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

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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
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

<table>
<thead>
<tr>
<th>Mode</th>
<th>Automobile (HVs, AVs, &amp; SAVs)</th>
<th>Bus</th>
<th>Rail</th>
<th>Air</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Trips before</strong></td>
<td>&lt; 50 miles (short-distance)</td>
<td>64,678 k/day</td>
<td>1,837 k/day</td>
<td>2,219 k/day</td>
</tr>
<tr>
<td><strong>Trips after</strong></td>
<td>75,088 k/day</td>
<td>623.8 k/day</td>
<td>642.3 k/day</td>
<td>N/A</td>
</tr>
<tr>
<td><strong>Change</strong></td>
<td>+16.1%</td>
<td>-66.1%</td>
<td>-71.1%</td>
<td>N/A</td>
</tr>
<tr>
<td><strong>Trips before</strong></td>
<td>&gt; 50 miles (long-distance)</td>
<td>2,946 k/day</td>
<td>33.64 k/day</td>
<td>988.2 k/day</td>
</tr>
<tr>
<td><strong>Trips after</strong></td>
<td>6171 k/day</td>
<td>2.416 k/day</td>
<td>595.7 k/day</td>
<td>2.497 k/day</td>
</tr>
<tr>
<td><strong>Change</strong></td>
<td>109.5%</td>
<td>-92.8%</td>
<td>-39.7%</td>
<td>-82.5%</td>
</tr>
<tr>
<td><strong>Total change</strong></td>
<td>+20.2%</td>
<td>-66.5%</td>
<td>-61.4%</td>
<td>-82.5%</td>
</tr>
</tbody>
</table>
## Freight Mode Splits

<table>
<thead>
<tr>
<th>Commodity</th>
<th>Mode Shares After Atrucks Introduced</th>
<th>Total Ton-mile (Billion)</th>
<th>Change from Base Case</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Atruck</td>
<td>Htruck</td>
<td>Truck</td>
</tr>
<tr>
<td>Agriculture</td>
<td>30.4%</td>
<td>52.6%</td>
<td>83.0%</td>
</tr>
<tr>
<td>Mining</td>
<td>37.1%</td>
<td>58.0%</td>
<td>95.1%</td>
</tr>
<tr>
<td>Coal</td>
<td>2.5%</td>
<td>3.5%</td>
<td>6.0%</td>
</tr>
<tr>
<td>Nonmetallic Minerals</td>
<td>26.6%</td>
<td>56.1%</td>
<td>82.7%</td>
</tr>
<tr>
<td>Food</td>
<td>34.5%</td>
<td>58.0%</td>
<td>92.4%</td>
</tr>
<tr>
<td>Consumer Manufacturing</td>
<td>38.6%</td>
<td>60.7%</td>
<td>99.2%</td>
</tr>
<tr>
<td>Non-Durable Manufacturing</td>
<td>35.9%</td>
<td>63.7%</td>
<td>99.6%</td>
</tr>
<tr>
<td>Lumber</td>
<td>36.3%</td>
<td>61.2%</td>
<td>97.5%</td>
</tr>
<tr>
<td>Durable Manufacturing</td>
<td><strong>48.1%</strong></td>
<td><strong>38.4%</strong></td>
<td><strong>86.5%</strong></td>
</tr>
<tr>
<td>Paper</td>
<td>33.8%</td>
<td>54.5%</td>
<td>88.3%</td>
</tr>
<tr>
<td>Chemicals</td>
<td>30.6%</td>
<td>46.6%</td>
<td>77.2%</td>
</tr>
<tr>
<td>Petroleum</td>
<td>30.6%</td>
<td>62.9%</td>
<td>93.5%</td>
</tr>
<tr>
<td>Clay, Concrete, Glass</td>
<td>34.3%</td>
<td>60.5%</td>
<td>94.8%</td>
</tr>
<tr>
<td>Primary Metal</td>
<td>34.2%</td>
<td>47.7%</td>
<td>81.9%</td>
</tr>
<tr>
<td>Secondary &amp; Misc. Mixed</td>
<td>36.6%</td>
<td>61.7%</td>
<td>98.3%</td>
</tr>
</tbody>
</table>
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.

<table>
<thead>
<tr>
<th>VMT (1M mi per day)</th>
<th>Automobile</th>
<th>Rail</th>
<th>Bus</th>
<th>Air</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before</td>
<td>955.2M mi/day</td>
<td>19.4M mi/day</td>
<td>114.1M mi/day</td>
<td>2.0M mi/day</td>
</tr>
<tr>
<td>After</td>
<td>1400.9</td>
<td>4.5</td>
<td>57.3</td>
<td>0.3</td>
</tr>
<tr>
<td>Change</td>
<td>+46.7%</td>
<td>-77.1%</td>
<td>-49.8%</td>
<td>-84.6%</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th></th>
<th>Automobile VMT before AV (1M per day)</th>
<th>Automobile VMT after AV (1M per day)</th>
<th>Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dallas-Fort Worth</td>
<td>453M miles</td>
<td>669M miles</td>
<td>+47.7%</td>
</tr>
<tr>
<td>San Antonio Region</td>
<td>118</td>
<td>171</td>
<td>+45.8%</td>
</tr>
<tr>
<td>Austin Region</td>
<td>119</td>
<td>186</td>
<td>+56.9%</td>
</tr>
<tr>
<td>Houston Region</td>
<td>432</td>
<td>587</td>
<td>+36.0%</td>
</tr>
<tr>
<td>Total Megaregion</td>
<td>1,367</td>
<td>2,012</td>
<td>+47.2%</td>
</tr>
</tbody>
</table>

- **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
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

After AVs

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

V/C >1 on **9.9%** of links
# AV Sensitivity Analysis Results

- **Scenario**
  - 1
  - 2
  - 3
  - 4
  - 5
  - 6
  - 7
  - 8
  - 9
  - 10
  - 11
  - 12
  - 13
  - 14
  - 15

<table>
<thead>
<tr>
<th>Scenario Assumptions</th>
<th>Base</th>
<th>1</th>
<th>2</th>
<th>3*</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7*</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12*</th>
<th>13</th>
<th>14</th>
<th>15</th>
</tr>
</thead>
<tbody>
<tr>
<td>HV VMT (Billion per day)</td>
<td>0.96</td>
<td>0.58</td>
<td>0.51</td>
<td>0.45</td>
<td>0.40</td>
<td>0.34</td>
<td>0.40</td>
<td>0.51</td>
<td>0.51</td>
<td>0.54</td>
<td>0.51</td>
<td>0.51</td>
<td>0.50</td>
<td>0.48</td>
<td>0.47</td>
<td>0.45</td>
</tr>
<tr>
<td>AV VMT (Billion per day)</td>
<td>N/A</td>
<td>0.67</td>
<td>0.74</td>
<td>0.81</td>
<td>0.87</td>
<td>0.94</td>
<td>0.58</td>
<td>0.74</td>
<td>0.74</td>
<td>0.75</td>
<td>0.85</td>
<td>0.74</td>
<td>0.67</td>
<td>0.61</td>
<td>0.56</td>
<td>0.52</td>
</tr>
<tr>
<td>SAV VMT (Billion per day)</td>
<td>N/A</td>
<td>0.13</td>
<td>0.14</td>
<td>0.14</td>
<td>0.15</td>
<td>0.16</td>
<td>0.14</td>
<td>0.14</td>
<td>0.14</td>
<td>0.16</td>
<td>0.11</td>
<td>0.14</td>
<td>0.16</td>
<td>0.17</td>
<td>0.19</td>
<td>0.20</td>
</tr>
<tr>
<td>HV market penetration</td>
<td>93.0</td>
<td>40.1</td>
<td>37.6</td>
<td>35.3</td>
<td>33.1</td>
<td>30.45</td>
<td>31.9</td>
<td>37.6</td>
<td>37.7</td>
<td>40.6</td>
<td>37.4</td>
<td>37.6</td>
<td>37.6</td>
<td>37.5</td>
<td>37.3</td>
<td>37.0</td>
</tr>
<tr>
<td>AV market penetration</td>
<td>N/A</td>
<td>41.4</td>
<td>43.5</td>
<td>45.6</td>
<td>47.5</td>
<td>49.84</td>
<td>36.5</td>
<td>43.5</td>
<td>43.4</td>
<td>46.7</td>
<td>45.5</td>
<td>43.5</td>
<td>42.0</td>
<td>40.8</td>
<td>39.9</td>
<td>39.1</td>
</tr>
<tr>
<td>SAV market penetration</td>
<td>N/A</td>
<td>16.2</td>
<td>16.6</td>
<td>17.0</td>
<td>17.4</td>
<td>17.81</td>
<td>29.4</td>
<td>16.6</td>
<td>16.7</td>
<td>10.5</td>
<td>14.4</td>
<td>16.6</td>
<td>18.5</td>
<td>20.1</td>
<td>21.4</td>
<td>22.6</td>
</tr>
<tr>
<td>Maximum V/C</td>
<td>3.22</td>
<td>4.05</td>
<td>4.07</td>
<td>4.07</td>
<td>4.09</td>
<td>4.12</td>
<td>4.13</td>
<td>4.06</td>
<td>4.03</td>
<td>4.04</td>
<td>4.21</td>
<td>4.06</td>
<td>3.88</td>
<td>3.73</td>
<td>3.61</td>
<td>3.49</td>
</tr>
</tbody>
</table>

- **AV & SAV VOTT ($/hr)**
  - N/A
  - 14.25
  - 12.67
  - 11.08
  - 9.50
  - 7.92

- **Operating Cost ($/mile)**
  - AV
  - AV
  - AV
  - AV

- **Nesting Coefficients of Automobile Mode**
  - 0.5
  - 0.6
  - 0.7
  - 0.8
  - 0.9
  - 1

- **Reduced VOTT (% less than original)**
  - 0.6
  - 0.8
  - 1

- **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
  - 1.991
  - 1.990
  - 2.088
  - 2.012
  - 1.991
  - 1.990
  - 2.152

- **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
  - 0.75
  - 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
  - 0.14
  - 0.14
  - 0.14
  - 0.16
  - 0.11
  - 0.14
  - 0.16
  - 0.17
  - 0.19
  - 0.20

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