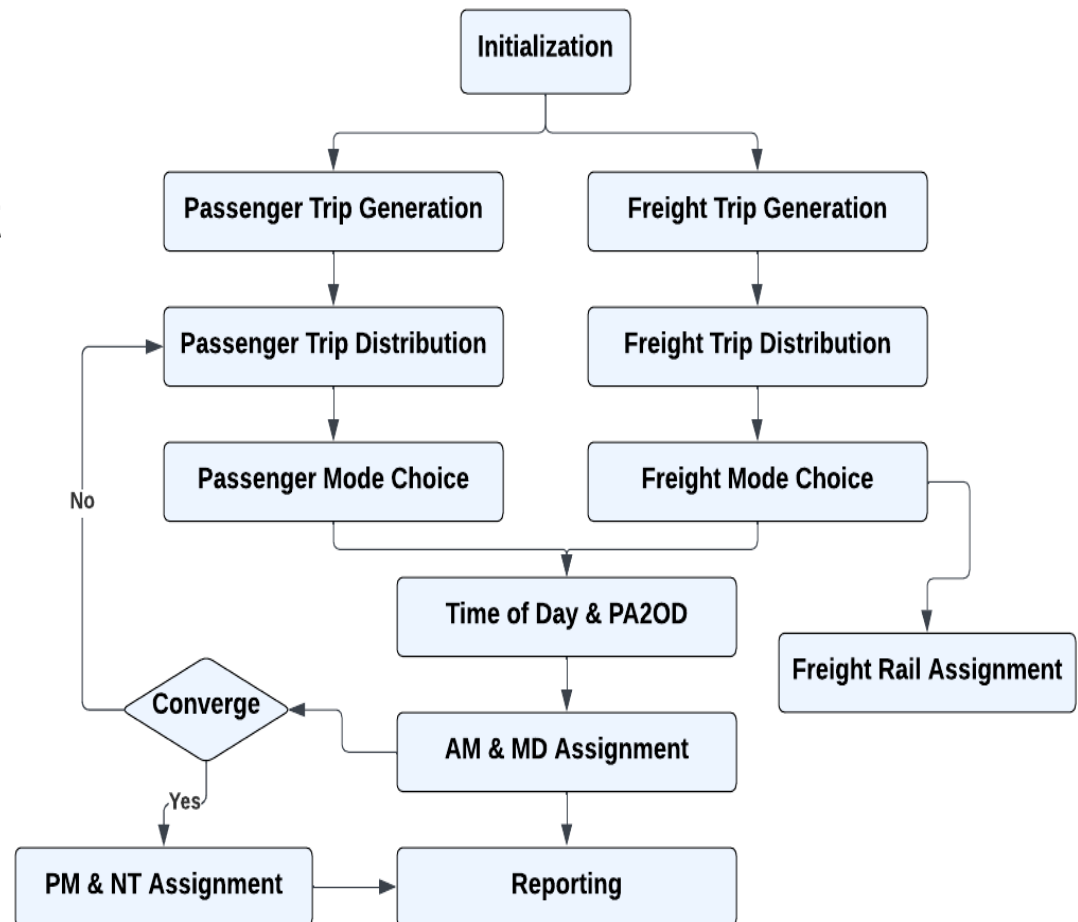
Source: Alliance Transportation Group, 2019

Passenger Model Trips

- **Short-distance** person-trips: < 50 miles (one way)
- **Long-distance (LD): > 50 miles one-way & can occur over multiple days.**
- **Non-freight truck**: Short-distance, local-serving delivery trips *not captured in SAM's freight model.* These vehicles **deliver goods & services < 50 miles** each way.

Freight Model

- SAM-V4's freight models were developed using **2015 TranSearch data.**

- **Incremental logit model** pivots across **5 Mode choices** for each of 15 commodities, based on variations in travel time, cost, new modes, etc.

- **348 Destination TAZs** = **254 TX counties** + 49 US states + DC + 32 Mexican states + 13 Canadian provinces.

- 348 freight TAZs are **disaggregated into 6860**-passenger model **TAZs** for roadway **assignment**.

	Commodity Name
1	Agriculture
2	Metallic Ores & Coal Mining
3	Crude Petroleum/Natural Gas
4	Nonmetallic Minerals
5	Food
6	Consumer Manufacturing
7	Non-Durable Manufacturing
8	Lumber
9	Durable Manufacturing
10	Paper
11	Chemicals
12	Petroleum
13	Clay, Concrete, Glass
14	Primary Metal
15	Secondary & Misc. Mixed

Freight Tonnages → Truck | Carload Rail | Intermodal Rail | Water | Air
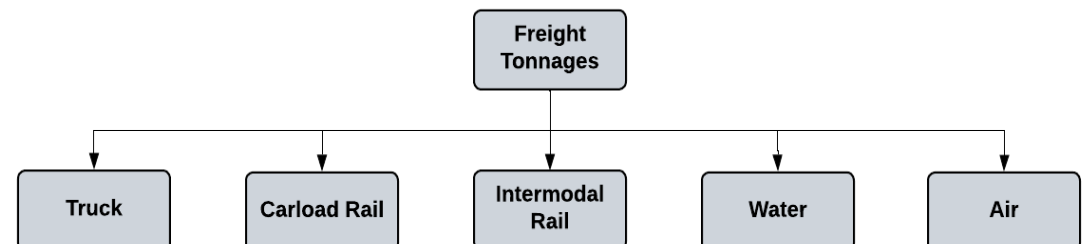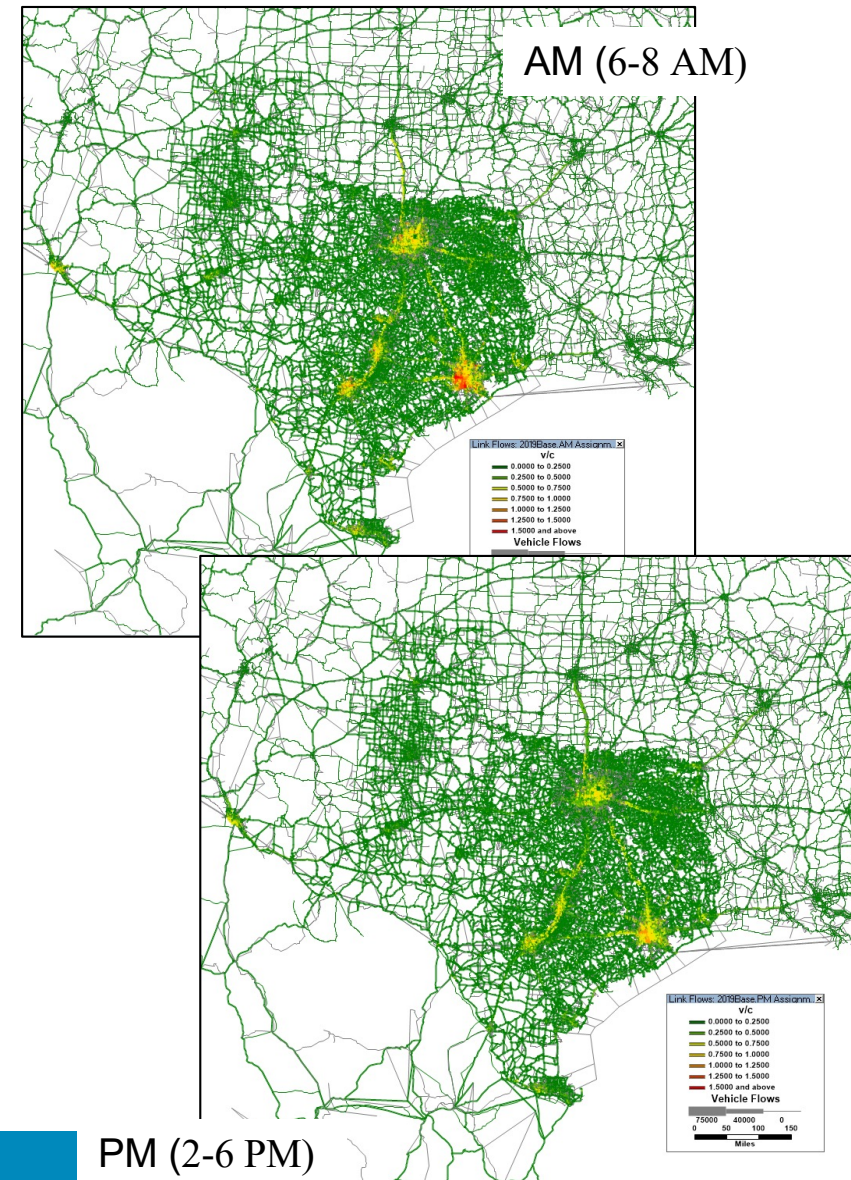
Passenger LD Mode Choices
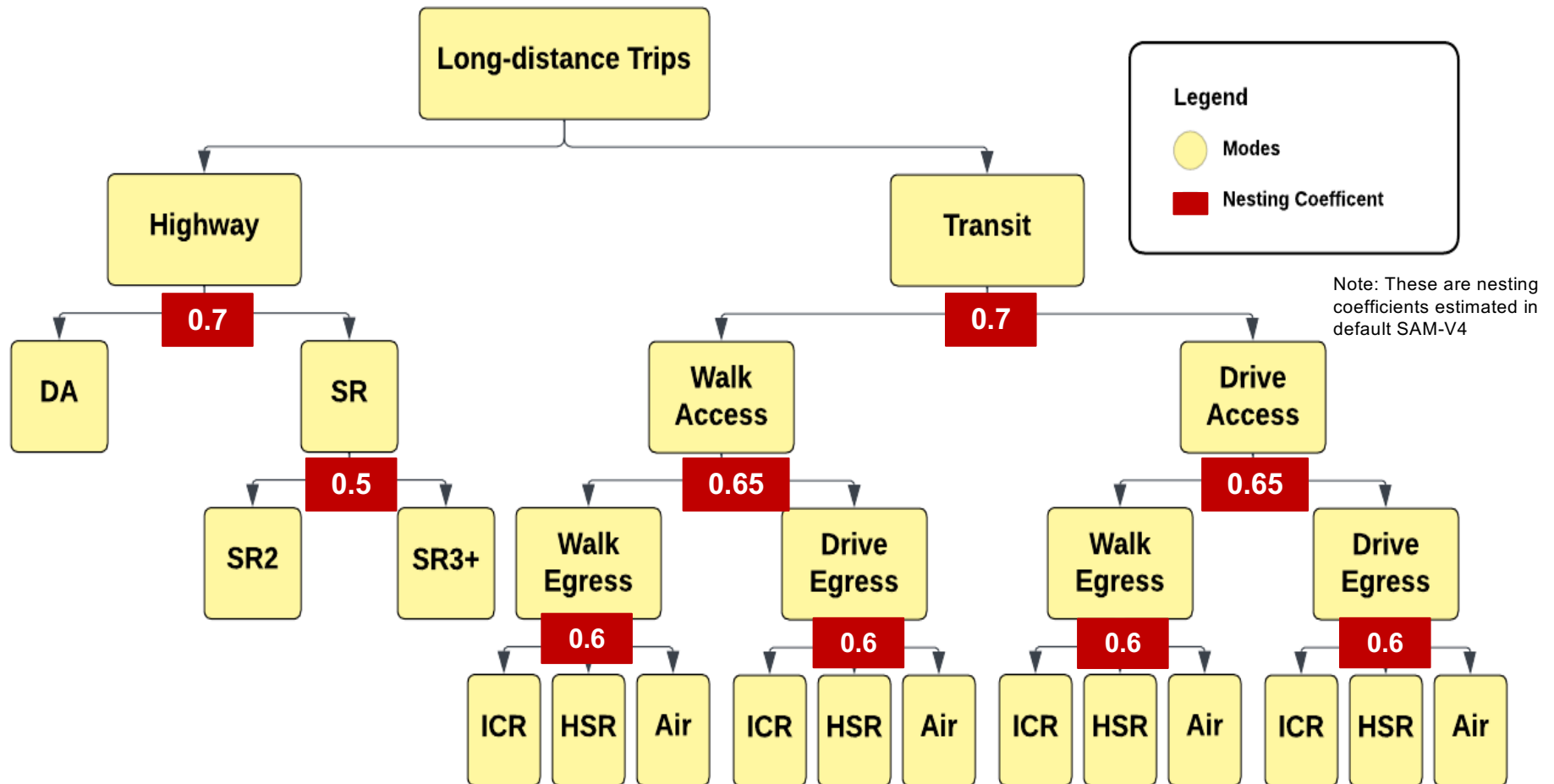
DA = drive alone, SR = shared ride (2 or 3+ persons), ICR = inter-city rail, HSR = high-speed rail (not used here)

Source: Alliance Transportation Group, 2019

COLLABORATE. INNOVATE. EDUCATE.

2019 Validation Year = Base Case

- **Year-2019 scenario** with default SAM-V4 inputs & parameters run as **Base Case.**

- Congestion (**v/c ratios over 1.25**) observed mostly in major cities, like **DFW, Houston, & San Antonio** - followed by **El Paso, Corpus Christi**, & southern border (near McAllen & Harlingen).

AM (6-8 AM)

PM (2-6 PM)

Code Improvements for AVs

- SAM was updated to predict travel impacts of **AVs, SAVs, & ATrucks in Texas.**

- Solo & shared-ride options (**SAM's mode choice model** modified for passenger trips **over 50 miles** (1-way) including AVs & SAVs nested under drive-alone DA, SR2, & SR3+ persons).

- Full feedback loops from Traffic Assignment back to Trip Distribution excluded due to lengthy run times (>**24 hr per scenario**).

Year 2040 Scenarios

- **First** is **No AVs** with default TxDOT SAM settings

- **Second** allows **AV, SAV, & ATruck** modes.

- Year 2040 **No AV Scenario** results are
  the **benchmark for 6 AV/ATruck scenarios**.

AV Integration in Passenger Model

- SAM's nested logit model adapted for **trips > 50 miles**, including **HVs, AVs, & SAVs** under DA & SR modes.

- **DA, SR2, & SR3+** show convey travel-**party size (1 to 3+ persons).**

- New model parameters pivot off base parameters using estimates from **Huang et al.'s (2020) Texas megaregion study**.
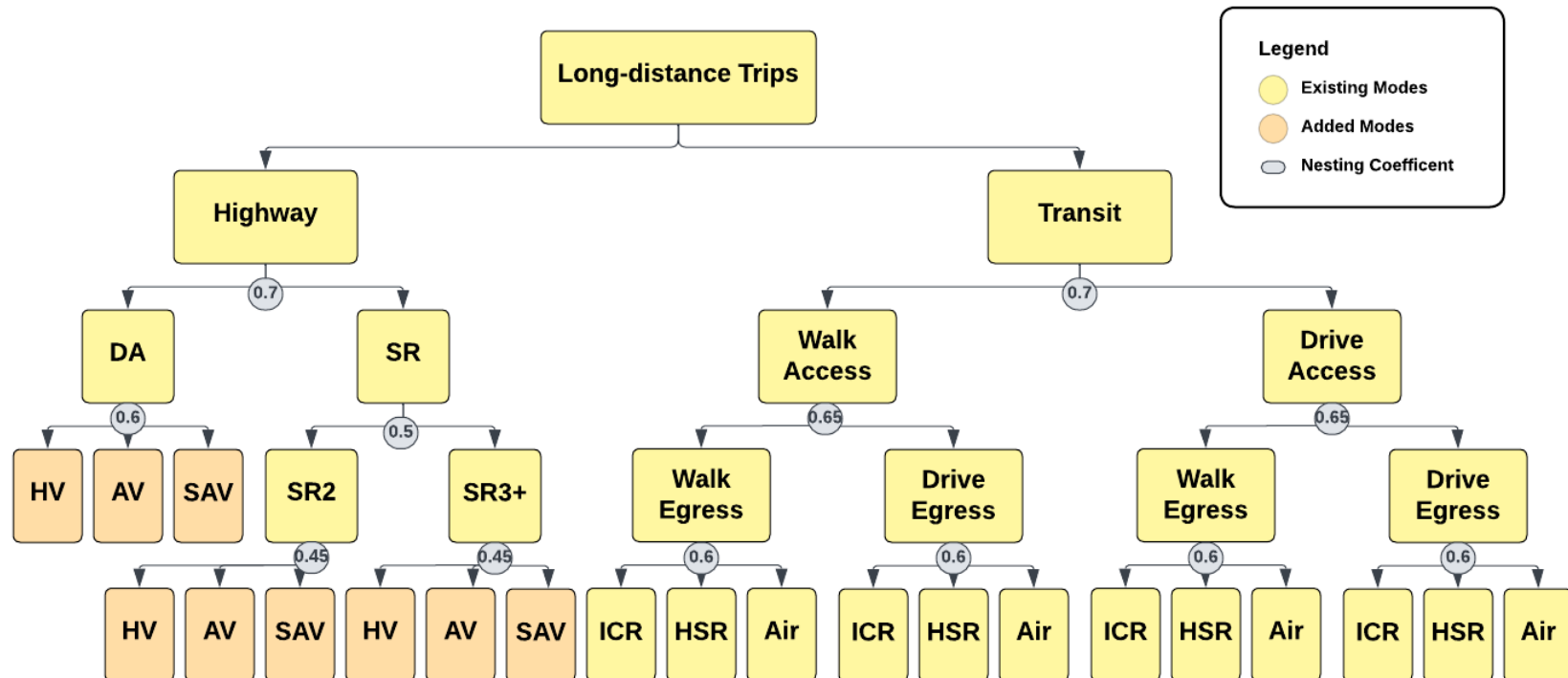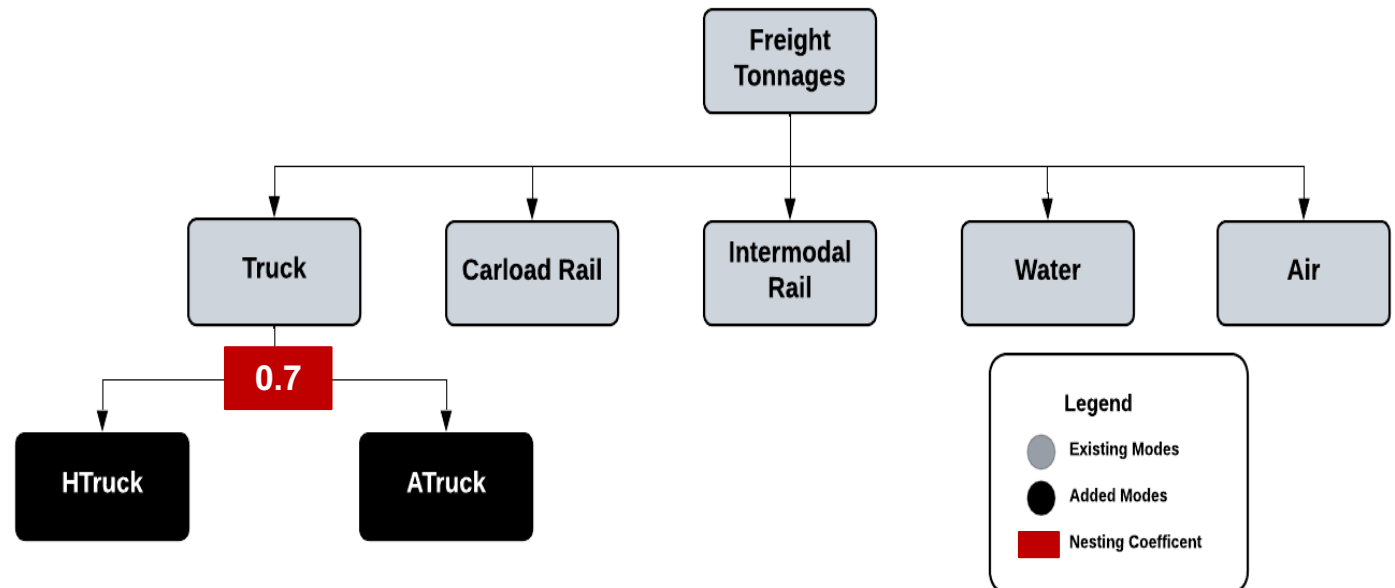
Running Modified TransCAD Steps

- **Step 1:** Save the unzipped "**SAM AV Module**" in your local directory.

- **Step 2:** Navigate to **Tools > GIS Developer's Kit > Setup Add-ins** to display the Setup Add-ins dialog box.
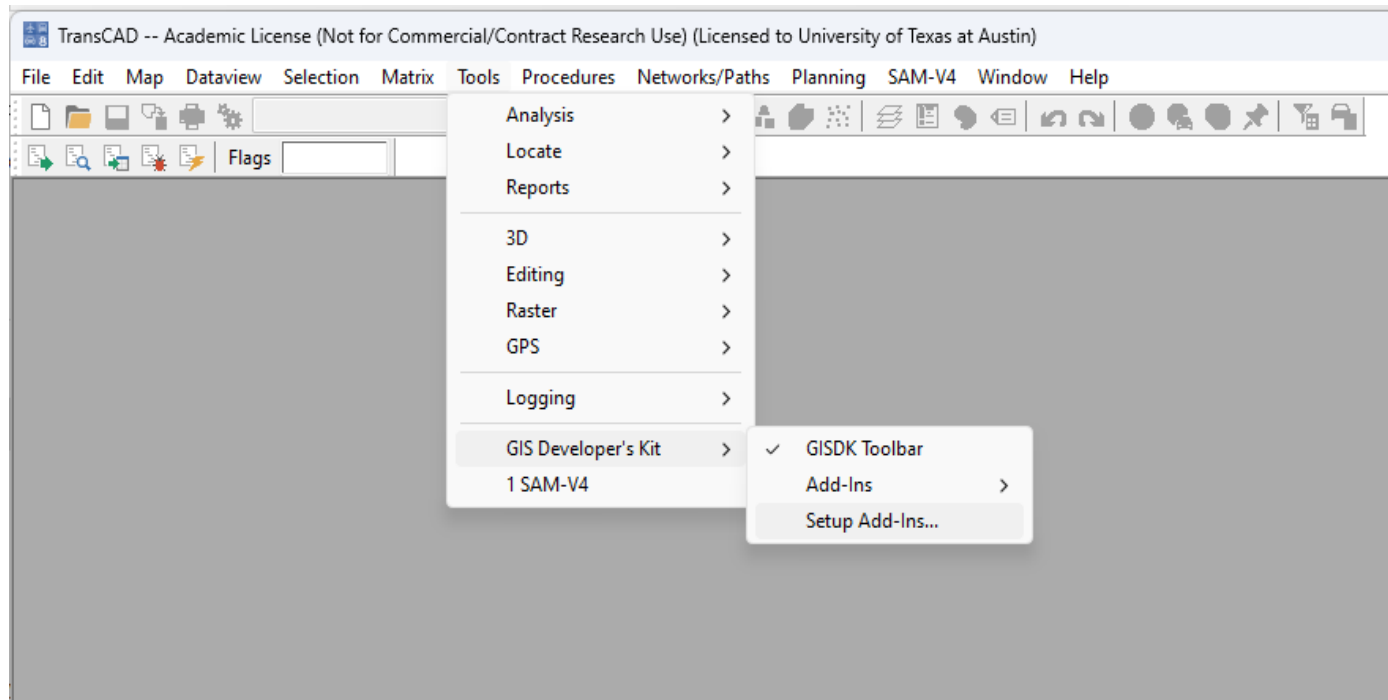
AV Integration in Freight Model

- **Nest for ATrucks vs HTruck** added to Truck branch.

- **Nesting coefficient of 0.7** assumed to reflect **relative substitutability** of both truck types.

- ATruck operating costs assumed to be **1.5 x HTruck** ($/mile).

- ATruck travel time skim set at **0.42 x HTruck**, reflecting the **continuous operation ability** of automated trucks.

Running Modified TransCAD Steps (2)

- **Step 3:** Create a new add-in by selecting the Add button on the right-hand side.

- **Step 4:** Provide an appropriate name in the Description information box.

Note: For UI Database, select the **"sam_av"** interface located within the **"SAM AV Module"** folder,
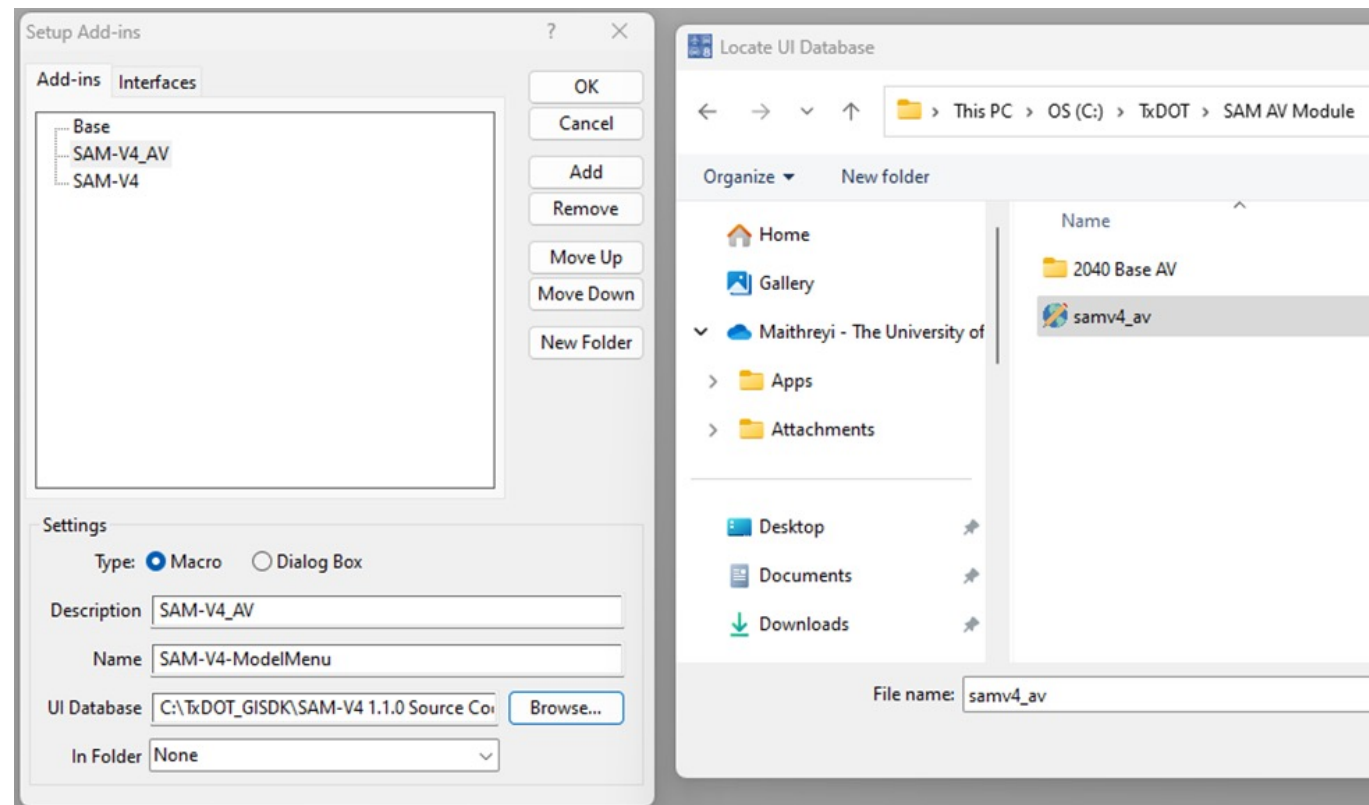
Running Modified TransCAD Steps (3)

- **Step 5:** Click the **OK button** to complete the add-in setup process.
- **Step 6:** Under **Tools > GIS Developer's Kit > Add-ins**, select the newly created add-in.
- **Step 7:** Selecting Model Interface under it will load the interface.

Running Modified TransCAD Steps (4)
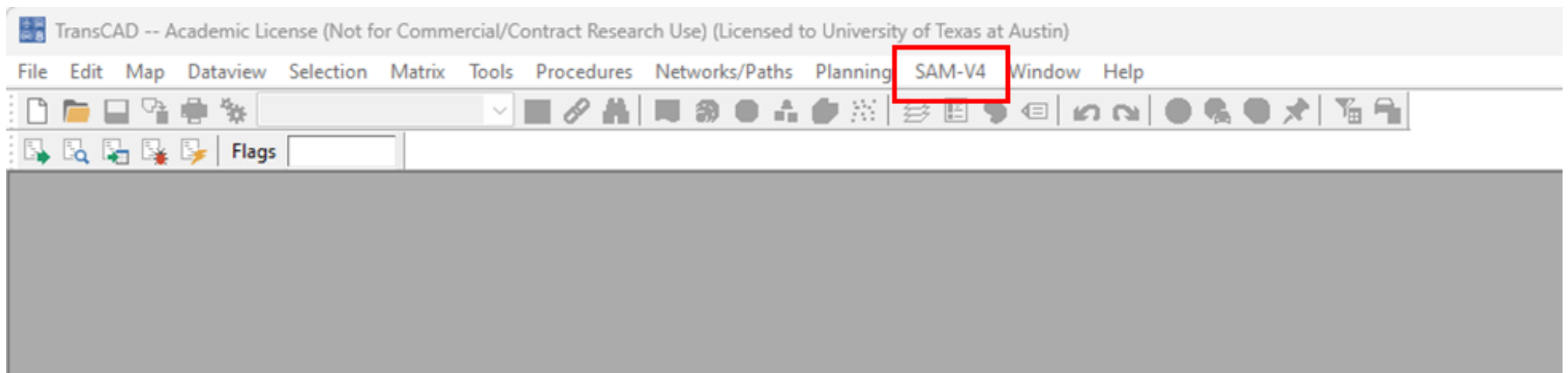
Ensure to **copy the "2040 Base AV"** folder within the "SAM AV Module" folder to the **TxDOT**>**SAM-V4** folder. Once the interface is open:

- Click on **"Setup"** & **duplicate** (click **Copy**) one of the scenarios to create a new scenario. Provide appropriate name & **update folder path** by double-clicking on folder tab.

- To run the model, navigate outside the setup options, **select the desired scenario** (e.g., "2040 Base AV"), & initiate the model run.
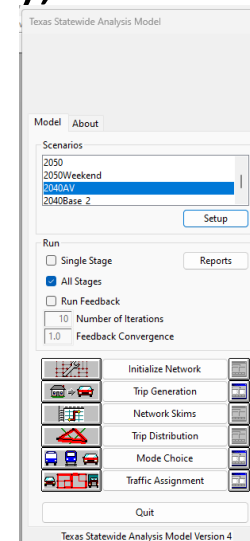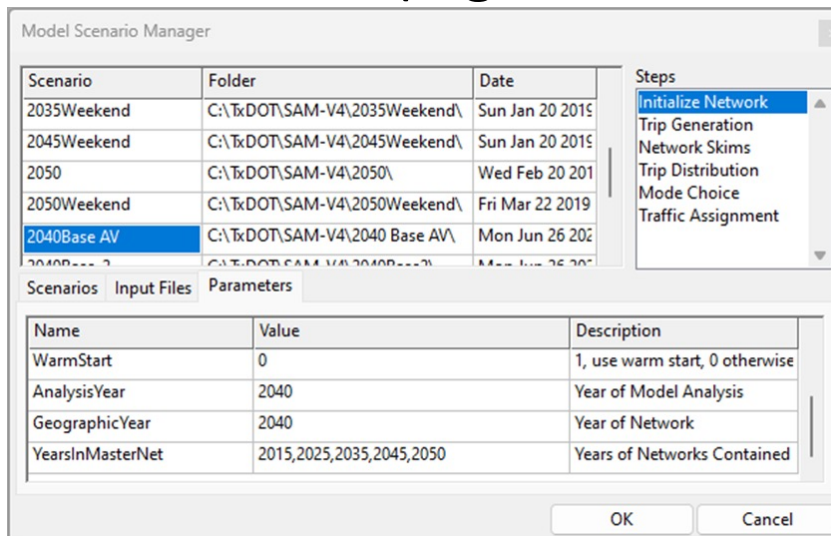
Edited Scripts for AV Integration

- **Edited input files & scripts:** trip generation, skim creation, mode choice, traffic assignment, & report generation.

_0SAMV4.lst	2 TripGen 1 - Household SubModel	6 Assignment 1 - PrepareAutoTripTables
0 Interface 1 - Menu	2 TripGen 2 - Calculate Ps and As	6 Assignment 2 - CombineTripMatricesByTimePeriod
0 Interface 2 - Model	2 TripGen 3 - Freight	6 Assignment 3 - HighwayAssignment
0 Interface 3 - Interpolation	3 Skim 1 - HighwayPassengerSkim	6 Assignment 4 - PrepareTransitTripTables
0 Interface 4 - ExternalExtraction	3 Skim 2 - TransitSkim	6 Assignment 5 - TransitAssignment
0 Interface 5 - DHV	4 TripDist 1 - Destination Choice	6 Assignment 6 - FreightRailAssignment
0 Interface 6 - TransearchAssignment	4 TripDist 2 - Gravity Model	7 Feedback
1 Initialization 1 - CreateScenarioNetwork	4 TripDist 3 - Freight	8 Report 01 - DemoGenDistMode
1 Initialization 2 - CreateRouteSystem	5 ModeChoice 1 - TransitAccessMatrix	8 Report 02 - VMTCount
1 Initialization 3 - CreateScenarioTAZ	5 ModeChoice 2 - ShortDistanceTrips	8 Report 03 - Freight
1 Initialization 4 - UpdateNetAttributes	5 ModeChoice 3 - TransitSkimPostProcess	8 Report 04 - Transit
1 Initialization 5 - FreightRailCap	5 ModeChoice 4 - LongDistanceTrips	8 Report 05 - Performance
1 Initialization 6 - CheckNetAttributes	5 ModeChoice 5 - Freight	MacroUtility

TransCAD Module Update

- **Production rates** for all person-trip purposes **increased by 15%**. Ex: New 'ProdRate_HBW' column = (Old ProdRate_HBW **x 1.15**).

'ProdRates' bin file located under **INPUT** > **PASSENGER** > **TRIP_GEN**

State	MSA	IncomeGroup	HouseholdSize	ProdRate_HBW_old	ProdRate_HBW	ProdRate_HBO_old	ProdRate_HBO	ProdRate_HBS_old	ProdRate_HBS	ProdRate_NHB_old	ProdRate_NHB	ProdRate_ILDB_old	ProdRate_ILDB	ProdRate_ILDO_old	ProdRate_ILDO	ProdRate_ILLB_old	ProdF
1	1	1	1	0.25800	0.29670	1.35300	1.55595	0.00000	0.00000	1.00300	1.15345	0.01000	0.01150	0.00800	0.00920	0.00025	
1	1	1	2	0.87300	1.00395	3.15500	3.62825	0.08600	0.09890	1.60200	1.84230	0.01500	0.01725	0.02100	0.02415	0.00045	
1	1	1	3	1.24600	1.43290	4.99300	5.74195	0.75100	0.86365	1.88000	2.16200	0.02300	0.02645	0.05200	0.05980	0.00078	
1	1	1	4	1.34200	1.54330	7.13600	8.20640	1.80100	2.07115	3.01600	3.46840	0.02700	0.03105	0.43300	0.49795	0.00138	
1	1	2	1	0.66500	0.76475	1.79500	2.06425	0.00000	0.00000	1.30800	1.50420	0.01400	0.01610	0.04200	0.04830	0.00160	
1	1	2	2	1.19300	1.37195	3.47300	3.99395	0.08600	0.09890	2.01700	2.31955	0.01600	0.01840	0.05500	0.06325	0.00131	
1	1	2	3	1.92400	2.21260	5.08400	5.84660	1.15800	1.33170	4.01000	4.61150	0.05300	0.06095	0.05500	0.06325	0.00131	
1	1	2	4	2.16300	2.48745	7.73400	8.89410	3.54200	4.07330	4.12600	4.74490	0.10000	0.11500	0.12000	0.13800	0.00388	
1	1	3	1	1.12400	1.29260	1.64100	1.88715	0.00000	0.00000	1.66200	1.91130	0.04900	0.05635	0.05100	0.05865	0.00270	
1	1	3	2	1.48100	1.70315	2.95600	3.39940	0.05900	0.06785	4.01000	4.61150	0.08200	0.09430	0.16600	0.19090	0.00440	
1	1	3	3	2.57500	2.96125	4.62100	5.31415	2.12400	2.44260	4.22700	4.86105	0.08700	0.10005	0.27300	0.31395	0.00554	
1	1	3	4	2.64800	3.04520	7.64700	8.79405	2.90200	3.33730	5.61200	6.45380	0.20100	0.23115	0.29400	0.33810	0.00654	
1	1	4	1	1.51200	1.73880	1.63500	1.88025	0.00000	0.00000	1.67000	1.92050	0.10500	0.12075	0.14900	0.17135	0.00463	
1	1	4	2	1.79800	2.06770	2.99400	3.44310	0.05300	0.06095	3.21800	3.70070	0.12000	0.13800	0.27500	0.31625	0.00768	
1	1	4	3	2.92700	3.36605	4.30700	4.95305	2.12400	2.44260	4.45000	5.11750	0.12600	0.14490	0.32100	0.36915	0.01123	
1	1	4	4	2.94300	3.38445	9.41200	10.82380	2.90200	3.33730	7.55200	8.68480	0.29400	0.33810	0.39400	0.45310	0.01904	
1	2	1	1	0.42700	0.49105	1.97800	2.27470	0.00000	0.00000	1.45300	1.67095	0.00200	0.00230	0.01300	0.01495	0.00025	
1	2	1	2	0.87500	1.00625	4.34400	4.99560	0.23900	0.27485	1.60200	1.84230	0.00200	0.00230	0.01800	0.02070	0.00045	
1	2	1	3	1.28300	1.47545	4.48600	5.15890	0.67900	0.78085	1.88000	2.16200	0.00400	0.00460	0.02700	0.03105	0.00078	
1	2	1	4	2.08700	2.40005	6.41800	7.38070	3.51800	4.04570	3.62700	4.17105	0.00800	0.00920	0.02800	0.03220	0.00138	
1	2	2	1	0.58200	0.66930	1.75900	2.02285	0.00000	0.00000	1.69800	1.95270	0.01300	0.01495	0.04200	0.04830	0.00160	
1	2	2	2	1.27200	1.46280	3.90400	4.48960	0.08700	0.10005	2.01700	2.31955	0.01400	0.01610	0.04800	0.05520	0.00131	
1	2	2	3	1.79200	2.06080	4.41400	5.07610	0.91300	1.04995	2.42400	2.78760	0.01200	0.01380	0.08700	0.10005	0.00131	
1	2	2	4	2.54200	2.92330	8.37800	9.63470	2.93800	3.37870	4.34200	4.99330	0.01900	0.02185	0.15100	0.17365	0.00388	
1	2	3	1	0.88300	1.01545	1.73300	1.99295	0.00000	0.00000	1.19000	1.36850	0.02600	0.02990	0.05100	0.05865	0.00270	
1	2	3	2	1.32100	1.51915	3.07100	3.53165	0.03200	0.03680	2.48300	2.85545	0.03800	0.04370	0.06700	0.07705	0.00440	
1	2	3	3	2.07800	2.38970	5.28900	6.08235	0.51800	0.59570	2.82200	3.24530	0.07200	0.08280	0.12100	0.13915	0.00554	
1	2	3	4	2.30300	2.64845	7.44100	8.55715	2.72400	3.13260	4.71300	5.41995	0.11100	0.12765	0.22100	0.25415	0.00654	
1	2	4	1	1.17000	1.34550	1.70900	1.96535	0.00000	0.00000	1.55000	1.78250	0.03200	0.03680	0.05100	0.05865	0.00463	
1	2	4	2	1.79800	2.06770	3.19300	3.67195	0.03200	0.03680	2.42100	2.78415	0.06800	0.07820	0.10800	0.12420	0.00768	
1	2	4	3	1.91500	2.20225	6.22300	7.15645	0.81200	0.93380	4.45000	5.11750	0.08200	0.09430	0.15800	0.18170	0.01123	
1	2	4	4	2.76400	3.17860	7.55100	8.68365	3.19000	3.66850	5.46100	6.28015	0.17200	0.19780	0.19200	0.22080	0.01904	
1	3	1	1	0.32000	0.36800	1.57400	1.81010	0.00000	0.00000	0.99900	1.14885	0.00200	0.00230	0.01300	0.01495	0.00025	
1	3	1	2	0.84900	0.97635	2.76100	3.17515	0.29000	0.33350	1.59500	1.83425	0.01400	0.01610	0.01800	0.02070	0.00045	
1	3	1	3	1.52200	1.75030	4.05700	4.66555	1.26400	1.45360	2.83600	3.26140	0.02300	0.02645	0.02700	0.03105	0.00078	
1	3	1	4	1.77400	2.04010	6.17400	7.10010	2.95900	3.40285	3.23300	3.71795	0.03400	0.03910	0.05300	0.06095	0.00138	
1	3	2	1	0.64400	0.74060	1.57600	1.81240	0.00000	0.00000	1.35900	1.56285	0.00700	0.00805	0.01500	0.01725	0.00160	
1	3	2	2	1.21100	1.39265	3.08600	3.54890	0.16400	0.18860	2.01100	2.31265	0.02600	0.02990	0.05100	0.05865	0.00131	
1	3	2	3	1.68700	1.94005	4.73400	5.44410	1.17000	1.34550	3.14700	3.61905	0.03300	0.03795	0.05500	0.06325	0.00131	
1	3	2	4	1.91300	2.19995	6.30400	7.24960	3.11600	3.58340	3.89200	4.47580	0.04100	0.04715	0.08200	0.09430	0.00388	
1	3	3	1	0.86300	0.99245	1.64800	1.89520	0.00000	0.00000	1.62600	1.86990	0.02400	0.02760	0.04000	0.04600	0.00270	

Short-trip Mode Splits (<50 mi)

| Income Level	Trip Purpose	DA			SR2+			SR3+			Other
		HV	**AV**	**SAV**	**HV**	**AV**	**SAV**	**HV**	**AV**	**SAV**	
1	HBW	0.316	0.316	0.158	0.064	0.064	0.032	0.02	0.02	0.01	-
	HBO	0.184	0.184	0.092	0.116	0.116	0.058	0.1	0.1	0.05	-
	NHB	0.184	0.184	0.092	0.12	0.12	0.06	0.096	0.096	0.048	-
	HBS	0.048	0.048	0.024	0.092	0.092	0.046	0.144	0.144	0.072	0.29
2	HBW	0.332	0.332	0.166	0.048	0.048	0.024	0.024	0.024	0.012	-
	HBO	0.18	0.18	0.09	0.124	0.124	0.062	0.096	0.096	0.048	-
	NHB	0.196	0.196	0.098	0.112	0.112	0.056	0.092	0.092	0.046	-
	HBS	0.056	0.056	0.028	0.128	0.128	0.064	0.136	0.136	0.068	0.21
3	HBW	0.344	0.344	0.172	0.044	0.044	0.022	0.012	0.012	0.006	-
	HBO	0.192	0.192	0.096	0.128	0.128	0.064	0.084	0.084	0.042	-
	NHB	0.216	0.216	0.108	0.108	0.108	0.054	0.076	0.076	0.038	-
	HBS	0.048	0.048	0.024	0.128	0.128	0.064	0.144	0.144	0.072	0.2
4	HBW	0.356	0.356	0.178	0.036	0.036	0.018	0.004	0.004	0.002	-
	HBO	0.176	0.176	0.088	0.12	0.12	0.06	0.104	0.104	0.052	-
	NHB	0.212	0.212	0.106	0.104	0.104	0.052	0.084	0.084	0.042	-
	HBS	0.064	0.064	0.032	0.124	0.124	0.062	0.156	0.156	0.078	0.14
All	NHBV	0.14	0.14	0.07	0.116	0.116	0.058	0.144	0.144	0.072	-

Short-distance Mode Splits

- Mode shares are based on **transit availability** for different trip purposes & income groups.

  - **No Transit Available Areas:** **40%** for HV, **40%** for AVs, & **20%** for SAVs for DA, SR2, & SR3+.

  - **Transit Available Area (bus & urban rail):** **40%** for HVs, **40%** for AVs**,** & **20%** for SAVs for DA, SR2, & SR3+ *plus* **50%** shift in mode shares from "Other" modes to SAVs.

- Edited file: **"ModeShareSplit"** bin file (in **INPUT>PASSENGER>MODE)** & **"5 ModeChoice 2 – ShortDistanceTrips"** GISDK script.
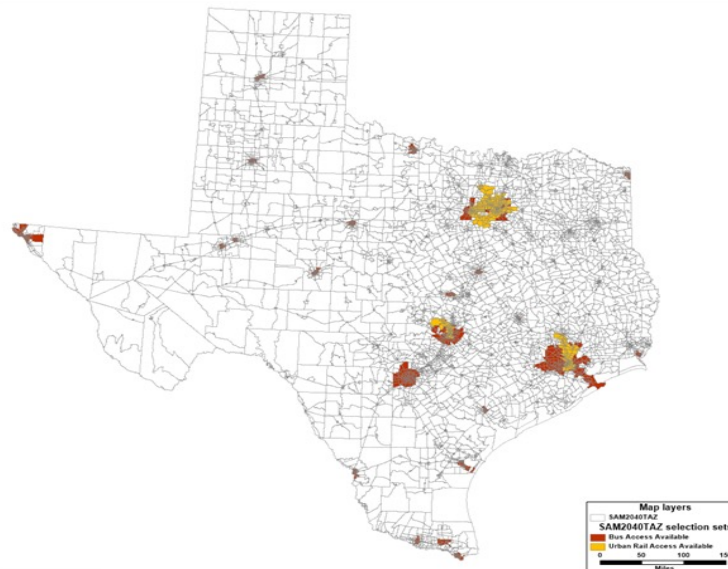
Mode Choice for LD Pax Trips

- Edited file: "AutoOperatCost", "MC_Parameters" bin files (in **INPUT>PASSENGER>MODE)** & '3 Skim 1 - HighwayPassengerSkim', "5 Mode Choice 4 – LongDistanceTrips" GISDK scripts.
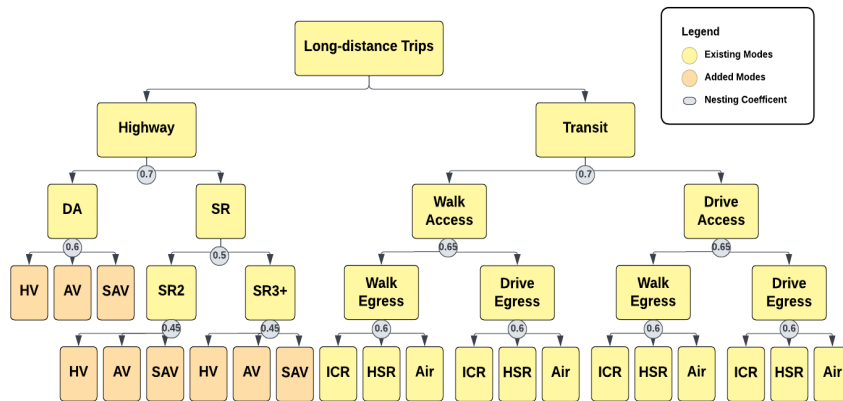
Mode		Business (ILDB & ILLB)	Non-Business (ILDO & ILLO)
Operating Cost ($/mile)	HV	0.346	0.17
	AV	0.6	0.6
	SAV	1	1

VOT (Dollar/Hour)								
	ILDB		**ILDO**		**ILLB**		**ILLO**	
	HV	AV/SAV	HV	AV/SAV	HV	AV/SAV	HV	AV/SAV
Income I	7.2	5.76	5.4	4.32	7.2	5.76	5.4	4.32
Income II	21.6	17.28	16.2	12.96	21.6	17.28	16.2	12.96
Income III	43.3	34.64	32.4	25.92	43.3	34.64	32.4	25.92
Income IV	72.3	57.84	54.1	43.28	72.3	57.84	54	43.2

|	Mode		ILDB	ILDO	ILLB	ILLO
ASC	DA (drive alone)	Human-Driven Vehicles (HVs) = Base	--	--	--	--
	SR2 (shared car ride, 2 persons)	Privately owned AVs	-0.05	-0.05	-0.05	-0.05
	SR3+ (3+ persons in car)	Shared AVs (SAVs)	-0.2	-0.2	-0.2	-0.2
	HV		-1.5	-0.1	-3	-0.8
	AV		-1.55	-0.15	-3.05	-0.85
	SAV		-1.7	-0.3	-3.2	-1
	HV		-2	-0.2	-4.2	-2
	AV		-2.05	-0.25	-4.25	-2.05
	SAV		-2.2	-0.4	-4.4	-2.2
	High-Speed Rail (HSR)		-1.1	-2.5	2.5	-0.4
	Intercity Rail (ICR)		-5	-3.8	-5	-2.5
	Air		-1.1	-2.5	2.5	-0.4
Variable Coefficient	In-vehicle Time		-0.02	-0.01	-0.02	-0.01
	Out-of-vehicle Time		-0.02	-0.01	-0.02	-0.01
	Travel Cost	Income I	-0.1664	-0.1109	-0.1664	-0.1109
		Income II	-0.0555	-0.037	-0.0555	-0.037
		Income III	-0.0277	-0.0185	-0.0277	-0.0185
		Income IV	-0.0166	-0.0111	-0.0166	-0.0111

Freight Mode Choice

- Edited files: "5 ModeChoice 5 - Freight" (modified incremental logit) & "BaseShare" bin file (Modified matrix cores for ATrucks) under **INPUT > FREIGHT > MODE**

- **Matrix cores** with base share (15 commodity groups) for ATrucks were duplicated from Truck matrix cores to maintain consistency in code after inclusion of new ATruck mode.

Freight Mode Choice (2)

- **Utilities of HTrucks & ATrucks** for every commodity group & zone pair were computed using **explanatory variables & modal constant terms** (same as base model).

- **Utility of truck mode** was determined by calculating **logsum of utilities** of HTrucks & ATrucks.

- **New truck share** were calculated (same as base model) using **base mode shares**.

- For truck mode, **change in utility** was determined by comparing **newly calculated utility of truck mode** (logsum of HTrucks & ATrucks) with **previous utility of truck mode**, before introduction of new mode (& nest).

- The **shares of ATrucks & HTrucks** (for every zone pair) were then derived from the **total number of truck trips.**
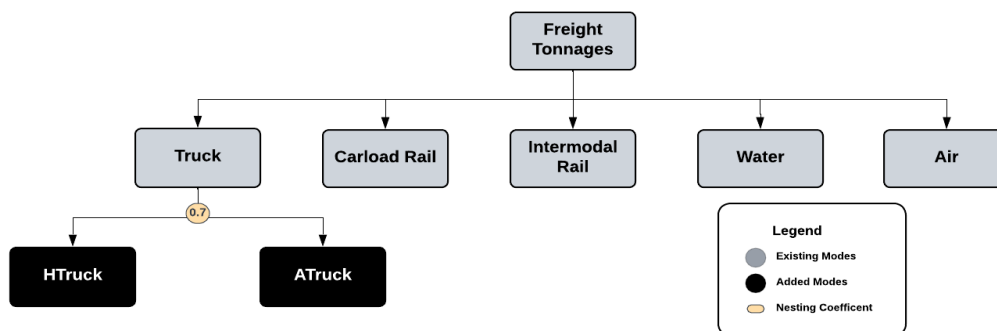
Traffic Assignment

- **Scripts associated to trip assignment** ('6 Assignment 1 – PrepareAutoTripTables', '6 Assignment 2 – CombineTripMatricesByTimePeriod', '6 Assignment 4 – PrepareTransitTripTables') & **report generation** ('8 Report 01 – DemoGenDistMode', '8 Report 03 – Freight').

- '**AutoOccupancy_SAV**' bin file similar to 'AutoOccupany' file in the **INPUT** > **ASSIGNMENT** folder was created where rates were reduced by **20%** to account for empty VMT due to SAVs.
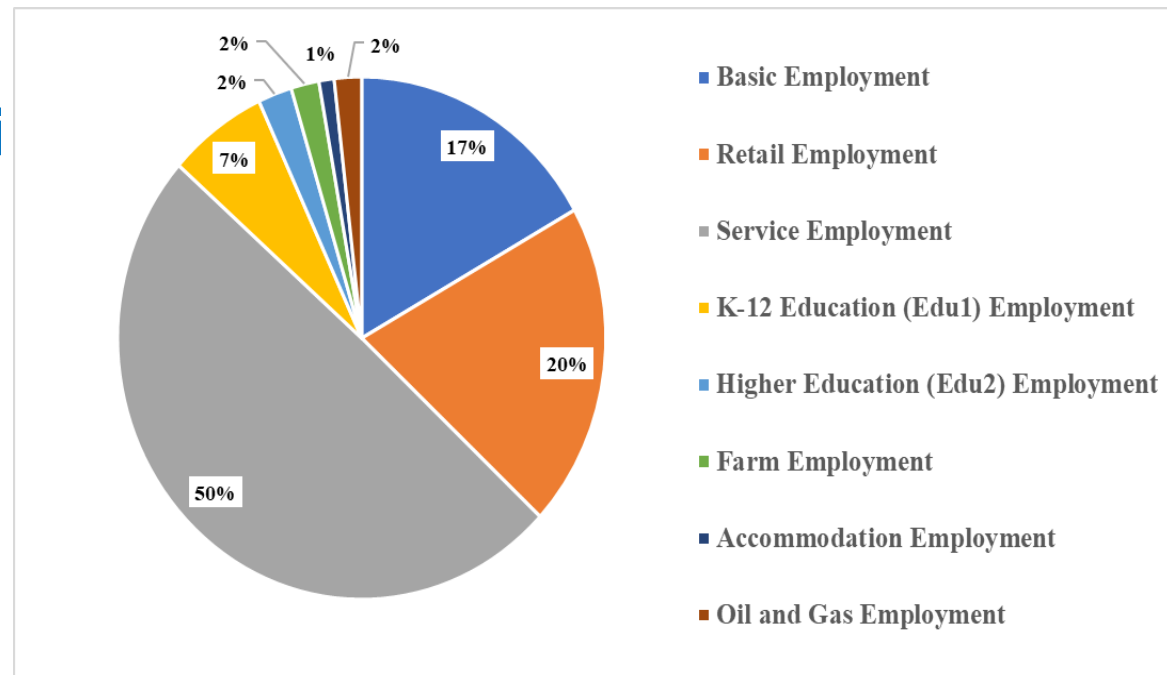
Dataview1 - AutoOccupancy				
TripPurpose	inc1	inc2	inc3	inc4
HBW	3.10	3.35	3.61	3.50
HBO	3.57	3.41	3.40	3.44
HBS	3.39	3.48	3.41	3.38
NHB	3.52	3.39	3.50	3.48
NHBV	3.47	3.47	3.47	3.47
ILDB	3.77	3.16	4.79	3.03
ILDO	3.28	3.92	4.58	4.12
ILLB	3.77	3.16	4.79	3.03
ILLO	3.28	3.92	4.58	4.12

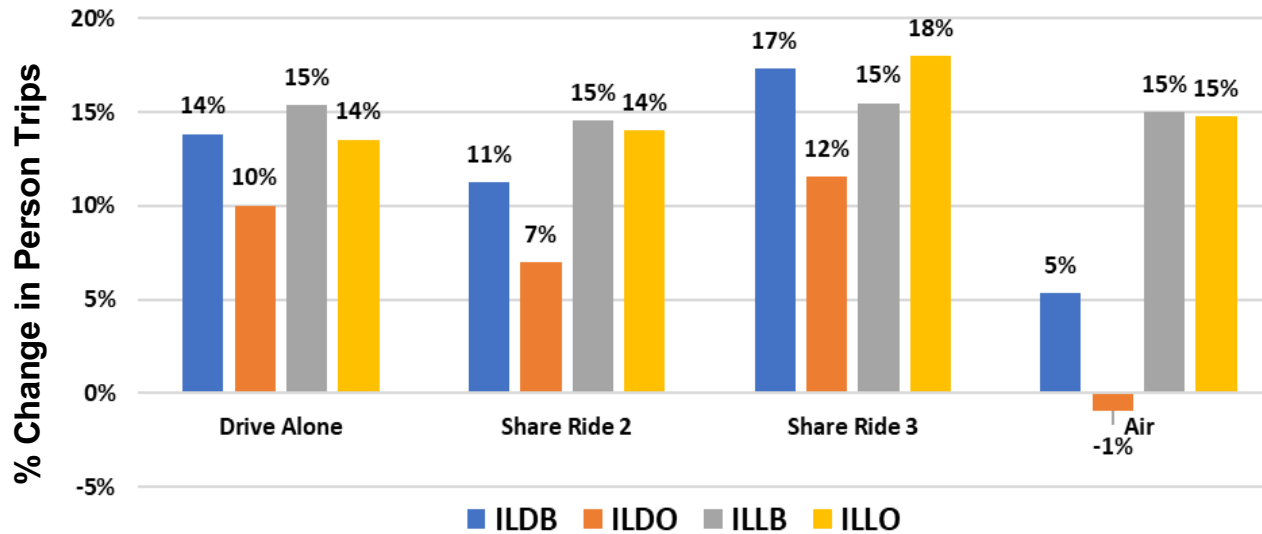| Dataview2 - AutoOccupancy_SAV				
TripPurpose	inc1	inc2	inc3	inc4
HBW	2.48	2.68	2.89	2.80
HBO	2.86	2.73	2.72	2.75
HBS	2.71	2.78	2.73	2.70
NHB	2.82	2.71	2.80	2.78
NHBV	2.78	2.78	2.78	2.78
ILDB	3.02	2.53	3.83	2.42
ILDO	2.62	3.14	3.66	3.30
ILLB	3.02	2.53	3.83	2.42
ILLO	2.62	3.14	3.66	3.30

Comparing Base & AV Scenarios

- In **year 2040,** SAM assumes Texas has **40.2M persons** living in 13.5M households & working in **19.1M jobs**.

- We assume **trip production rises 15%** when AVs are readily available for all trip types (Huang et al. 2020).

- We assume **$0.6/mile for personal AVs, $1/mi for SAVs,** & **ATrucks** are **50% more expensive** than HTruck.
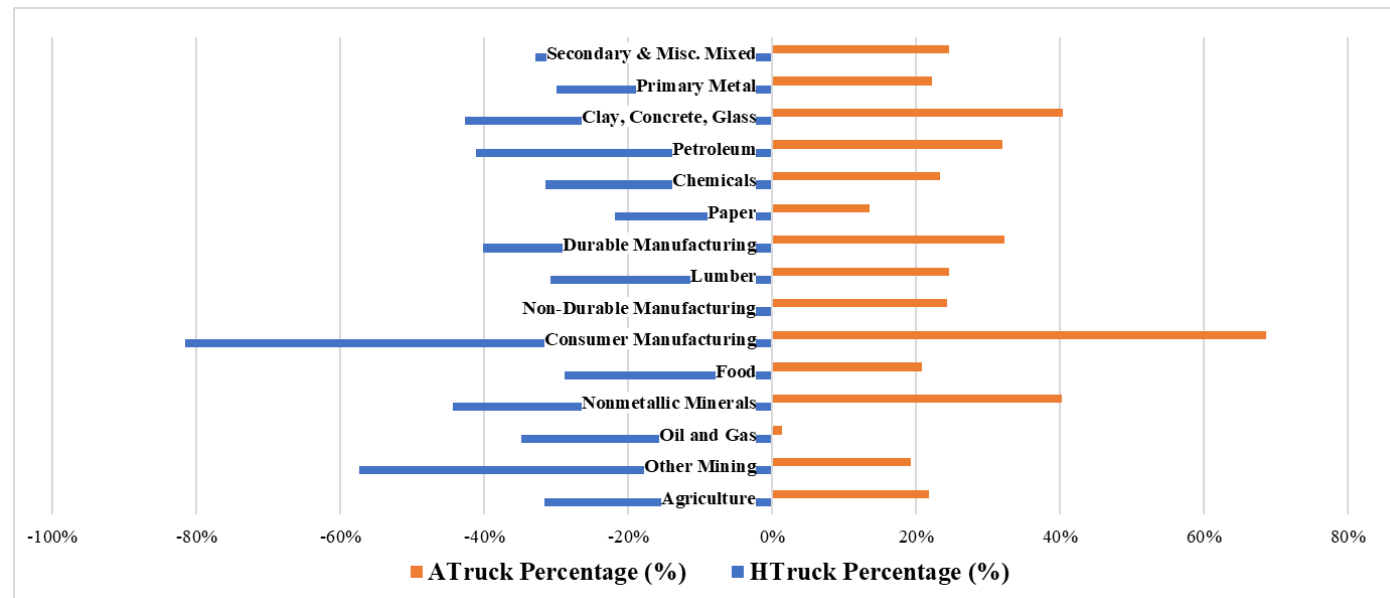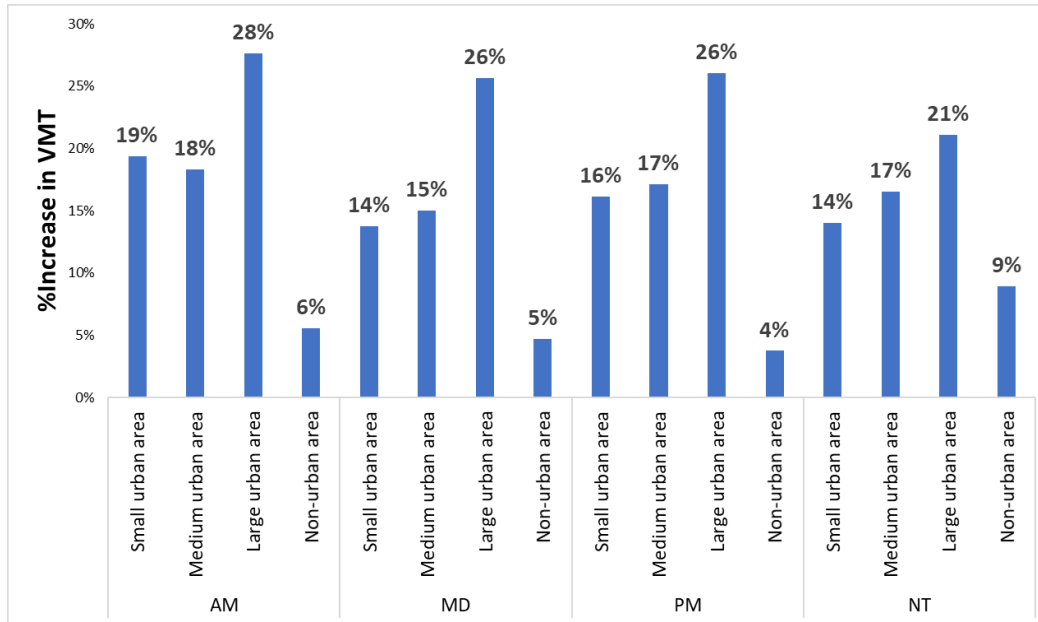

Pie chart:
- 17% Basic Employment
- 20% Retail Employment
- 50% Service Employment
- 7% K-12 Education (Edu1) Employment
- 2% Higher Education (Edu2) Employment
- 1% Farm Employment
- 2% Accommodation Employment
- 2% Oil and Gas Employment

AV Scenario Effects

% Change in person-trips after AVs added

HTruck vs ATruck Splits by Commodity Type

AVs Add VMT & Delay

More Congestion

%Rise in VMT across Region Types for the 4 Times of Day

% Rise in Network Delays by Region Type across 4 Times of Day
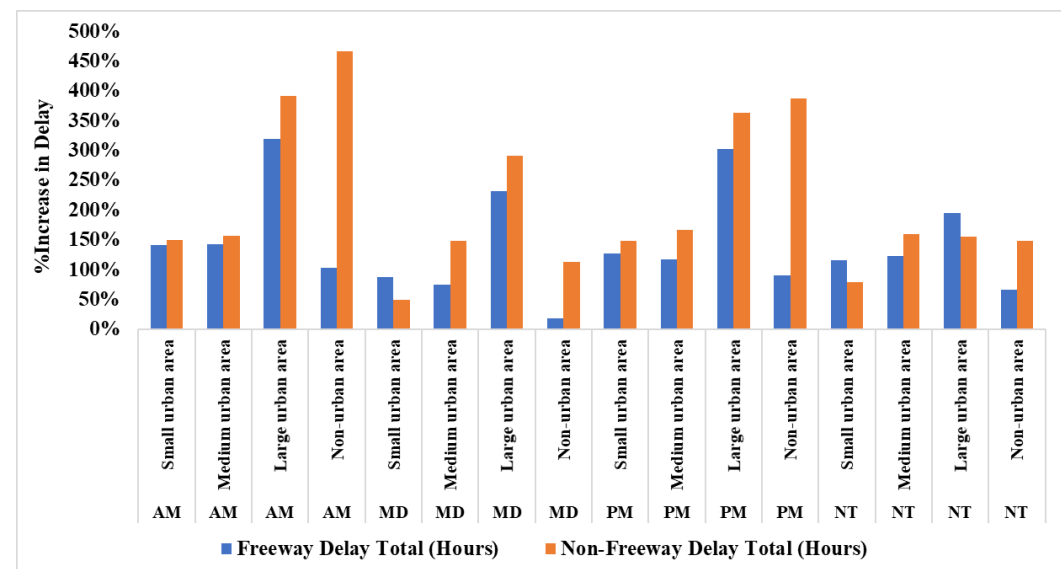
AV Scenarios

We **pivot off Initial AV scenario** to **simulate 6 more AV scenarios**.

- **New Scenario 1 = Lower Cost AVs: SAVs cost 40% less** than initial scenario, & **ATrucks cost 20%** more than HTrucks.

- **2 = Higher Cost AVs: AV** oper costs rise 33% (to **$0.80/mi**) & SAV costs unchanged at **$1/mi**.

- **3 = Lower Value of Travel Time: AV VOTTs fall 50%** across all income groups.

- **4 = No HVs Allowed: no HV or HTruck options** in passenger & freight mode choice models.

- **5 = Private AVs Too Pricey:** Only SAVs & HVs available.

- **6 = Empty AV Driving:** To better reflect empty AV travel, we use 25% higher pax-car equivalence for AVs. (Same as assuming 20% lower AV occupancies.)
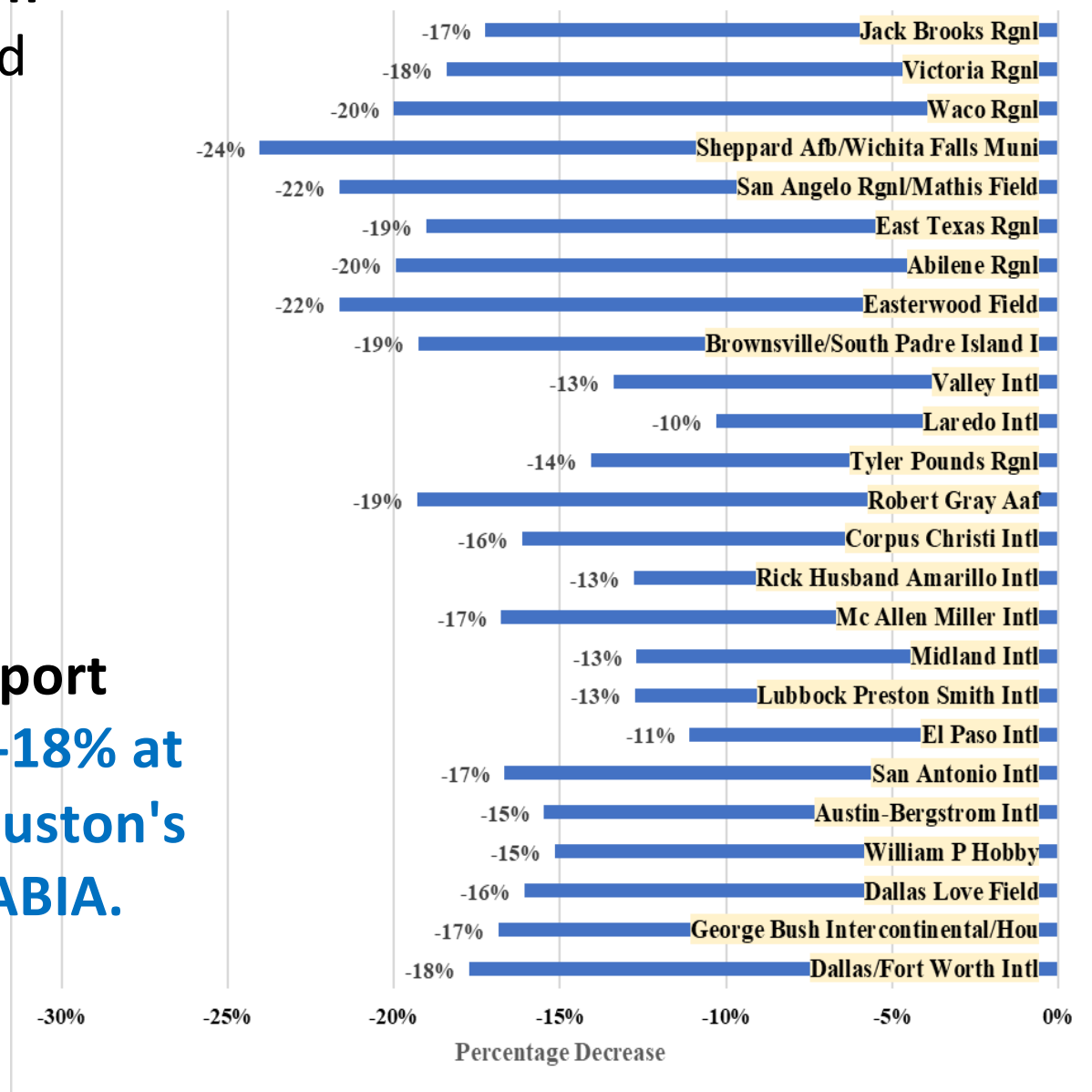
Results
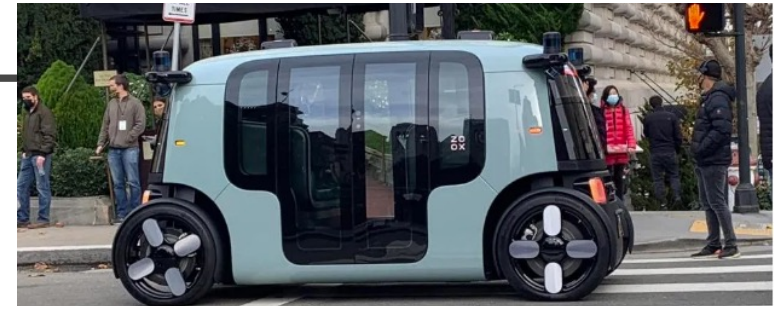
- Adding SAVs & AVs => **10% increase in "drive alone"** & many shared SAVs for **business purposes** (50-400 miles).

- **ATrucks** win **68% of goods** transport in the AV scenario while, Htrucks lost 38% of their share.

- **First AV scenario**: **40% less expensive SAV** operating costs resulted in **11% overall AV use, & 41% increase** in freeway VMT **during afternoon** in medium urban areas.

- **Scenario 2**: **Expensive ATrucks** (twice as costly as HTrucks) **lowered their use (by tons moved)** by **37%** & **32%** for **paper & lumber** freight movement.

More Results

- **Scenario 3: 50% reduction in VOTT** for AVs increased AV usage for **drive-alone business trips** by **50%.**

- **Air travel remained dominant** for long-long trips (>400 mi), at **4% of business trips** & **52% of non-business trips.**

- But **major declines in airport boardings** across Texas: **-18% at DFW** Airport, **-17% at Houston's IAH**, & **-15% at Austin's ABIA.**

Airport	Percentage Decrease
Jack Brooks Rgnl	-17%
Victoria Rgnl	-18%
Waco Rgnl	-20%
Sheppard Afb/Wichita Falls Muni	-24%
San Angelo Rgnl/Mathis Field	-22%
East Texas Rgnl	-19%
Abilene Rgnl	-20%
Easterwood Field	-22%
Brownsville/South Padre Island I	-19%
Valley Intl	-13%
Laredo Intl	-10%
Tyler Pounds Rgnl	-14%
Robert Gray Aaf	-19%
Corpus Christi Intl	-16%
Rick Husband Amarillo Intl	-13%
Mc Allen Miller Intl	-17%
Midland Intl	-13%
Lubbock Preston Smith Intl	-13%
El Paso Intl	-11%
San Antonio Intl	-17%
Austin-Bergstrom Intl	-15%
William P Hobby	-15%
Dallas Love Field	-16%
George Bush Intercontinental/Hou	-17%
Dallas/Fort Worth Intl	-18%

Results (3)

- **Scenario 4**: **Absence of HVs** => **+300% jump in daily delay hours** & **150% increase in VHT** in large urban regions, **+100% & 75% increases in freeway VMT** in non-urban areas during AM & PM periods.

- **Delay hours rose 300% in large urban** regions, **148%** in **medium** & **126% in small urban** areas.

Expect Delays
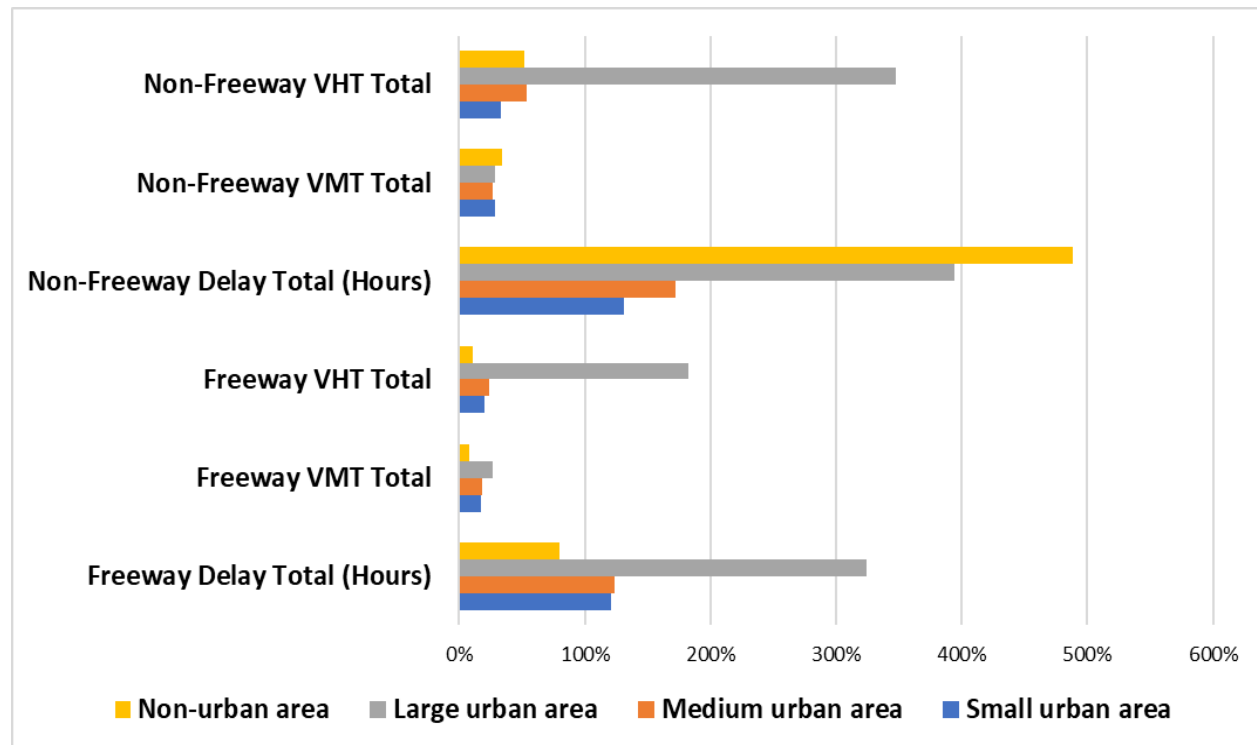
Results (4)

- **Personal AVs no longer available:** led to **6% increase** in SAV usage for business trips & **3% for non-business trips** within 50–400-mile

- Shift back towards HVs was seen **with 64% rise** **in solo driving**, **27% in shared rides** with 2 passengers & 30% in shared ride with more than 2 riders.

- **Decreasing AV AVO by 20%** resulted in a **tenfold increase in delay hours** across various road types.

SAM V4's Limitations

- **Fixed Splits for Short-Distance** Trips ignore half of TX traffic: **64% of Texas PMT is < 50 mi each way** => unrealistic predictions across scenarios

- **Missing Bus Mode** in LD Model limits predictions & and realism across scenarios.

- **Documentation Needed to allow SAM users to customize results** for basic info. (Ex: we all need **VMT & VHT** by mode & commodity).

- **Major Memory for many modes + times of day + traveler classes in Network Assignment** (approx. 100-200 GB per scenario) => Need **powerful computers** + abundant storage. (Note: TransCAD **limits concurrent execution** to two models.)

- **Extremely Long Runtimes** exceeding **20 hours** in all scenarios **=> Unable to run outer feedback** loops across multiple scenarios due to time constraints affects equilibrium & thus predictions.

TxDOT STATEWIDE TDM PREDICTIONS vs OBSERVED TRAVEL DATA

- **How well** do SAM's **predictions compare** to observable data?
- Can we **use observed data** to introduce **demand variations** in SAM equations?
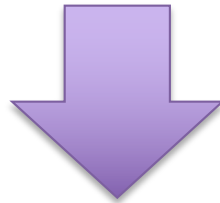
- **RITIS' Nextgen Trip Analytics** offers trip tables from vehicle geolocation (INRIX) data.
- Analyzed heavy and light-duty vehicle data **spring + fall months in 2021** (Feb-April & Sept-Nov).

RITIS' Nextgen Trip Analytics

- Nextgen Trip Analytics V4 delivers "**probe vehicle**" **trip tables** from 2 **INRIX** data sets:
  - **Location-based services** (**LBS**) data from cell-phone apps
    - Trips end when vehicle doesn't move 200+ m in 10 minutes.
  - **Connected vehicles** (**CV**) data from in-vehicle GPS systems
    - Trip starts/ends are determined by engine on/off.
- Heavy-duty vehicles (**HDVs**) are **mostly LBS** & medium- & light-duty (**MDVs & LDVs**) are **mostly CV**.

RITIS HDV Trip Counts & VMT

- Obtained 35 weekdays & 15 weekend days.

- **Weekend** data average just **56.1% & 70.6%** of **weekday trip counts & VMT**.

- More trips at start of weekdays, but higher VMT (longer trips) mid-week.

- Counts & VMT fall slightly over 6 months.

- **Unbelievable spikes in mid-October & November** (so removed from later analyses).
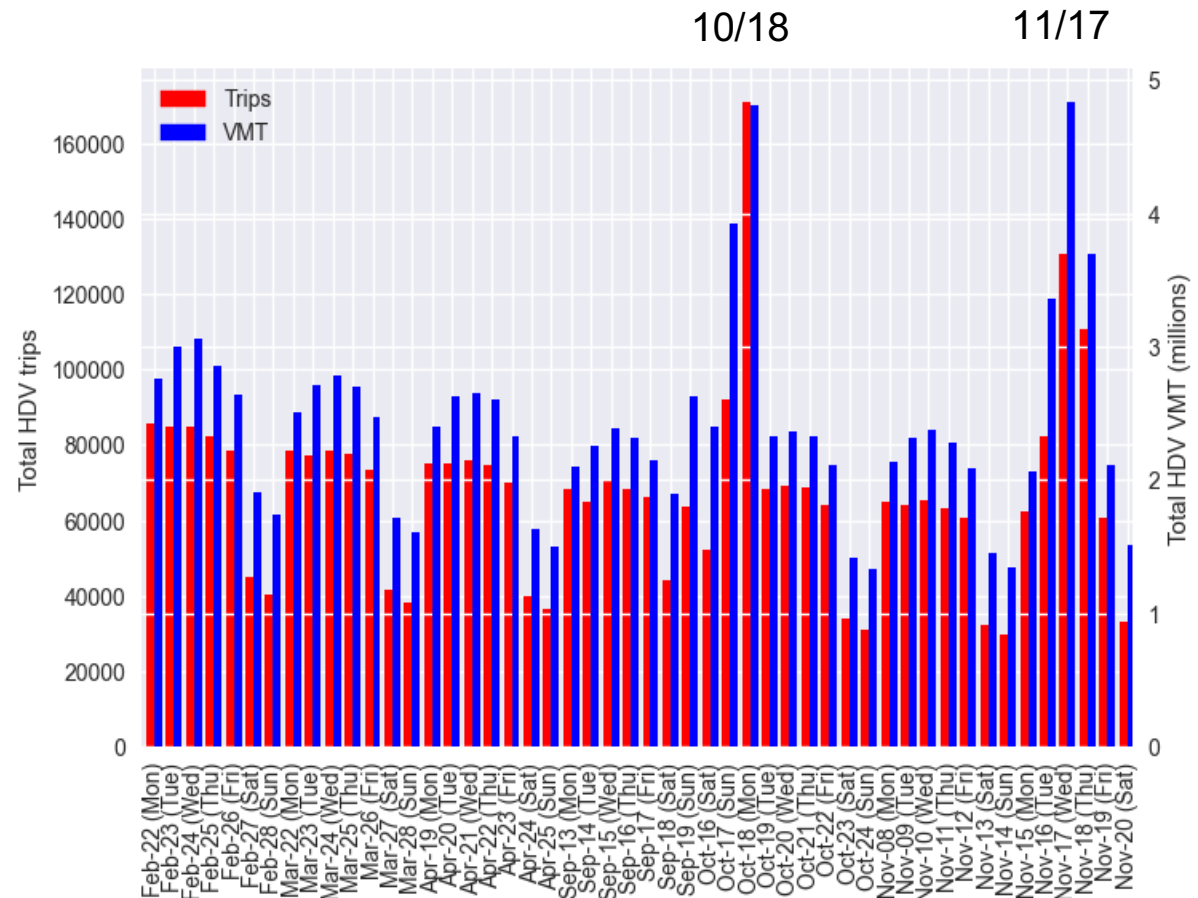
RITIS vs SAM Estimates for HDVs

- RITIS has **more intrazonal trips** than SAM (20% vs 9.5%).
  - Removed from analysis
- RITIS trip tables have **more < 20-mile trips on weekdays**.
- RITIS weekday **trips & VMT are 16.6%b & 14.8% of SAM** values.
- RITIS' average trip distance is **shorter on weekdays but longer on weekends**.
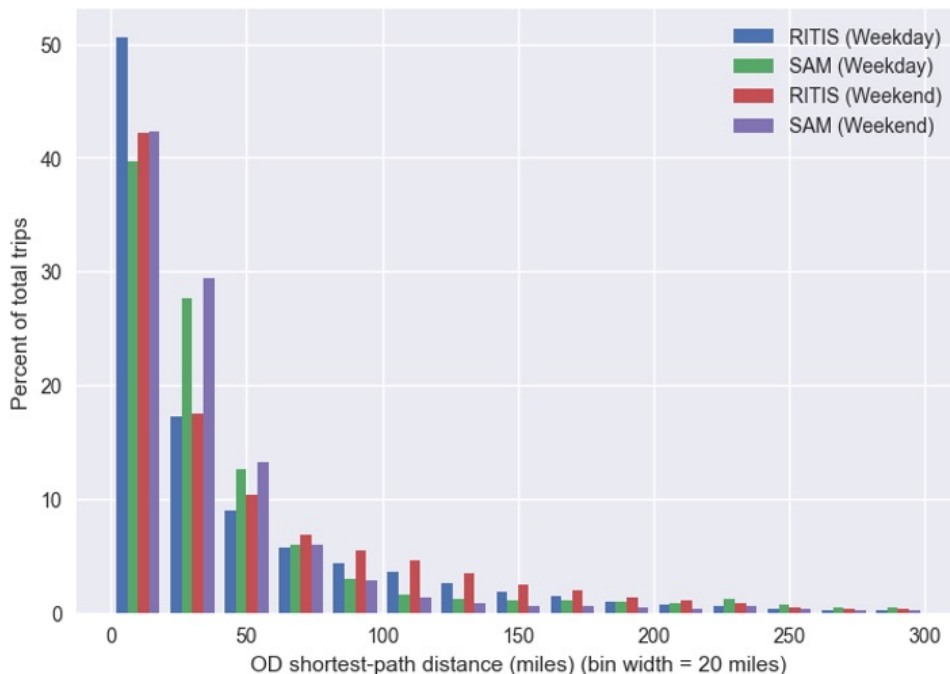
HDV Trips	HDV Trips per Day	HDV VMT per day	Avg HDV Trip Distance
RITIS weekday avg	57,254 trips/d	2.45 M mi/d	42.7 mi
SAM weekday	344,350	16.9 M	49.0
RITIS weekend avg	29,930	1.56 M	52.1
SAM weekend	309,994	12.0 M	38.8

RITIS vs SAM Trip Production + Attraction for HDVs

- Average weekday HDV trip production + attraction (>97% corr. between prod. & attac. in both RITS and SAM) for each county.
- **RITIS missing trips starting/ending in western TX.**

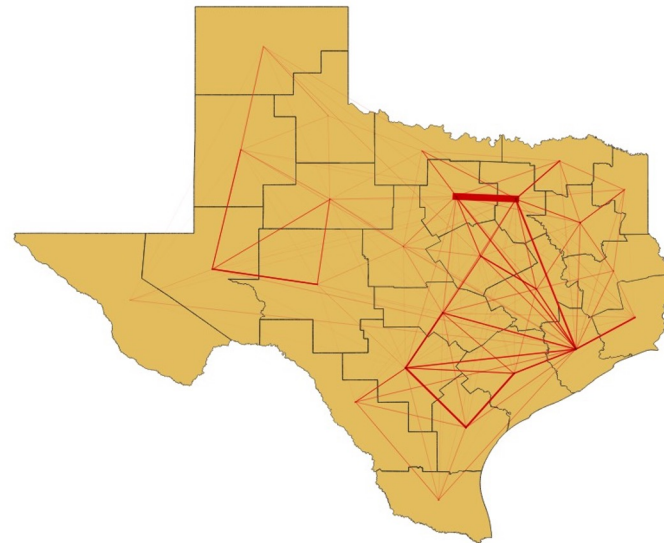Average RITIS Weekday HDV   vs   SAM Predictions

Production + Attraction

RITIS vs SAM HDV Flows

- Weekday HDV flows mapped between **TxDOT's 25 districts** (approx 10 counties each).

- RITIS captures SAM's high freight flows from Laredo to Dallas & Fort Worth districts, through San Antonio, Austin, & Waco districts, but **missing flows to & from Houston district**.
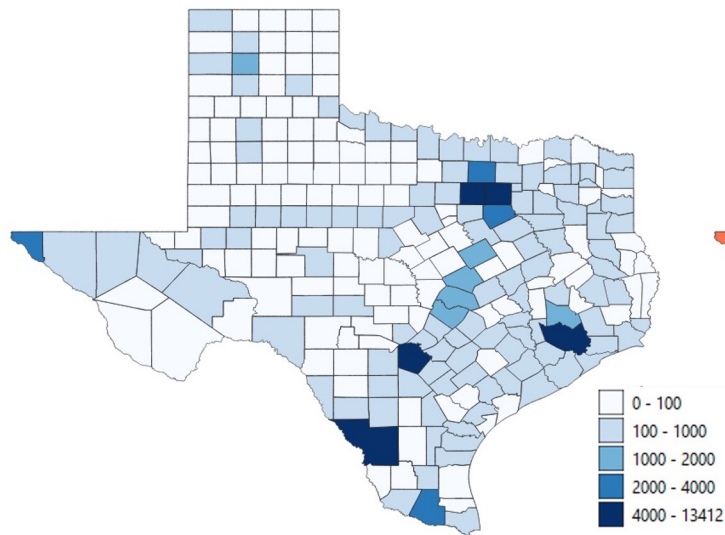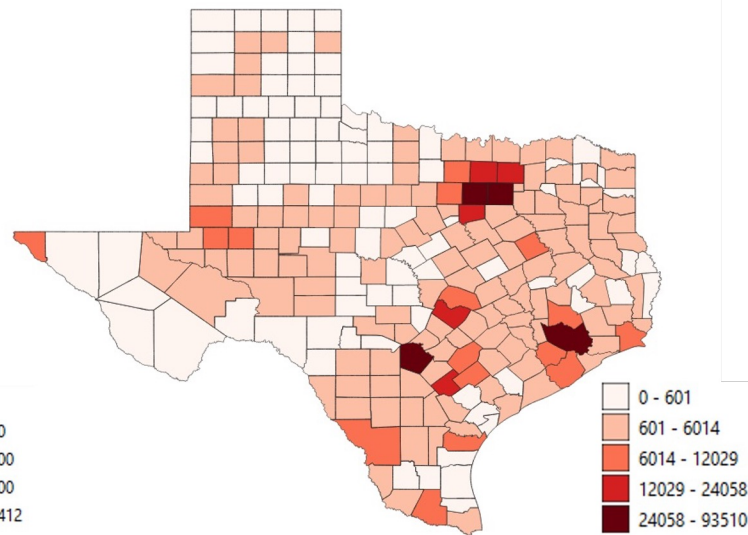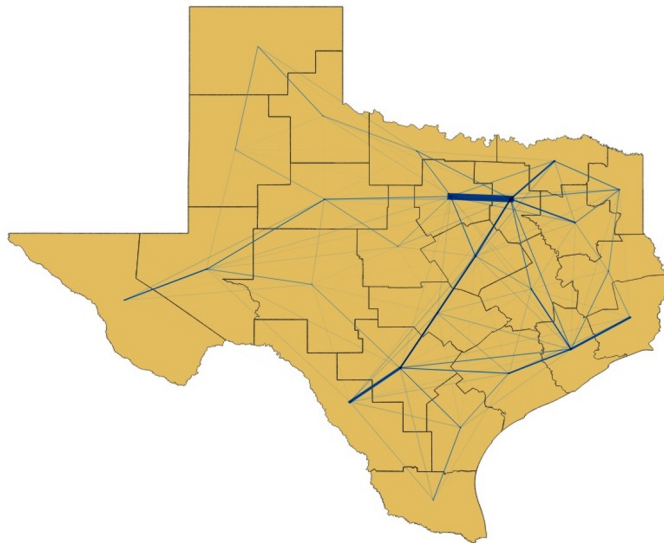

Average RITIS Weekday HDV Flows   vs   SAM Predictions

RITIS vs SAM Trip Count Comparison

- Bivariate **OLS for Y = SAM prediction vs X = avg RITIS** counts at both TAZ & county levels, after excluding all OD pairs (points) with 0,0 HDV flows.

- **Very poor fit** for 44M TAZ pairs (R2 = 0.001) vs. **R2 = 0.639 at 254-County level** (n=63k), but too affected by **14 high-flow outliers** (see below).

- **R2 = 0.302** with slope of 4.59 (closer to expected 6) after removing the 8.

y = 3.23 + 2.44x
$R^2 = 0.639$

y = 1.92 + 4.59x
$R^2 = 0.302$
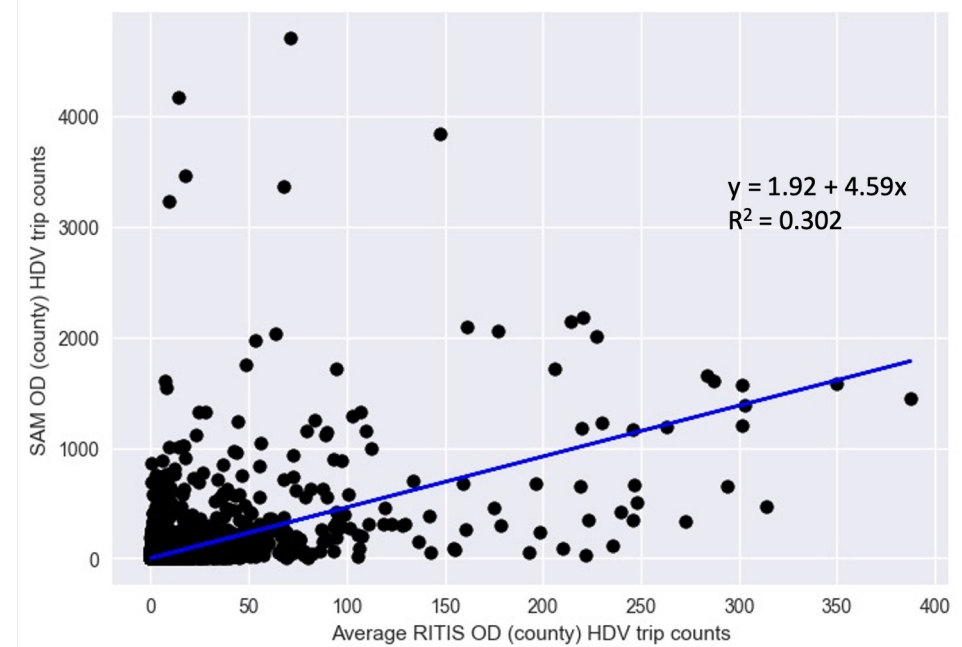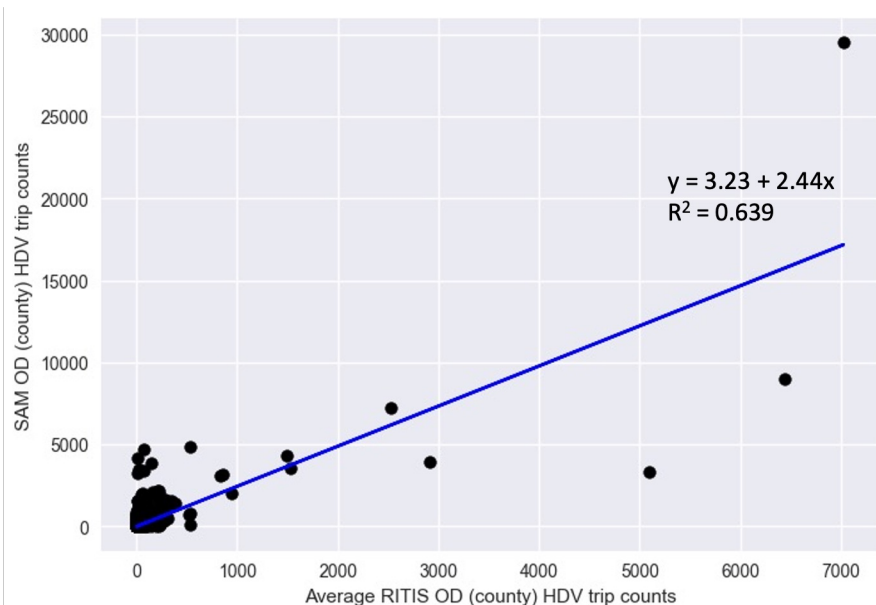
RITIS Average **Weekday HDV Counts vs SAM** between **all 254 Counties**
before & after removing 14 high-count (>500 HDV trips/d) outliers (n = 63,440 -> 63,426)
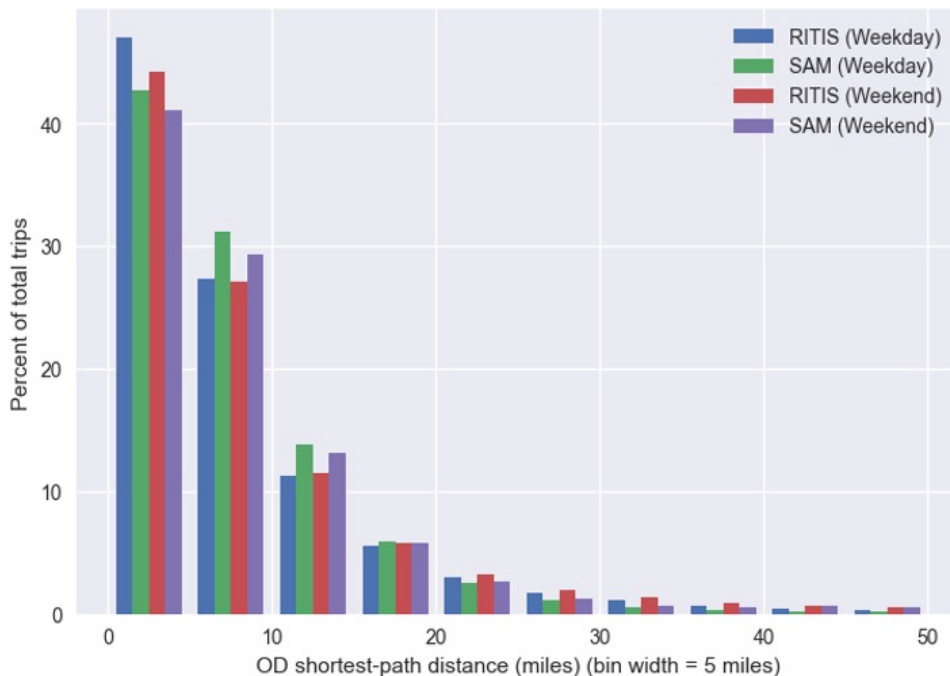
RITIS LDV Trip Counts & VMT

- Obtained 35 weekdays & 15 weekend days.
- **Fridays have the most trips**, but **Saturdays have the highest avg VMT**.
- Counts & VMT rise slightly over 6 months.
- **Same spikes in mid-October & November as HDVs.**
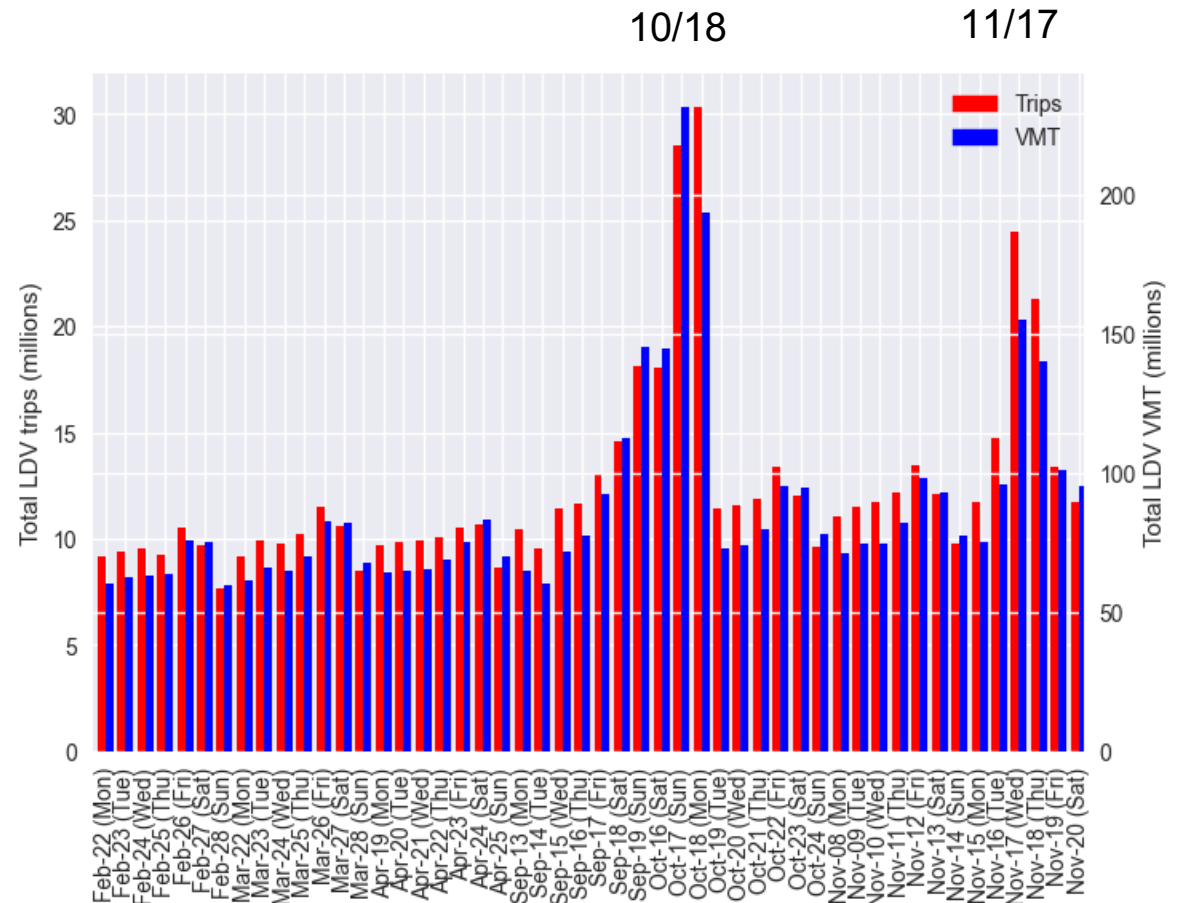
RITIS vs SAM Estimates for LDVs

- RITIS has **more intrazonal trips** than SAM (26% vs 15%).
  - Removed from analysis
- RITIS trip tables have **more < 5-mile trips**.
- RITIS weekday **trips & VMT are 14.8% of SAM** values.
- RITIS' average **weekend** trip distance is **2 mi shorter**.

LDV Trips	LDV Trips per Day	LDV VMT per day	Avg LDV Trip Distance
RITIS weekday avg	8.1 M trips/d	73.4 M mi/d	9.1 mi
SAM weekday	54.7 M	496 M	9.1
RITIS weekend avg	7.6 M	79.7 M	10.4
SAM weekend	41.5 M	522 M	12.6

RITIS vs SAM Trip Count Comparison

- Bivariate **OLS for Y = SAM prediction vs X = avg RITIS** counts at both TAZ & county levels, after excluding all OD pairs (points) with 0,0 HDV flows.

- Good fit for 44M TAZ pairs (**R2 = 0.614**), unlike HDVs, but too slope is too shallow.

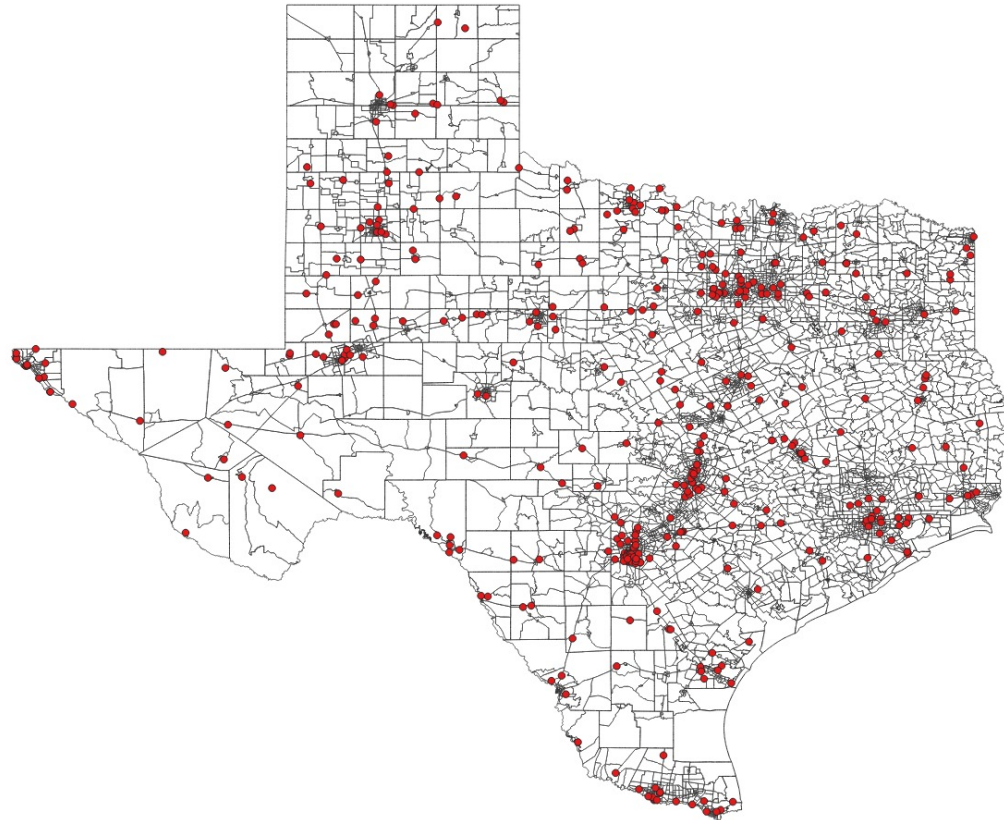- At the county level, **R2 = 0.948** with slope of 8.66 (closer to expected 7).
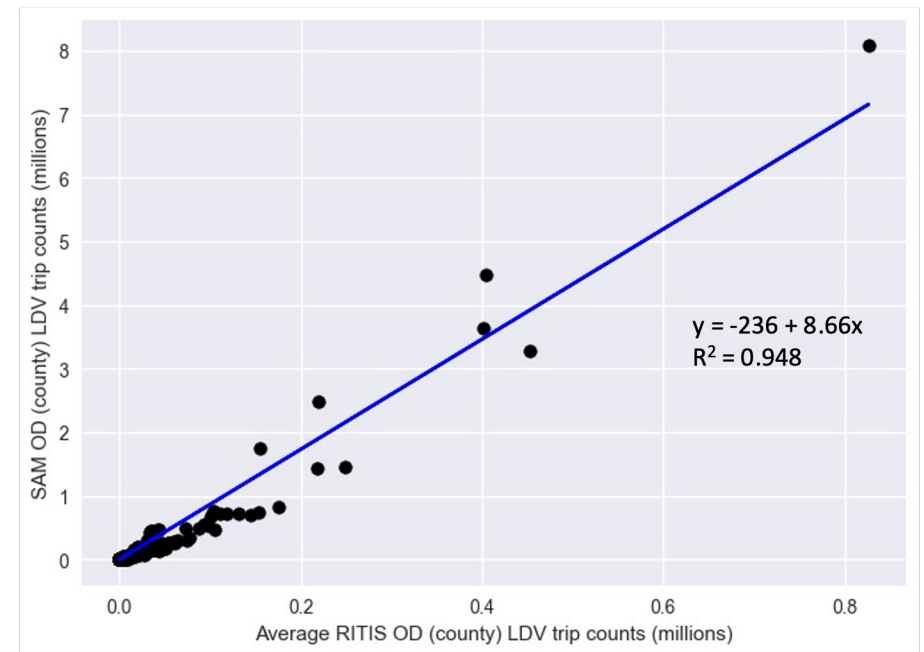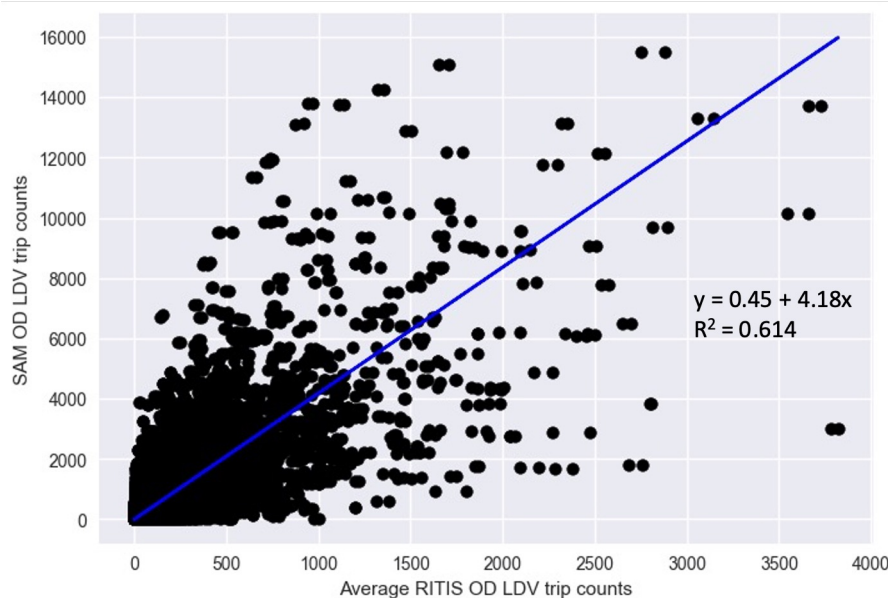
RITIS Average **Weekday LDV Counts vs SAM** between **6860 TAZs** and **254 Counties**
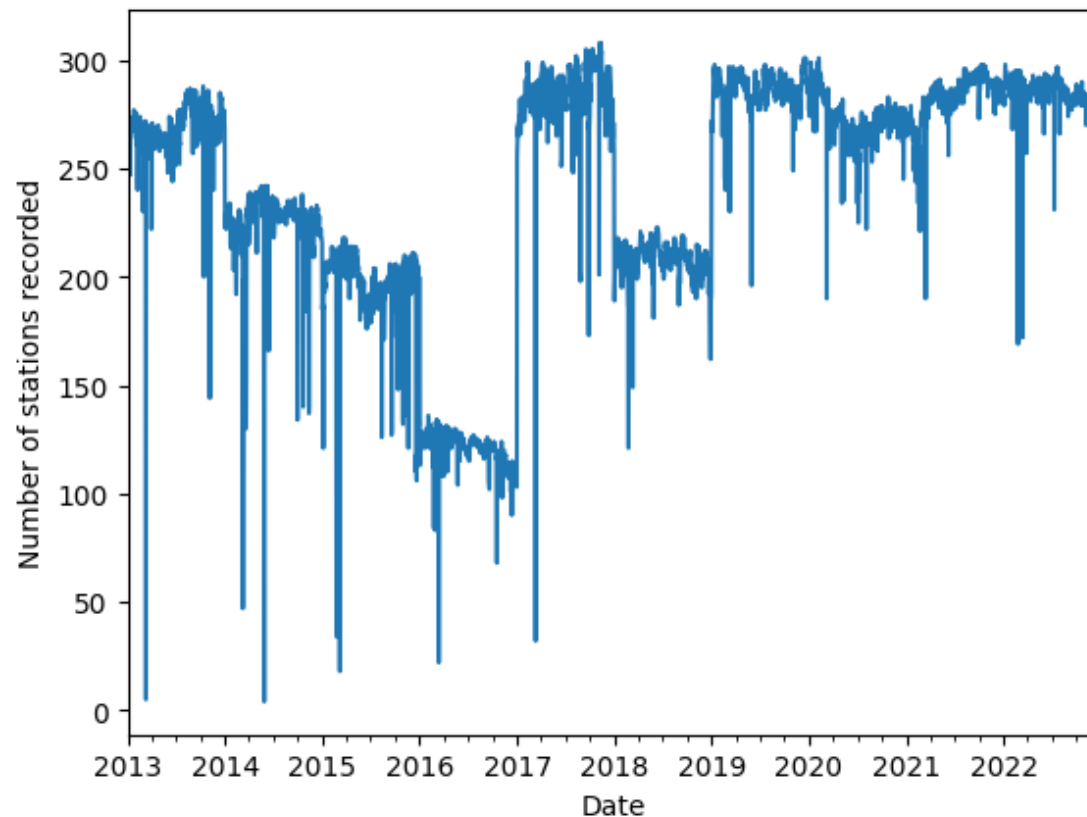
Permanent Traffic Recorders (PTR)

- From 2013 thru 2022, TxDOT maintained 398 **PTR stations** (100 to 300 active at one time, depending on year), which records traffic counts using **loop detectors**.

Permanent Traffic Recorders (PTR)

- The number of active stations varies depending on day and **year**.


Number of stations with data per day

Permanent Traffic Recorders (PTR)

- Plotted the total daily counts for the 178 stations more than 90% active during 2019-2022, imputing missing values.
  - Years after 2019 are offset to align the day of the week.
- Counts align very closely from year to year with **Fridays** & **Sundays** being the **peaks** & **valleys** of the weekly fluctuations.
- Winter traffic counts were highly affected by **severe weather**.
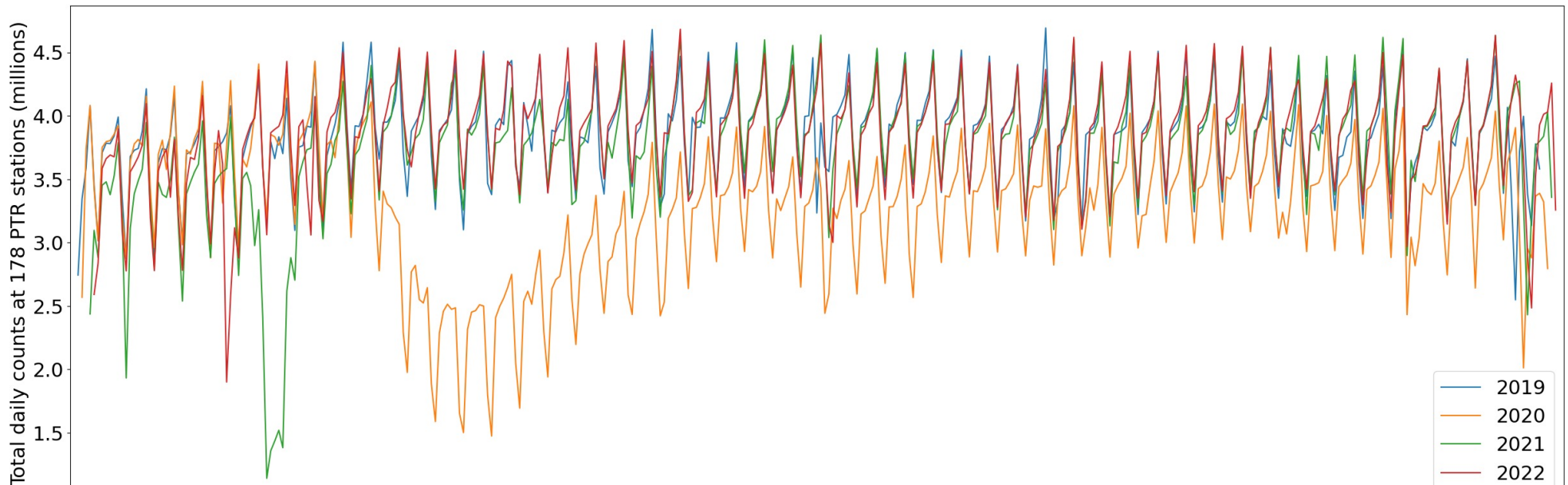
PTR Regression Results
(Day of Week Variables)

- Daily total traffic counts at each station were standardized to **z-scores** using the mean & std dev at the station. (**n=885,274**)

- Explanatory variables include days of the week, month, year, & holiday peaks. (**R^2=0.362**)

- On average, traffic volumes fluctuate by **1.63 std dev** over the course of a week, with **Sundays** having the least counts & **Fridays** having the most.

Variable	Estimate
Intercept	-0.945
Monday/Tuesday	0
Wednesday	0.088
Thursday	0.281
Friday	0.852
Saturday	-0.202
Sunday	-0.778

*All |t-statistics| >5

PTR Regression Result (Month Variables)

- **January** has the least counts, while **June & July** has the most.
- The largest one-month increase (0.344 std. dev.) occurs from **February to March**.
- The largest one month decrease (0.438 std. dev.) occurs from **December to January**.

Variable	Estimate
January	0
February	0.149
March	0.494
April	0.314
May	0.450
June	0.570

Variable	Estimate
July	0.529
August	0.465
September	0.402
October	0.498
November	0.484
December	0.438

PTR Regression Result
(Year Variables)

- Traffic volumes have been steadily rising since 2013, with the 2022 counts being **0.89 std. dev.** above 2013 counts on avg.

- Even the pandemic counts of 2020 where higher than that of 2014.

- Traffic volumes fully recovered and surpassed 2019 levels in 2022.

Variable	Estimate
Year 2013	0
Year 2014	0.142
Year 2015	0.339
Year 2016	0.506
Year 2017	0.612

Variable	Estimate
Year 2018	0.737
Year 2019	0.850
Year 2020	0.210
Year 2021	0.801
Year 2022	**0.891**

PTR Regression Result (Holiday Variables)

- Total decrease of >1 std. dev. for **Fourth of July, Thanksgiving Day, Friday after Thanksgiving, & Christmas**.

- Total increase of >1 std. dev. for **Wednesday before Thanksgiving**.

Variable	Estimate	Variable	Estimate
Federal holiday	-0.307	Thanksgiving Day	**-1.121**
Friday before Memorial Day	0.445	Friday after Thanksgiving	**-1.199**
Memorial Day	-0.301	Saturday after Thanksgiving	-0.102
July 3	0.307	Sunday after Thanksgiving	0.890
Fourth of July	**-0.736**	December 23	0.364
Friday before Labor Day	0.518	Christmas Eve	-0.720
Labor Day	-0.099	Christmas	**-1.691**
Tuesday before Thanksgiving	0.669	December 26	-0.216
Wednesday before Thanksgiving	**1.275**		

Thank you for your support!

Questions, Comments, & Suggestions?
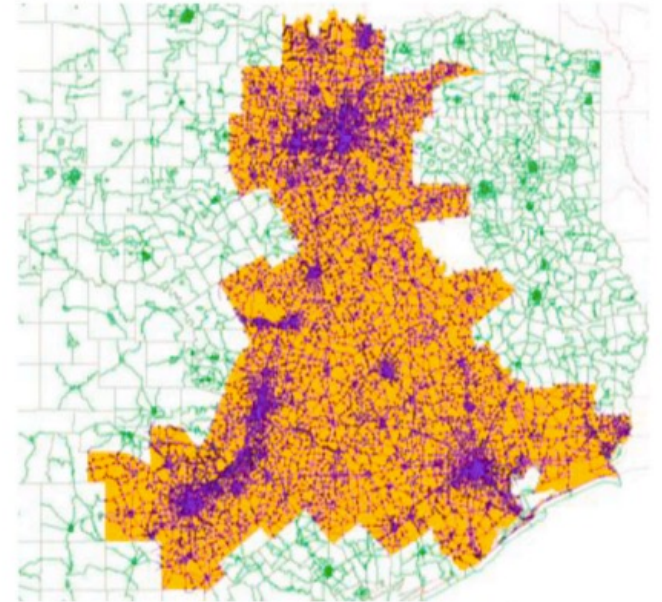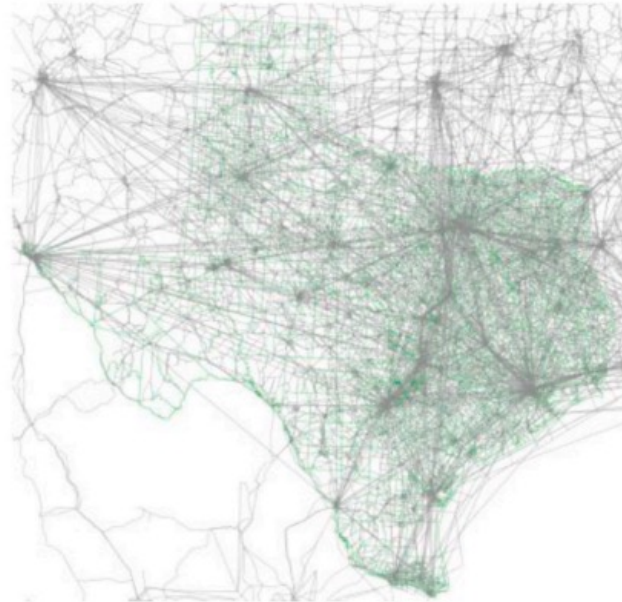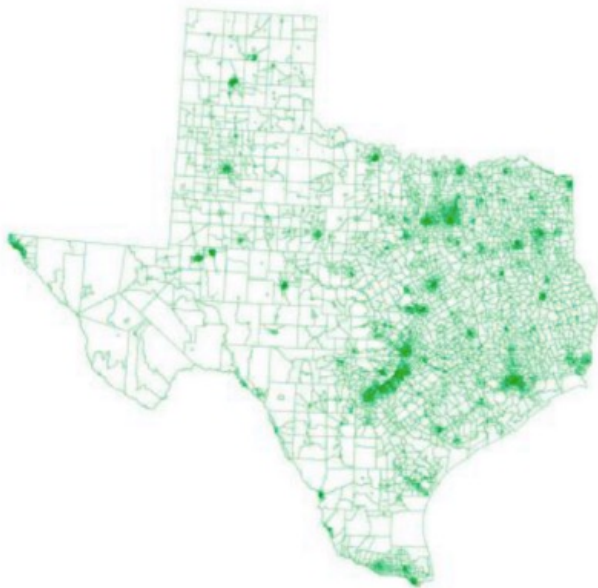
kkockelm@mail.utexas.edu   512-471-0210