VTO SYSTEMS-LEVEL R&D

SINGLE COMPONENT

SINGLE VEHICLE

SMALL NETWORK

TRAFFIC FLOW

ENTIRE URBAN AREA
The SMART Mobility Consortium is a multi-year, multi-laboratory collaborative dedicated to further understanding the energy implications and opportunities of advanced mobility solutions.
FIVE RESEARCH FOCUS AREAS

CONNECTED AND AUTOMATED VEHICLES
Identifying the energy, technology, and usage implications of connectivity and automation and identifying efficient CAV solutions.

MOBILITY DECISION SCIENCE
Understanding the human role in the mobility system including travel decision-making and technology adoption in the context of future mobility.

MULTI-MODAL FREIGHT
Evaluating the evolution of freight movement and understanding the impacts of new modes for long-distance goods transport and last-mile package delivery.

URBAN SCIENCE
Understanding the linkages between transportation networks and the built environment and identifying the potential to enhance access to economic opportunity.

ADVANCED FUELING INFRASTRUCTURE
Understanding the costs, benefits, and requirements for fueling/charging infrastructure to support energy efficient future mobility systems.
TRANSPORTATION IS A SYSTEM OF SYSTEMS
Mobility

The quality of a network or system to connect people to goods, services, and employment that define a high quality of life.
WHOLETRAVELER STUDY & MOBILITY DATA ANALYSIS

- Mode Choice
- Technology Adoption
- Vehicle Dependence
- EV Penetration
- Ride-Hailing
- E-Commerce
By creating a multi-fidelity end-to-end modeling workflow, SMART Mobility researchers advanced the state-of-the-art in transportation system modeling and simulation.
MOVING PEOPLE IN A SMART MOBILITY SYSTEM
MOVING PEOPLE IN A SMART MOBILITY SYSTEM

C. ANNA SPURLOCK
Lawrence Berkeley National Laboratory

JOSH AULD
Argonne National Laboratory
Examined the underlying...

Critical drivers of…
Critical barriers to…

adoption and use of emerging transportation technologies and services.

What does this mean for system outcomes?
A diverse set of research approaches tackling a range of topics

Mobility Decision Science Pillar

WholeTraveler Transportation Behavior Study

Data Collection and Analysis

Transportation Behavior and Life Context

Behavior, Energy, Autonomy, and Mobility Model (BEAM)

Agent-Based Transportation System Simulation

Agent-Based Transportation System Simulation

Ride-Hailing Impact & VOTT and Time-Use Analyses

Self-contained analyses

Psychological and Identity Affecting Transportation Preferences

E-commerce Use and Impact on Shopping Travel

Impact of Ride-hailing on The Transportation System
BEHAVIORAL FINDINGS THROUGH SURVEY AND DATA ANALYSIS
AGE AND MODE CHOICE/TECHNOLOGY ADOPTION

MDS researchers filled gaps in the literature

Spurlock et al. (2019)
VEHICLE TECHNOLOGY PREFERENCES OF OLDER GENERATIONS MATTER FOR ENERGY

Vehicle-dependence increases with age
CRITICAL DRIVERS OF VEHICLE DEPENDENCE

Lifecycle patterns evolve..

SAN FRANCISCO

Jin et al. (2020)
CRITICAL DRIVERS OF VEHICLE DEPENDENCE

Timing and order of life events impact on mode use

“Have-it-all” cohort: ramps up car use at each lifecycle transition, resulting in highest rate of car use occurring earliest of all cohorts, and persisting.

Jin et al. (2020)
CRITICAL DRIVERS OF VEHICLE DEPENDENCE

When women “have it all” they rely more on vehicles

SAN FRANCISCO

When preparing for/having children Have-it-all women, more than men:
• Engage in more family-member transportation responsibilities
• Use public transit even less
• Move to public transit poor areas more
• Drive even more
• Live in households with more vehicles
• Live in households with bigger (SUV) vehicles
What underlying factors drive this gender gap?

**Risk preferences?**
- Monetary
- Safety
- Travel time certainty

**Personality characteristics?**
- Openness
- Agreeableness
- Extraversion
- Neuroticism
- Conscientiousness

**Willingness or ability to pay?**
- Income

**Transportation needs?**
- Moving people/stuff
- Commute habits

**Environmental attitudes?**
BARRIERS TO ELECTRIC VEHICLE ADOPTION

All included factors included explain 35% of the gender gap

SAN FRANCISCO

• If women had the same income on average as men, the gender gap would be smaller by 10%
• If women had the same responsibility for transporting family members, cargo space and vehicle capacity needs, and errand-running needs as men, the gender gap would be smaller by 15%
 Behavior of ride-hail drivers has an impact

Especially in urban areas with:
- lower per-capita vehicle ownership and
- high rates of economic growth,

ride-hailing entering the market has increased the number of vehicle registrations by 0.7% on average

Though with notable heterogeneity between urban areas.
Behavior of ride-hail drivers has an impact

In the case of RideAustin, due to:
- commuting relatively long distances
- driving to reposition their vehicle between ride-hail trips

increase system-wide energy consumption by 41-90%, depending on assumptions about pooling and modal shift.

Wenzel at al. (2019)
E-COMMERCE AND DELIVERY IMPACT ON SYSTEM ENERGY USE

Deliveries substitute for, and are in addition to, shopping trips

SAN FRANCISCO

- Pre-COVID e-commerce and delivery context
- A typical week of shopping events by item type and mode
  - Very little grocery delivery
  - Proportionally most delivery of clothes and household items

Spurlock et al. (2020)
In a typical week, a given delivery is about 1.7 times as likely to substitute for a shopping trip than not; of those that substitute, a given delivery is 300% more likely to substitute for a vehicle trip than a non-vehicle trip. A given delivery is 1.3 times as likely to replace a household vehicle shopping trip than add on to existing trips.

Spurlock et al. (2020)
BEHAVIORAL FINDINGS THROUGH SIMULATION MODELING

POLARIS

BEAM
BEHAVIORAL RESEARCH IMPROVES AND EXTENDS THE SMART MOBILITY WORKFLOW

Findings from surveys, data, simulation, etc. used to develop models

- Substantial research on a broad range of demand behaviors led to many new models
- Incorporated in SMART Workflow and impacts evaluated
- Evaluation of sensitivity of overall model to each component were performed
- Key findings published in multiple journal articles
**BEHAVIOR MODELING HIGHLIGHTS**

*VOTT and Time use (Krueger et al 2019, Enam et al 2019)*
- Incorporate data from multiple sources (HH survey, time use surveys, transit surveys)
- Used integrated choice and latent variable model framework to quantify VOTT while multitasking
- Significant variation found in VOT from different data sources
- Ability to multitask encourages use of non-drive modes & reduces VOT

*Mode and Timing Choice (Golshani et al 2018)*
- Mode modeled using Chicago Household travel survey using NL model
- Value of in-vehicle time varies substantially by mode and activity
- Start time and duration modeled jointly
- Depends on activity purpose, expected travel time, and travel time variability

*AV Sharing in Households (Auld et al 2019)*
- Intra-household Level AV sharing; with reposition between HH members and park at home
- Allow HH member to shift flexible activities and share rides to minimize cost
- Implemented in external optimizer

*E-Commerce (Stinson et al 2019)*
- Uses WholeTraveler; quantifies HH participation in e-commerce
- Displacement of physical shopping trips by deliveries
- Dependent on income, # of vehicles, location, transit and access to retail
SCENARIOS CONSIDERED

A world of

HIGH SHARING, PARTIAL AUTOMATION (Sharing)

New technology enables people to significantly increase the use of transit, ride-hailing and multi-modal travel. Partial automation is introduced and is primarily used on the highway.

HIGH SHARING, HIGH AUTOMATION (SAV)

Technology has taken over our lives, enabling high usage of fully automated driverless vehicles, ride-hailing and multi-modal trips, which are convenient and inexpensive. As a result, private ownership has decreased and e-commerce has increased.

LOW SHARING, HIGH AUTOMATION (Private-AV)

Fully automated privately owned driverless vehicles dominate the market. The ability to own AVs leads to low ride-sharing and an expansion of urban/sub-urban boundaries, while e-commerce has increased.
INDIVIDUAL TRAVEL BEHAVIOR CHANGES
DRIVE MOBILITY OUTCOMES

- Transit use grows from 6% to 12% mode share as HH dispose vehicles
- Private-AV encourage additional SOV trips
- Urban households shift to transit, suburban shift to TNC if disposing vehicle

Mode share substantially changes:

<table>
<thead>
<tr>
<th>Mode</th>
<th>Bus</th>
<th>Rail</th>
<th>SOV</th>
<th>HOV</th>
<th>AV</th>
<th>TNC</th>
<th>TNC Pool</th>
<th>Bike</th>
<th>Walk</th>
</tr>
</thead>
<tbody>
<tr>
<td>BASE</td>
<td>65%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HIGH SHARING PARTIAL AUTOMATION</td>
<td>3%</td>
<td>3%</td>
<td>13%</td>
<td>11%</td>
<td>7%</td>
<td>5%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HIGH SHARING HIGH AUTOMATION</td>
<td>3%</td>
<td>4%</td>
<td>14%</td>
<td>15%</td>
<td>12%</td>
<td>10%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LOW SHARING HIGH AUTOMATION</td>
<td>3%</td>
<td>4%</td>
<td>17%</td>
<td>21%</td>
<td>12%</td>
<td>10%</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Legend:
- Bus
- Rail
- SOV
- HOV
- AV
- TNC
- TNC Pool
- Bike
- Walk
LOWER VOTT HAS GREATER IMPACT IN LOW-DENSITY ACTIVITY AREAS

Sensitivity of urban residents to VOTT is low

VOTT: Value of Travel Time
Monetary cost I would be willing to pay to avoid an hour of travel; differs by mode, income, location

CHICAGO

When VOTT is reduced by 50%...

AVERAGE INCREASE OF 14 VMT PER CAPITA IN CORE SUBURBAN AREAS (52% INCREASE)

AVERAGE INCREASE OF 5 VMT PER CAPITA DOWNTOWN (38% INCREASE)
AUTOMATED VEHICLES HAVE MAJOR EFFECT ON TRAVEL BEHAVIOR

CHICAGO

Low Sharing / High Automation

Increase in travel metric for households with an AV versus those without

- PMT: 57%
- PHT: 40%
- VMT: 82%
HOUSEHOLDS WITH AV BEHAVE MUCH DIFFERENTLY

Up to 82% VMT increase in households owning an AV

- Discretionary activity trips 3–6 miles longer (+30%)
- Additional trips concentrated in PM peak
- Persons with AV spend up to 30 minutes more in travel per day

Driven by increased travel to discretionary activities

Per capita PMT

<table>
<thead>
<tr>
<th></th>
<th>No AV</th>
<th>Partial AV</th>
<th>Full AV</th>
</tr>
</thead>
<tbody>
<tr>
<td>EAT OUT</td>
<td>4.3</td>
<td>2.9</td>
<td>4.4</td>
</tr>
<tr>
<td>ERRANDS</td>
<td>4.5</td>
<td>3.2</td>
<td>4.1</td>
</tr>
<tr>
<td>LEISURE</td>
<td>4.1</td>
<td>2.9</td>
<td>4.4</td>
</tr>
<tr>
<td>PERSONAL</td>
<td>6.0</td>
<td>3.2</td>
<td>4.1</td>
</tr>
<tr>
<td>SHOP</td>
<td>1.2</td>
<td>-0.1</td>
<td>1.2</td>
</tr>
<tr>
<td>SOCIAL</td>
<td>0.0</td>
<td>-1.0</td>
<td>0.0</td>
</tr>
<tr>
<td>WORK</td>
<td>6.0</td>
<td>-0.1</td>
<td>0.0</td>
</tr>
<tr>
<td>SCHOOL</td>
<td>-0.1</td>
<td>-1.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>

Per capita VMT

- Households with AV drive more than others

Chicago
LOWER SUBJECTIVE TRAVEL COSTS AFFECT DEMAND FOR LAND OUTSIDE THE URBAN CORE
High accessibility via lower travel costs can induce sprawl

San Francisco

- All scenarios increase accessibility
- More demand to shift residence and businesses further from the urban core
- This was most prevalent in the high-sharing with high-automation scenario
  - lowest generalized travel cost
  - people willing to travel further
  - highest increase in land values further from CBD

More jobs reachable within 45 minutes from a location with the same job density
TRANSIT IS CRITICAL TO MOBILITY

Absent transit, energy use and congestion increase

CITY OF CHICAGO WITHOUT TRANSIT SYSTEM

29% Energy
37% VMT
52% VHT
10% Speed

Transit link type
- SSL Rail
- Halto Rail
- CTA Rail

Change in AM avg. link speed
- < 50%
- 50% to 10%
- 10% to 30%
- 30% to 50%
- > 50%

CHICAGO
TRANSIT AND RIDE-HAIL CAN BE COMPLEMENTARY

Transit provides key mobility in city, TNC serves suburbs

- Transit ridership grows as vehicle disposal rate increases
- Increase in transit along hub and spoke lines, even as TNC increases
- Limited increase in TNC use in high-quality transit areas
INTEGRATING TNC WITH TRANSIT CAN PRODUCE SYSTEM BENEFITS

BLOOMINGTON, IL

- Study of integrated first-mile/last-mile with transit
- TNC trips to stops included in transit fare
- Transit use is low in baseline (1.3%), increases by 11% when first/last mile included
- Adding 4k TNC VMT reduces total VMT by 33k and energy use by 1.1%

<table>
<thead>
<tr>
<th>Total VMT</th>
<th>TNC-to-transit VMT</th>
<th>Transit mode %</th>
<th>Total fuel (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>2,265,786</td>
<td>1,805</td>
<td>1.30%</td>
</tr>
<tr>
<td>TNC access</td>
<td>2,232,961</td>
<td>5,737</td>
<td>1.50%</td>
</tr>
<tr>
<td>% change</td>
<td>-1.40%</td>
<td>217.80%</td>
<td>10.90%</td>
</tr>
</tbody>
</table>
REDUCING RIDE-HAIL USAGE EFFECTS TRANSIT RIDERSHIP AND TOTAL ENERGY

- Reduced ride-hail results in lower use of transit and higher use of personal vehicles
- High reduction in ride-hail interest increases system energy consumption by 6.6%
- Although ride-hailing trips can produce more VMT than car trips, this can be offset by the lower total VMT of ride-hail to transit trips
INCREASE IN E-COMMERCE LOWERS OVERALL SYSTEM VMT AND ENERGY
Fewer shopping trips, more deliveries

CHICAGO

SHOPPING TRIP = 7 to 8 miles, one way

DELIVERY TRIP

1 ADDED STOP = 0.4 mile
UNDERSTANDING OF MOTIVATIONS AND CONSTRAINTS → REALISTIC SCENARIOS

People make the choices they make for a reason

- In SMART we looked at limited set of edge case scenarios, some of which assume relatively high willingness to use certain modes or technologies, such as shared ride-hail.
- Results from MDS demonstrate the extent to which people might face constraints, given their context or life choices, limiting their ability to adopt some of these alternatives.
- Understanding of these constraints can inform which scenarios are realistic and why.
- The simulation analyses underscore why this deeper understanding matters for system wide outcomes.
REFERENCES


MOBILITY FOR OPPORTUNITY

FOR MORE INFORMATION

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