Mobility and Energy Impacts of Automated Cars

Analysis using MTC Travel Model One

Michael Gucwa - mgucwa@stanford.edu

2014 Automated Vehicle Symposium
Research Question

How will automation change the daily travel decisions of individuals and alter overall vehicle miles traveled and energy use?

What is the magnitude of the rebound effect from the reduce generalized cost of travel?
Scope of analysis

● Advanced Level 3 automation
  ○ Vehicles must have driver present, but intervention rare

● Urban travel
  ○ Do not consider impacts on intercity travel

● Status quo for vehicle ownership and form
  ○ No shared economy or drastic changes to vehicle design
### Potential energy pathways

<table>
<thead>
<tr>
<th>Transportation &amp; Land-Use System</th>
<th>Individual Economic Decisions</th>
<th>Energy, Economic, &amp; Environmental Impacts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vehicle Design</td>
<td>Location Choice</td>
<td>Mobility Demand</td>
</tr>
<tr>
<td>- size</td>
<td>Auto Ownership</td>
<td>X</td>
</tr>
<tr>
<td>- performance</td>
<td>Activity Plan</td>
<td>Energy Intensity</td>
</tr>
<tr>
<td>- fuel</td>
<td>Tours / Trip Plan</td>
<td>↓</td>
</tr>
<tr>
<td>Transportation System</td>
<td>Time of Day</td>
<td>Energy Consumption</td>
</tr>
<tr>
<td>- available modes</td>
<td>Mode Choice</td>
<td>X</td>
</tr>
<tr>
<td>- capacity</td>
<td>Route Choice</td>
<td>Fuel Choice &amp; Intensity</td>
</tr>
<tr>
<td>- generalized costs of travel</td>
<td>Vehicle Operation</td>
<td>Emissions &amp; Impacts</td>
</tr>
<tr>
<td>Land Use</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- real estate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- local regulation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- spatial distribution</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## Research Focus

<table>
<thead>
<tr>
<th>Transportation &amp; Land-Use System</th>
<th>Individual Economic Decisions</th>
<th>Energy and Environmental Consequences</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vehicle Design</td>
<td>Location Choice</td>
<td>Mobility Demand</td>
</tr>
<tr>
<td>- size</td>
<td>Auto Ownership</td>
<td></td>
</tr>
<tr>
<td>- performance</td>
<td>Activity Plan</td>
<td></td>
</tr>
<tr>
<td>- fuel</td>
<td>Tours / Trip Plan</td>
<td></td>
</tr>
<tr>
<td>Transportation System</td>
<td>Time of Day</td>
<td></td>
</tr>
<tr>
<td>- available modes</td>
<td>Mode Choice</td>
<td></td>
</tr>
<tr>
<td>- capacity</td>
<td>Route Choice</td>
<td></td>
</tr>
<tr>
<td>- generalized costs of travel</td>
<td>Vehicle Operation</td>
<td>in Emissions &amp; Impacts</td>
</tr>
<tr>
<td>Land Use</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- real estate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- local regulation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- spatial distribution</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Emissions & Impacts**

- Energy Intensity
- Energy Consumption
- Fuel Choice & Intensity
- Mobility Demand
Methodology

● Model automated vehicle scenarios using San Francisco’s Metropolitan Commission’s *Travel Model One*

● Simulate the microeconomic travel decisions for every person in the 9 county San Francisco Bay Area

● Use activity-based model approach (ABA)

● Each decision follows a random utility model
Brief Discussion of Transport Models

Four Stage Models (FSM)

Activity-Based Approach (ABA)

$F_{a,b} = 1000$

$F_{b,a} = 2500$

Zones, Aggregates, Physics

Individuals, Activities, Microeconomics
Travel Model One Logical Overview

1. Population Synthesizer
   - Economic starting conditions

2. Network Warm Start
   - Transport system starting conditions

3. CT-RAMP
   - Individual level microeconomic decisions

4. Citilabs Cube
   - Transportation network model

Loop for convergence: 3+ iterations

Output Processing: Cube, EMFAC, SAS, Excel, R
CT-RAMP Schematic

1. Population Synthesizer
2. Long-term Decisions
   - Usual work and school location
   - Automobile Ownership
   - Free Parking Eligibility
3. Daily Decisions
   - Coordinated Daily Activity Pattern
   - Mandatory
   - Non-Mandatory
   - Home
   - Available time budget
   a. Individual mandatory tours
      - Frequency
      - Scheduling
   b. Joint non-mandatory tours
      - Frequency
      - Party size
      - Participation
      - Location
      - Scheduling
   c. Individual non-mandatory tours
      - Frequency
      - Location
      - Scheduling
   d. At-work sub-tours
      - Frequency
      - Location
      - Scheduling
4. Tour-level Decisions
   - Tour mode
   - Stop frequency
   - Stop location
5. Trip-level Decisions
   - Departure time
   - Trip mode
Random Utility Model

\[ U_{i,j} = V_{i,j}(X_{i,j} | \beta_{i,j}) + \epsilon_{i,j} \]

- Person \( i \) is choosing among discrete alternatives \( J \) (do I drive or walk)
- \( V \) is the deterministic (or representative) utility
- \( X \) is the observable factors (individual and alternative attributes)
- \( \beta \) estimated (or assumed) coefficient parameters.
- \( \epsilon_{i,j} \) - A random term to capture the effect of unobserved attributes and the idiosyncratic preference person \( i \) has for alternative \( j \)
Model Modifications

- Create scenarios on two primary dimensions:
  1. Value of in-vehicle time
  2. Roadway capacity

- Value of time
  - \( V_{i,o,d,m} = c_{\text{ivt}} m \cdot \text{ivt}_{o,d,m} + c_{\text{cost}} m \cdot \text{cost}_{o,d,m} + \text{(other terms)} \)
  - \( i = \) person, \( o = \) origin, \( d = \) destination, \( m = \) travel mode
  - \( c_{\text{ivt}} = \) utility coefficient on travel time, \( \text{ivt} = \) travel time, \( c_{\text{cost}} = \) utility coefficient on \$ \ costs, \( \text{cost} = \$ \)
  - We change the coefficient for automated vehicles
  - Affects dozens of decisions for each of millions of individuals

- Capacity
  - Change capacity / speed relationship in Citilabs transport network representation
## Scenarios

<table>
<thead>
<tr>
<th>Model scenarios considered</th>
<th>Roadway Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(B) - Base</td>
</tr>
<tr>
<td></td>
<td>Base + 10%</td>
</tr>
<tr>
<td>(B) - Base</td>
<td>BB</td>
</tr>
<tr>
<td>(H) - High quality rail</td>
<td>-</td>
</tr>
<tr>
<td>(L) - ½ current car</td>
<td>-</td>
</tr>
<tr>
<td>(0) - Zero time cost</td>
<td>0B</td>
</tr>
</tbody>
</table>

**In Vehicle Value of Time**
Results

- With automation can expect a short-run increase of 4-8% in daily vehicle miles travelled

<table>
<thead>
<tr>
<th>Vehicle Miles Traveled</th>
<th>Roadway Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Change from Base Case</td>
<td>Base (B)</td>
</tr>
<tr>
<td>(B) Base</td>
<td>0%</td>
</tr>
<tr>
<td>(H) High quality rail</td>
<td>-</td>
</tr>
<tr>
<td>(L) ½ current car</td>
<td>-</td>
</tr>
<tr>
<td>(0) Zero time cost</td>
<td>+13.2%</td>
</tr>
</tbody>
</table>
The unanswered questions...

- Long-term land-use adjustments
- Welfare and equity
- The role of policy
- Level 4 and shared economy (robotaxis)
Thank you!

mgucwa@stanford.edu