CM2 Cooperative Mobility for Competitive Megaregions

THE UNIVERSITY OF TEXAS AT AUSTIN
CENTER FOR TRANSPORTATION RESEARCH

# How Will Self-Driving Vehicles Affect U.S. Megaregion Traffic? The Case of the Texas Triangle

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*Sponsored by the USDOT's University Transportation Centers Program*

CM2 Cooperative Mobility for Competitive Megaregions

# Background

- Fully-automated vehicles (**AVs**), trucks (**Atrucks**), & shared AVs (**SAVs**), may dramatically shift **passenger & freight** travel patterns over time.
- The **Texas Triangle megaregion…**

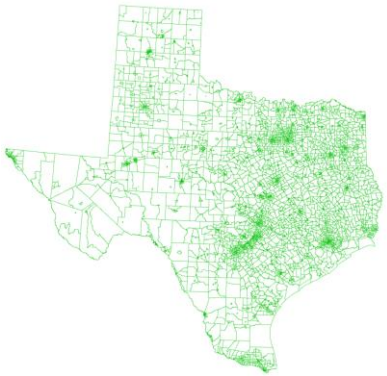
  is one of the nation's **11** megaregions,

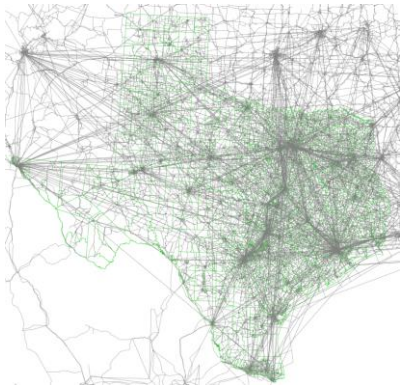
  contains **18.2 M** of Texas' 25.1 M residents,

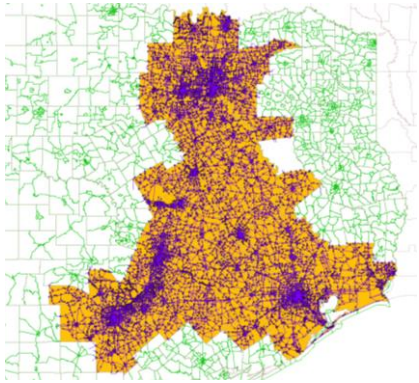
  has about **6%** of the U.S. population, & generated **7% of U.S. GDP** in 2010.
- We want to leverage **statewide analysis model** (SAM) data with new self-driving modes & see how the model responds.

# SAM Data

- The megaregion contains **2,160** of the state's **4,667 TAZs**, & **66** of the state's **254 counties**
- **19,549 nodes** & **27,976 links** of the SAM's network lie partially or entirely within the megaregion, including **26,556 roadway links**.
- The megaregion was modeled within the U.S. network, & results for the megaregion's links & zones were **pulled out** from of the results of the statewide analysis.

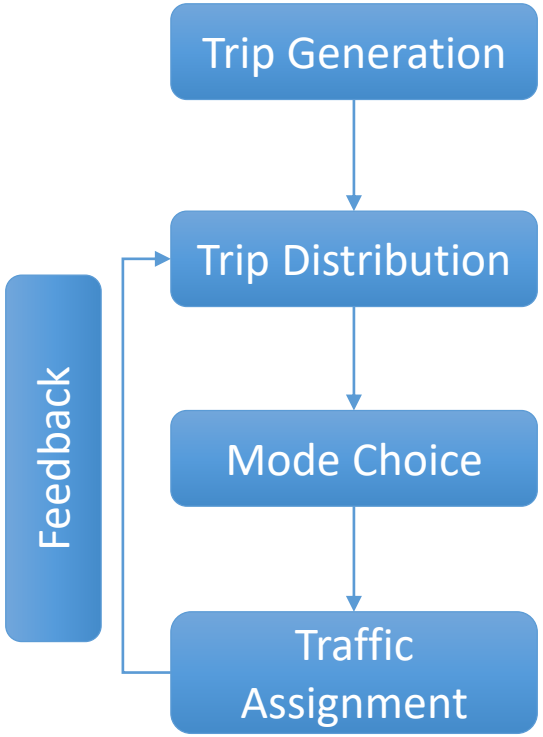






# Model Specifications

- **4-step travel demand** model with **feedback loop** is used here, to model traffic patterns across the **entire state of Texas.**
- **Base Case** (BAU) scenario - ***without AV, SAV & Atruck*** modes - was run first, to compare against **self-driving scenarios**.
- **Various parameter assumptions** also tested, using **sensitivity analysis**.




- **24 hr simulation** used to recognize that many trips are long in distance, spanning many times of day & congestion levels.

# Trip Generation

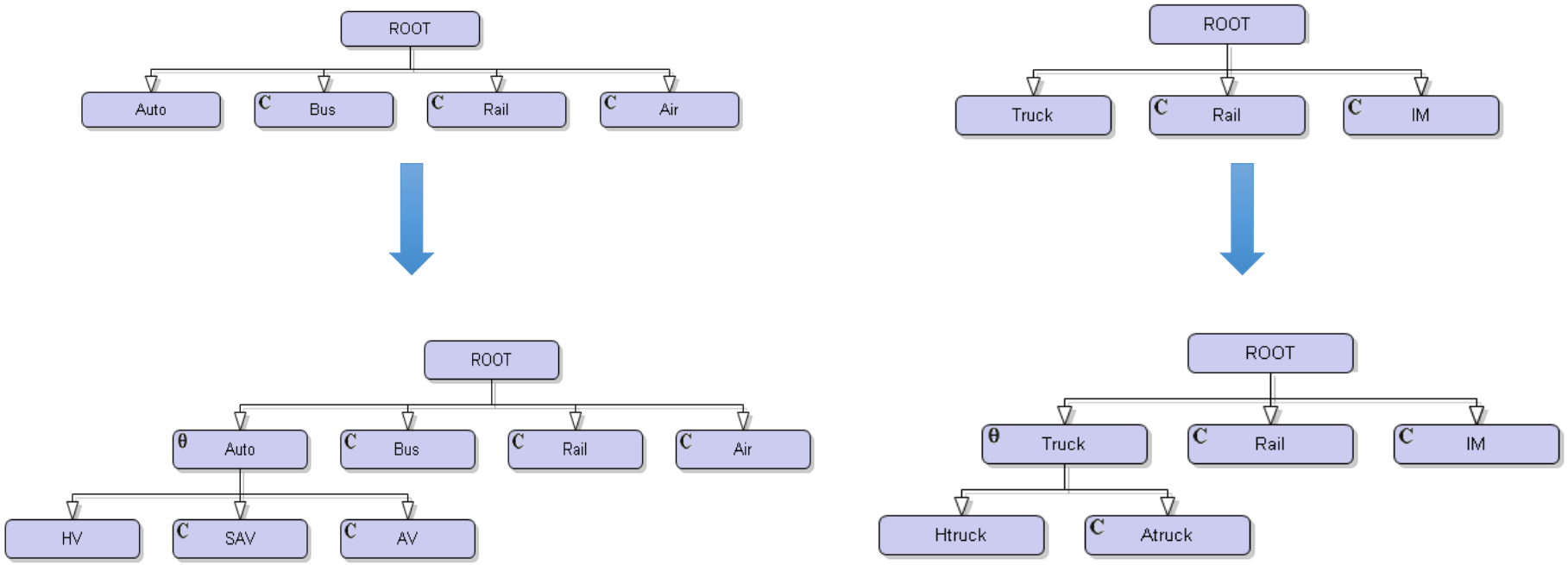
- Obtained from the SAM **Year 2040 scenario** results, based on underlying **population & jobs** forecasts by zone, using **2009 NHTS** data.
- An assumption of **15% increase** in Year 2040 trip generation rates (productions & attractions) due to AV technologies enabling new trip-making.
- All trip purposes are **aggregated.**

# Trip Distribution

- Traditional “trip distribution” step for **passenger** travel replaced by a **logit destination choice model.**
- Each destination TAZ’s attraction depends on a **logsum** across mode options & destination’s **population.**
- A **doubly-constrained** trip distribution procedure was used in the **freight model**, based on SAM’s Year 2040 freight-trip generation parameters.

# Mode Choice

- **4 passenger modes: HV, bus, rail & air**.
- 3 **freight** modes: **Truck, Rail, & Intermodal (IM).**
- Models expanded to include AV, SAV & Atruck modes

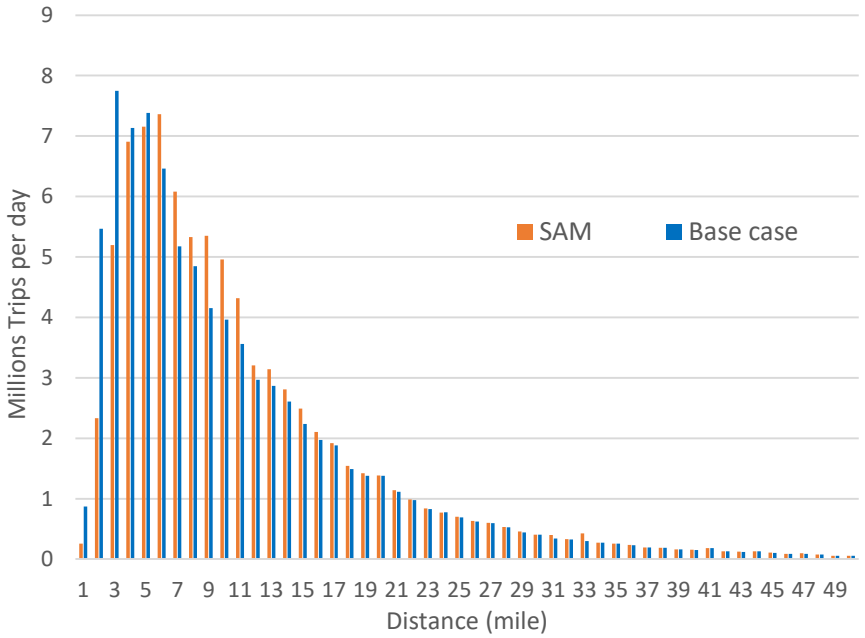


# Traffic Assignment & Feedback

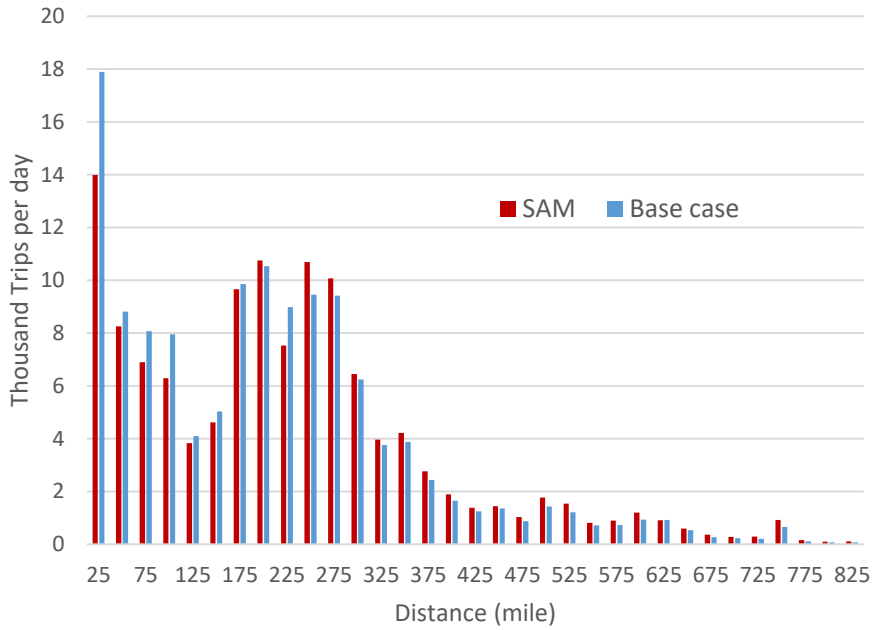
- **Passenger mode & destination choice** results transformed into “trip tables” (OD matrices).
- HV, AV & SAV occupancies = **1.5 persons**
- Freight trip table (in tons by commodity) converted to **trucks & rail cars**, based on average statewide model weights per load.
- Feedback loops (iteration) provide consistent results between **travel times, cost skims & network flows**, using method of successive average.
- Assignment is conducted on **whole U.S. network**.

# Trip Distance Correlations

- Correlation = **0.82** across flows between all >21M OD pairs
- Correlations = **0.81** for trip counts between every all U.S. OD pairs



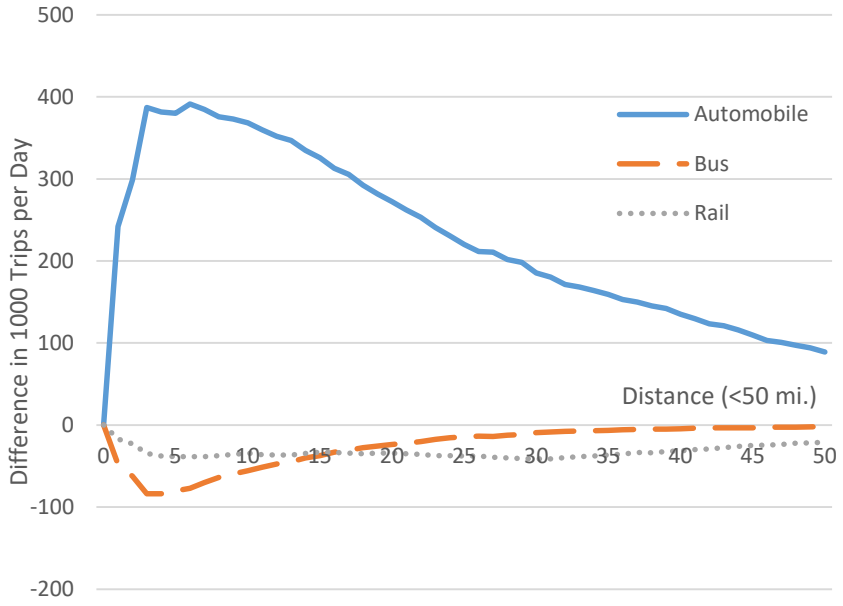

Passenger Trip Distances across Texas (< 50 mi.)

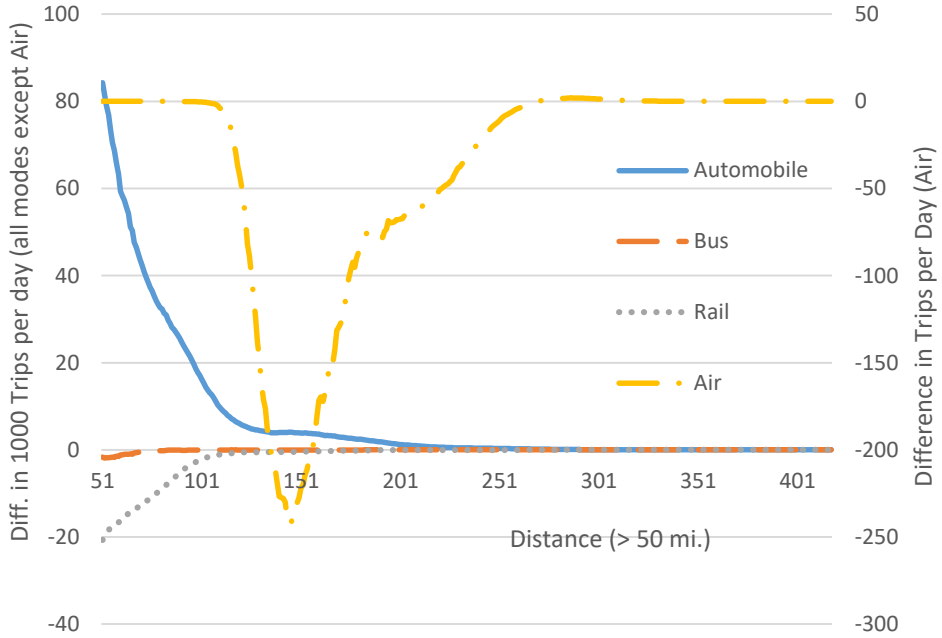



Freight Trip Distance across U.S.

# Mode Splits

- **Operating Costs: HVs = $0.6**/mile, **AVs = $0.8**/mi, & **SAVs = $1**/mi
- **Automobile shares rise** for **short & long-distance** trips across the megaregion, shifting markedly away from Texas **air travel**
- **Bus & rail #s fall**



# Mode Splits (2)

- AVs & SAVs see **less impact** on shorter distances
- Air trips less than 50 miles are not discussed
- Local **air trips reduce** significantly

| Mode | | Automobile (HVs, AVs, & SAVs) | Bus | Rail | Air |
|---|---|---|---|---|---|
| Trips before | < 50 miles (short-distance) | 64,678 k/day | 1,837 k/day | 2,219 k/day | N/A |
| Trips after | | 75,088 k/day | 623.8 k/day | 642.3 k/day | N/A |
| Change | | **+16.1%** | **-66.1%** | **-71.1%** | N/A |
| Trips before | > 50 miles (long-distance) | 2,946 k/day | 33.64 k/day | 988.2 k/day | 14.27 k/day |
| Trips after | | 6171 k/day | 2.416 k/day | 595.7 k/day | 2.497 k/day |
| Change | | 109.5% | -92.8% | -39.7% | -82.5% |
| Total change | | **+20.2%** | **-66.5%** | **-61.4%** | **-82.5%** |

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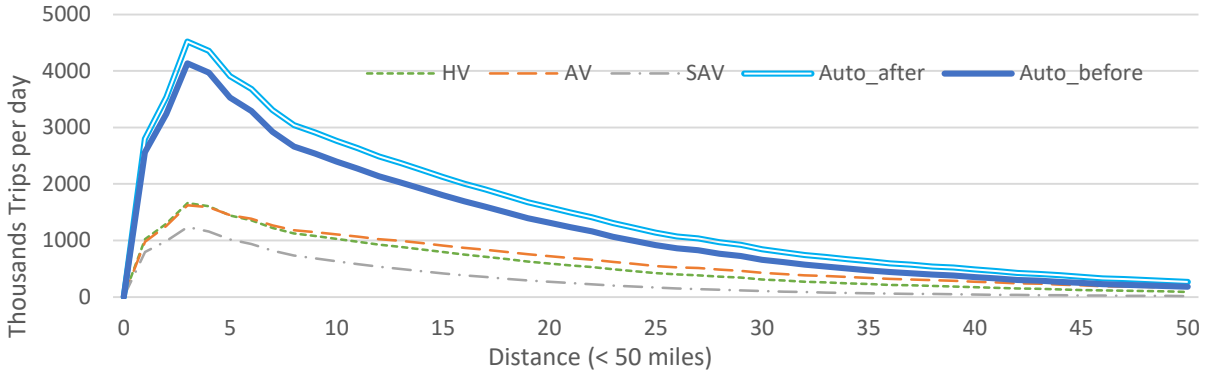
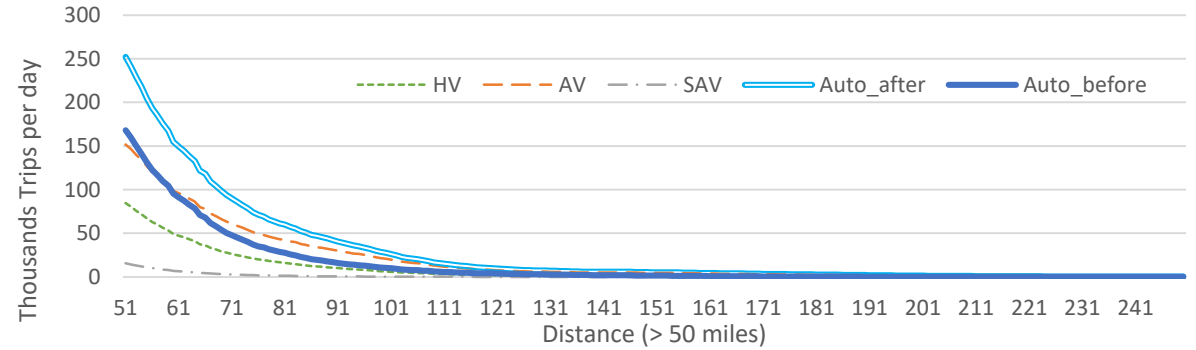
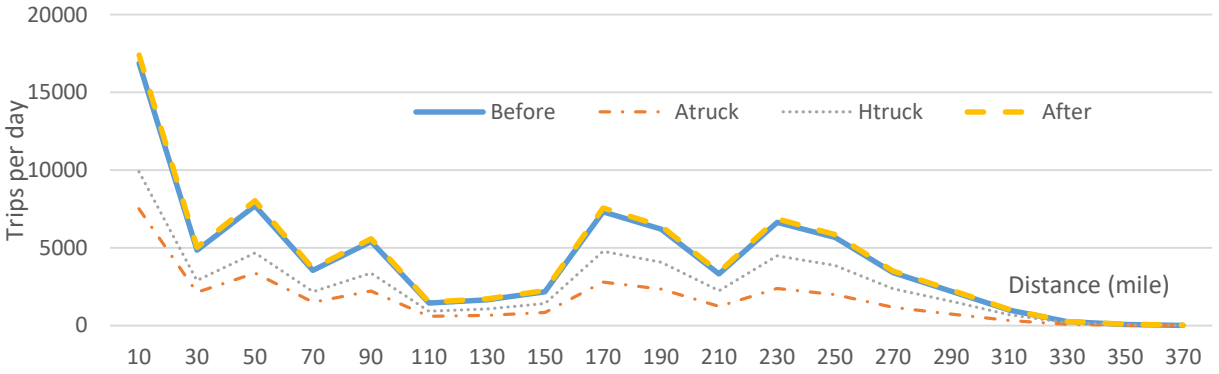
# Freight Mode Splits

| Commodity | Mode Shares After Atrucks Introduced | | | | | Total Ton-mile (Billion) | Change from Base Case | | |
|---|---|---|---|---|---|---|---|---|---|
| | Atruck | Htruck | Truck | Rail | IM | All modes | Truck | Rail | IM |
| Agriculture | 30.4% | 52.6% | 83.0% | 16.9% | 0.18% | 0.75 | +7.2% | -25.3% | -25.3% |
| Mining | 37.1% | 58.0% | 95.1% | 4.9% | 0.04% | 0.28 | +2.4% | -30.9% | -31.0% |
| Coal | 2.5% | 3.5% | 6.0% | 91.0% | 3.08% | 0.97 | +50.0% | -2.0% | -2.0% |
| Nonmetallic Minerals | 26.6% | 56.1% | 82.7% | 17.3% | 0.01% | 23.42 | +5.6% | -21.8% | -21.9% |
| Food | 34.5% | 58.0% | 92.4% | 7.5% | 0.06% | 3.22 | +3.1% | -28.8% | -28.8% |
| Consumer Manufacturing | 38.6% | 60.7% | 99.2% | 0.1% | 0.68% | 0.09 | +1.1% | -31.7% | -31.7% |
| Non-Durable Manufacturing | 35.9% | 63.7% | 99.6% | 0.2% | 0.19% | 0.49 | +0.2% | -29.6% | -29.7% |
| Lumber | 36.3% | 61.2% | 97.5% | 2.4% | 0.04% | 1.13 | +1.2% | -26.4% | -26.5% |
| Durable Manufacturing | 48.1% | 38.4% | 86.5% | 13.0% | 0.53% | 1.14 | +9.6% | -35.1% | -35.1% |
| Paper | 33.8% | 54.5% | 88.3% | 11.2% | 0.49% | 0.45 | +5.2% | -28.3% | -28.4% |
| Chemicals | 30.6% | 46.6% | 77.2% | 22.7% | 0.05% | 6.46 | +11.1% | -25.6% | -25.6% |
| Petroleum | 30.6% | 62.9% | 93.5% | 6.5% | 0.01% | 9.07 | +2.2% | -24.5% | -24.7% |
| Clay, Concrete, Glass | 34.3% | 60.5% | 94.8% | 5.2% | 0.06% | 8.85 | +2.1% | -28.4% | -28.4% |
| Primary Metal | 34.2% | 47.7% | 81.9% | 18.0% | 0.02% | 1.05 | +9.0% | -27.8% | -27.8% |
| Secondary & Misc. Mixed | 36.6% | 61.7% | 98.3% | 1.2% | 0.49% | 16.95 | +0.5% | -30.5% | -30.6% |

# Trip Distributions




- Trip distribution of a thousand trips per day by automobile **before & after** AV introduction
- Oper. Cost: **HV = 0.6** $/mile vs **AV = 0.8** $/mile vs **SAV = 1** $/mile
- **Average trip distance** is **14** miles before AVs, compared to 16 miles after the AV scenario
- Slight **increase** in truck trips of all trip distances

# VMT Results

- **VMT** = average trip distance x trip count for each distance band.

| VMT (1M mi per day) | Automobile | Rail | Bus | Air |
|---|---|---|---|---|
| Before | 955.2M mi/day | 19.4M mi/day | 114.1M mi/day | 2.0M mi/day |
| After | 1400.9 | 4.5 | 57.3 | 0.3 |
| Change | **+46.7%** | **-77.1%** | **-49.8%** | **-84.6%** |

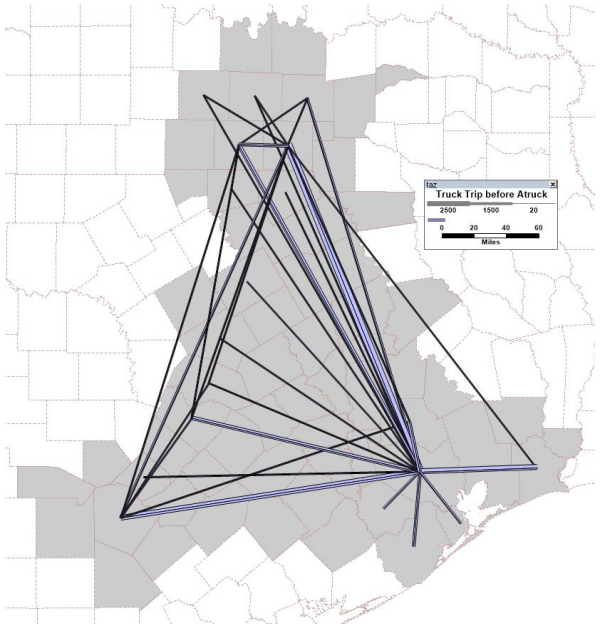
- **VMT** = Automobile VMT within Megaregion Border.

| | Automobile VMT before AV (1M per day) | Automobile VMT after AV (1M per day) | Change |
|---|---|---|---|
| Dallas-Fort Worth | 453M miles | 669M miles | **+47.7%** |
| San Antonio Region | 118 | 171 | **+45.8%** |
| Austin Region | 119 | 186 | **+56.9%** |
| Houston Region | 432 | 587 | **+36.0%** |
| Total Megaregion | 1,367 | 2,012 | **+47.2%** |

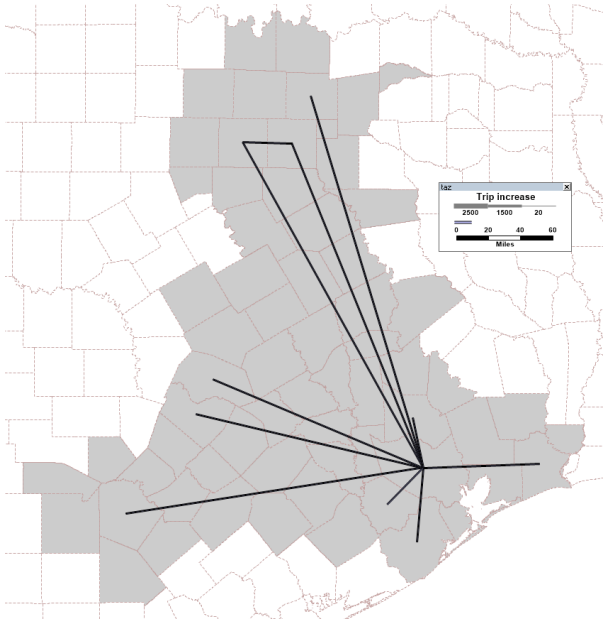
- **Raised burden** for the infrastructure of the major cities in the megaregion, especially in the Austin area

# Freight Spatial Patterns

- **Major commodity movements** (**90%** of megaregion's freight movement in tons) & **movement changes** between OD pairs in the Triangle
- Trade happens mostly between Triangle's **key sub-regions**: Houston, Dallas-Fort Worth, San Antonio & Austin




Truck Trips before AVs




Top Truck Trip Increases After Atrucks

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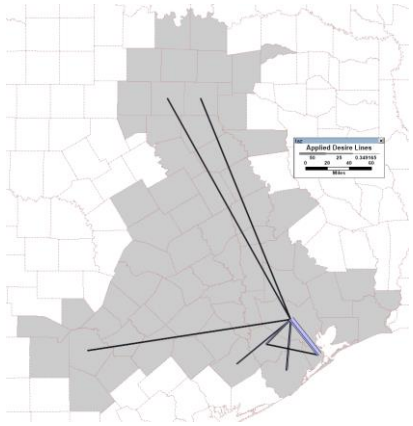
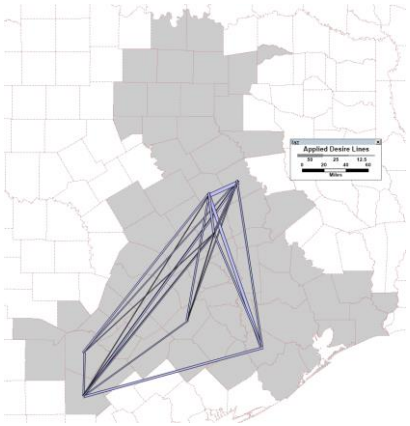
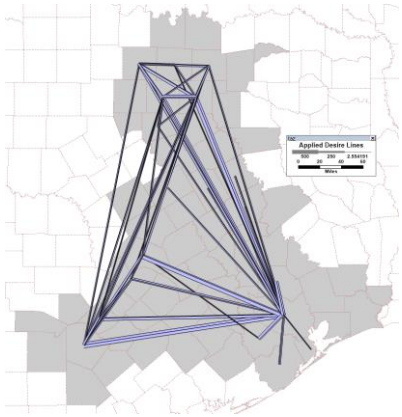
# Truck Trip Increases > 5%



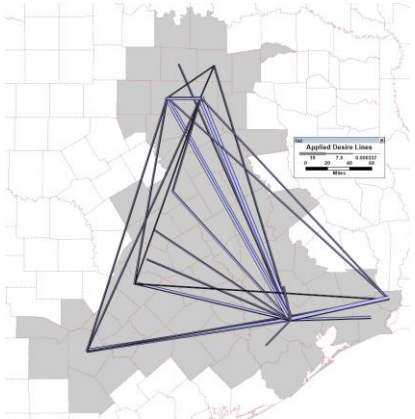
Agriculture



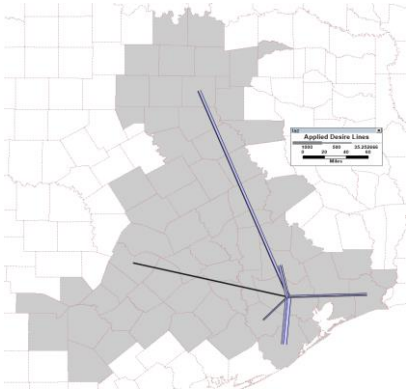
Coal



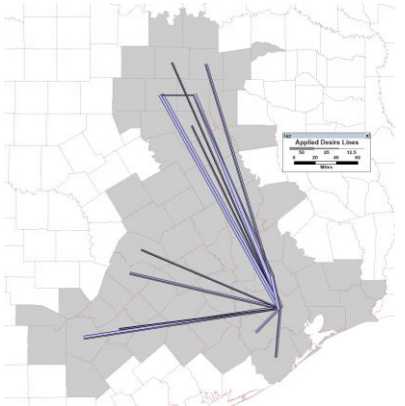
Nonmetallic Minerals



Paper



Chemicals

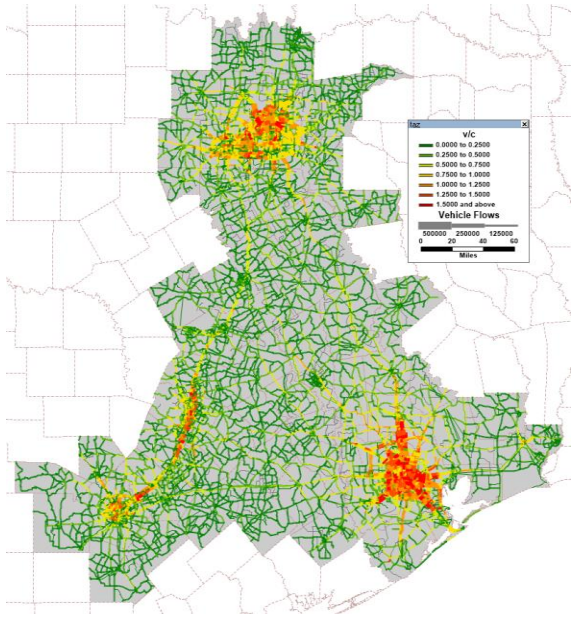


Primary Metals

# Network Congestion Results

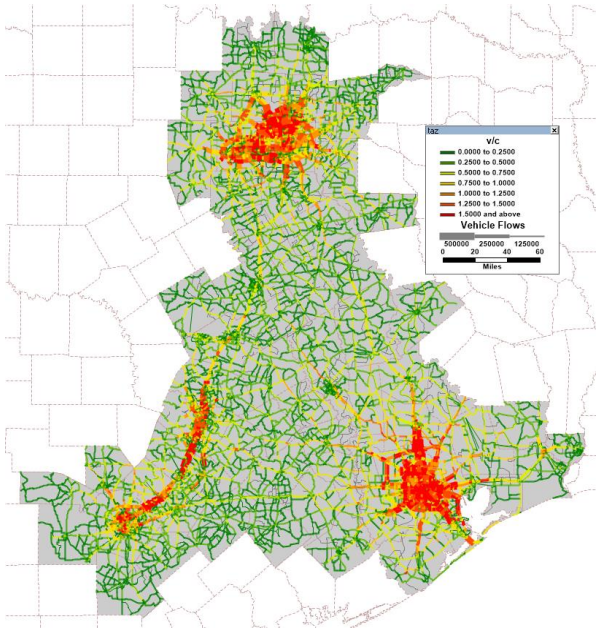
- **Traffic flows** (by line thickness) & **congestion levels** (volume-to-capacity ratios, by color)
- **92.3%** of the links experience higher flows in both directions

**Before AVs**




**V/C >1** on **4.9%** of 27,976 links

**After AVs**




V/C >1 on **9.9%** of links

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# AV Sensitivity Analysis Results

- **market penetration is in person-trips/day**

| Scenario | Base | 1 | 2 | 3* | 4 | 5 | 6 | 7* | 8 | 9 | 10 | 11 | 12* | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SCENARIO ASSUMPTIONS | AV & SAV VOTT ($/hr) | | | | | | Operating Cost ($/mile) | | | | Nesting Coefficients of Automobile Mode | | | | | |
| | N/A | 14.25 | 12.67 | 11.08 | 9.50 | 7.92 | AV | AV | AV | AV | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 | 1 |
| | Reduced VOTT (% less than original) | | | | | | 0.6 | 0.8 → | 1 | 1 | | | | | | |
| | 0 | 0.1 | 0.2 | 0.3 | 0.4 | 0.5 | SAV | SAV | SAV | SAV | | | | | | |
| | | | | | | | 0.6 | 1 | 1 → | 1.5 | | | | | | |
| Total VMT (Passenger + Freight) (Billion per day) | 1.4 B/day | 2.0 B/day | 2.012 | 2.030 | 2.051 | 2.086 | 2.088 | 2.012 → | 1.991 → | 1.990 | 2.152 | 2.012 | 1.894 | 1.793 | 1.707 | 1.632 |
| HV VMT (Billion per day) | 0.96 | 0.58 | 0.51 | 0.45 | 0.40 | 0.34 | 0.40 | 0.51 → | 0.51 → | 0.54 | 0.51 | 0.51 | 0.50 | 0.48 | 0.47 | 0.45 |
| AV VMT (Billion per day) | N/A | 0.67 | 0.74 | 0.81 | 0.87 | 0.94 | 0.58 | 0.74 → | 0.74 → | 0.78 | 0.85 | 0.74 | 0.67 | 0.61 | 0.56 | 0.52 |
| SAV VMT (Billion per day) | N/A | 0.13 | 0.14 | 0.14 | 0.15 | 0.16 | 0.46 | 0.14 → | 0.14 → | 0.06 | 0.11 | 0.14 | 0.16 | 0.17 | 0.19 | 0.20 |
| HV market penetration | 93.0 | 40.1 | 37.6 | 35.3 | 33.1 | 30.45 | 31.9 | 37.6 → | 37.7 → | 40.6 | 37.4 | 37.6 | 37.6 | 37.5 | 37.3 | 37.0 |
| AV market penetration | N/A | 41.4 | 43.5 | 45.6 | 47.5 | 49.84 | 36.5 | 43.5 → | 43.4 → | 46.7 | 45.5 | 43.5 | 42.0 | 40.8 | 39.9 | 39.1 |
| SAV market penetration | N/A | 16.2 | 16.6 | 17.0 | 17.4 | 17.81 | 29.4 | 16.6 → | 16.7 → | 10.5 | 14.4 | 16.6 | 18.5 | 20.1 | 21.4 | 22.6 |
| %Links with V/C > 1 | 4.60 | 9.60 | 9.78 | 9.94 | 10.20 | 10.60 | 10.63 | 9.78 → | 9.56 → | 9.55 | 11.47 | 9.78 | 8.56 | 7.83 | 7.19 | 6.64 |
| Maximum V/C | 3.22 | 4.05 | 4.07 | 4.07 | 4.09 | 4.12 | 4.13 | 4.06 → | 4.03 → | 4.04 | 4.21 | 4.06 | 3.88 | 3.73 | 3.61 | 3.49 |

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# Key Results

- Average **passenger-trip distance** across Texas Triangle **rises 14%**, from **14 to 16** miles.
- **Local Air travel** between Triangle airports expected **to fall dramatically**, by over **80%,** though just **4.3%** of all air trips in Texas.
- Without road pricing or other demand management, **VMT** predicted to **rise 47.2%**, along with links' V/C ratios, especially in the Triangle's biggest top sub-regions.
- The number of links having demand exceed capacity is predicted to **double.**
- Movements in **7** of **15 commodity** classes predicted to rise **>5%.**

# Future Work & Things to Try

- Reflect **dynamics of congestion** & use of **SAVs between drop-offs & pickups**
- Adjust **ASCs** in cases where AVs are introduced.
- Allow for **trips across U.S.-Mexico border.**
- Simulate SAVs serving as **first-mile & last-mile modes** in support of longer-distance travel (by trains, planes, & buses, for example).

# *Thank you!*

## *Questions & Suggestions?*

Paper at
www.caee.utexas.edu
prof/kockelman