NOVEMBER 19, 2020

U.S. DEPARTMENT OF ENERGY SMARTMOBILITY

Systems and Modeling for Accelerated Research in Transportation

MOVING PEOPLE IN A SMART MOBILITY SYSTEM

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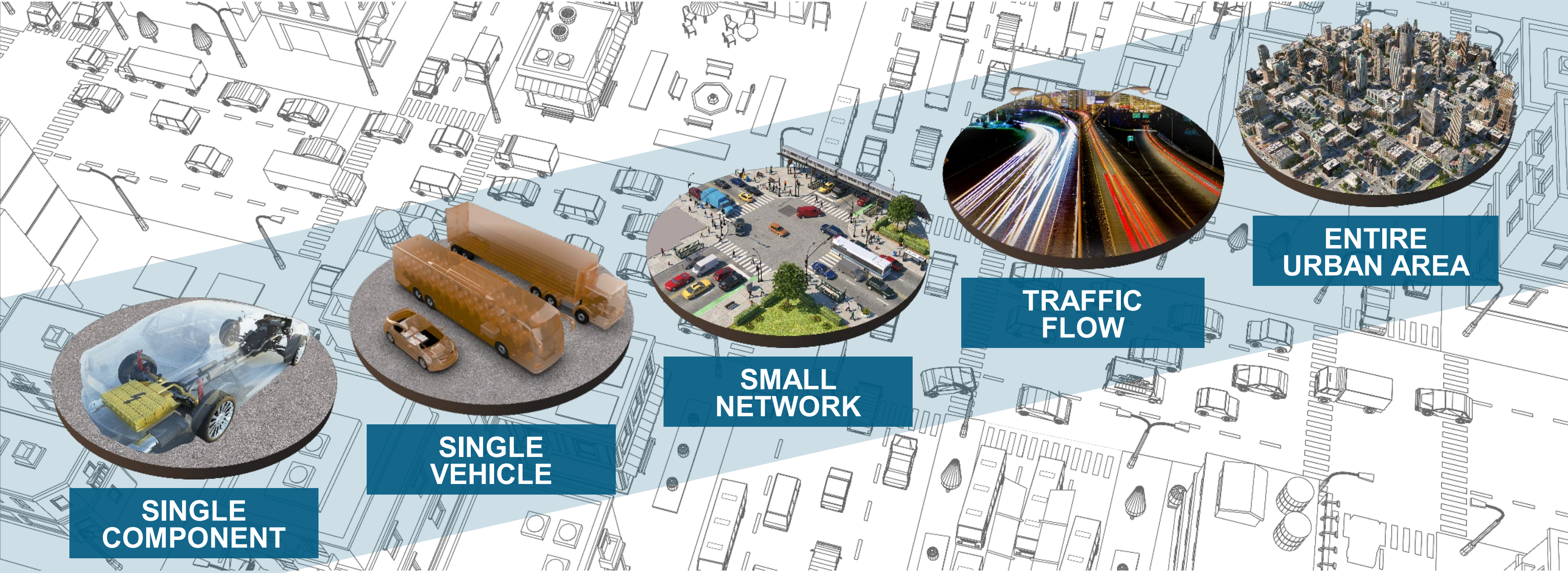
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Argonne NATIONAL LABORATORY · BERKELEY LAB · INL Idaho National Laboratory · NREL NATIONAL RENEWABLE ENERGY LABORATORY · OAK RIDGE National Laboratory

VTO SYSTEMS-LEVEL R&D



SMART MOBILITY CONSORTIUM

The SMART Mobility Consortium is a multi-year, multi-laboratory collaborative dedicated to further understanding the energy implications and opportunities of advanced mobility solutions.

Argonne NATIONAL LABORATORY

BERKELEY LAB

INL Idaho National Laboratory

NREL NATIONAL RENEWABLE ENERGY LABORATORY

OAK RIDGE National Laboratory

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.

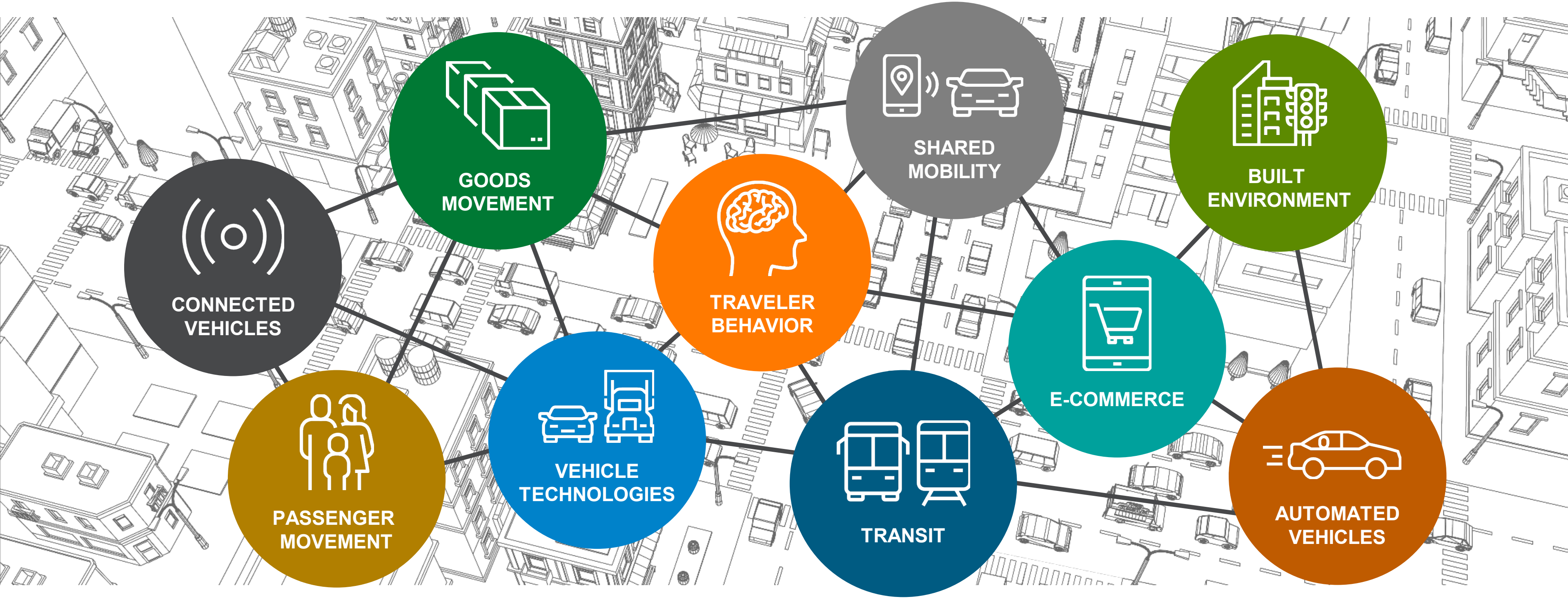
URBAN SCIENCE

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



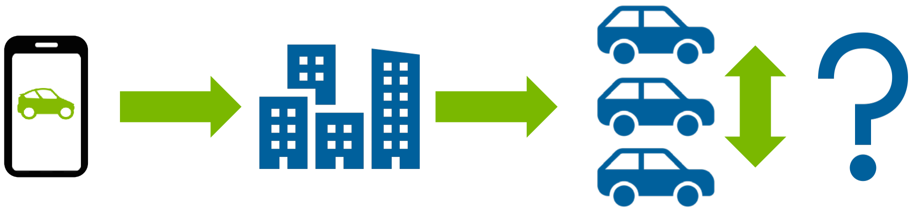
Mobility

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

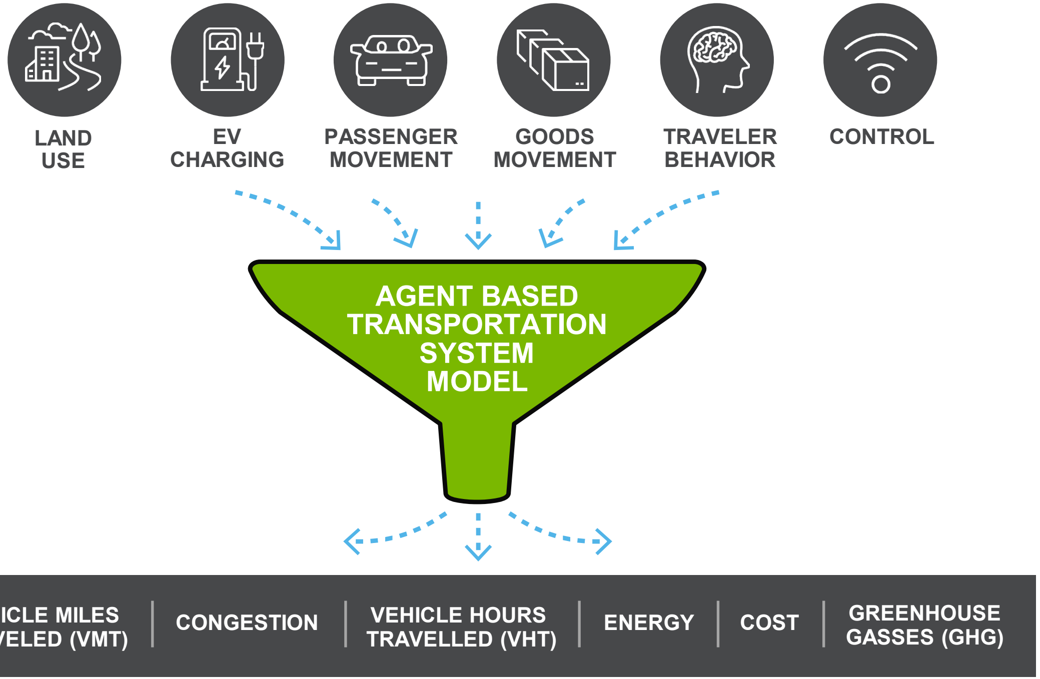
- Mode Choice
- Technology Adoption
- Vehicle Dependence
- EV Penetration
- Ride-Hailing
- E-Commerce

WholeTraveler
TRANSPORTATION BEHAVIOR STUDY

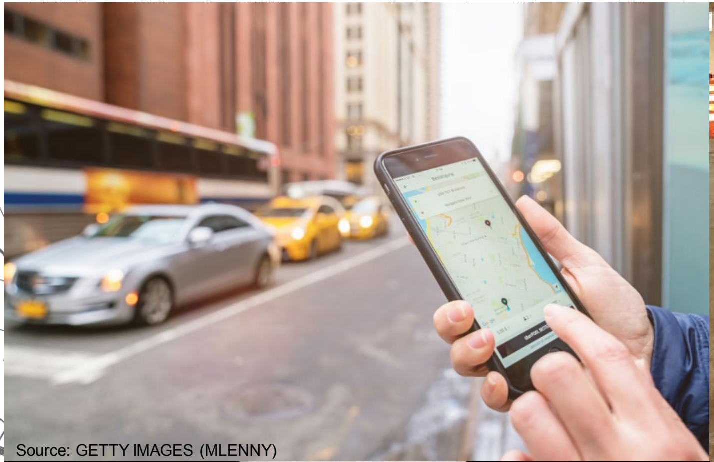


SMART MOBILITY MODELING WORKFLOW

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.

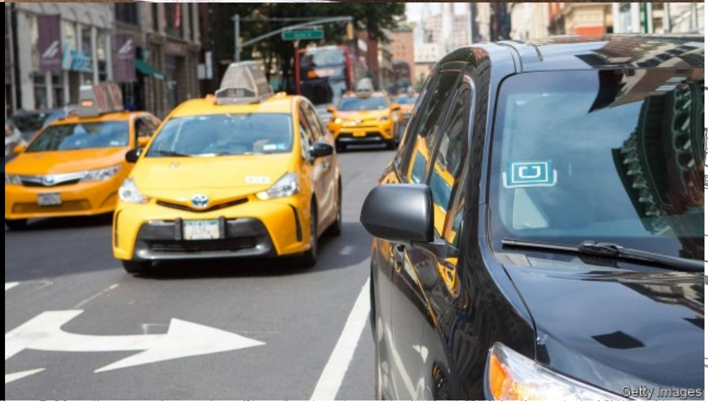


Source: Ford Motor Company


Source: GETTY IMAGES (MLENNY)

Source: Airportimprovement.com

Source: David Goldman/AP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MOBILITY FOR OPPORTUNITY

FOR MORE INFORMATION

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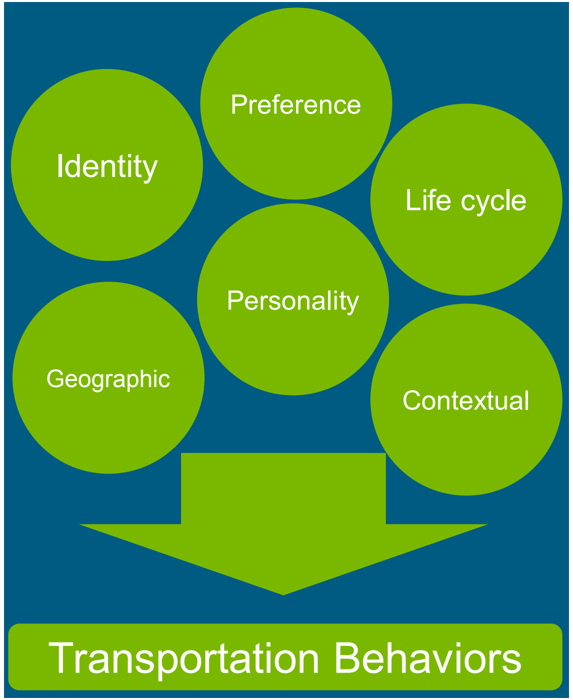
MOBILITY DECISION SCIENCE PILLAR

Examined the underlying…



Critical drivers of…

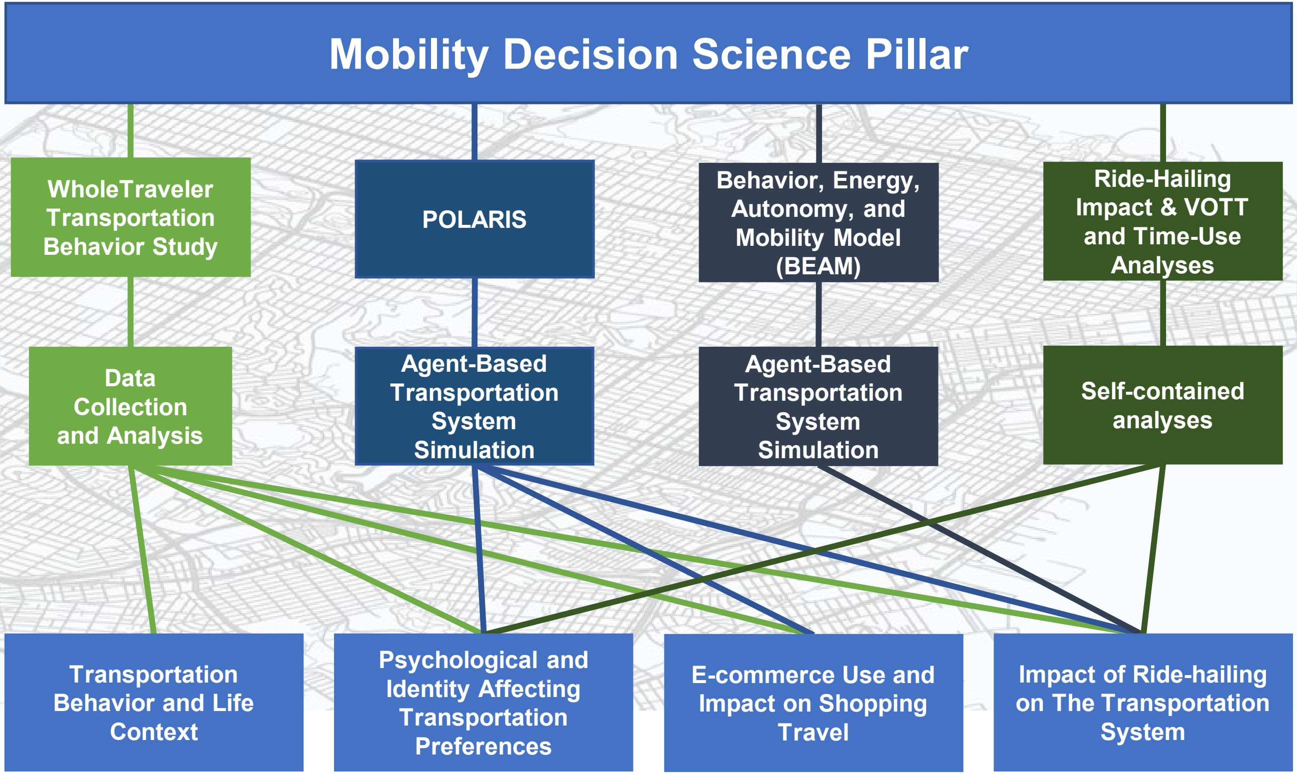
Critical barriers to…

adoption and use of emerging transportation technologies and services.

What does this mean for system outcomes?

MOBILITY DECISION SCIENCE PILLAR

A diverse set of research approaches tackling a range of topics



BEHAVIORAL FINDINGS THROUGH SURVEY AND DATA ANALYSIS

AGE AND MODE CHOICE/ TECHNOLOGY ADOPTION

MDS researchers filled gaps in the literature

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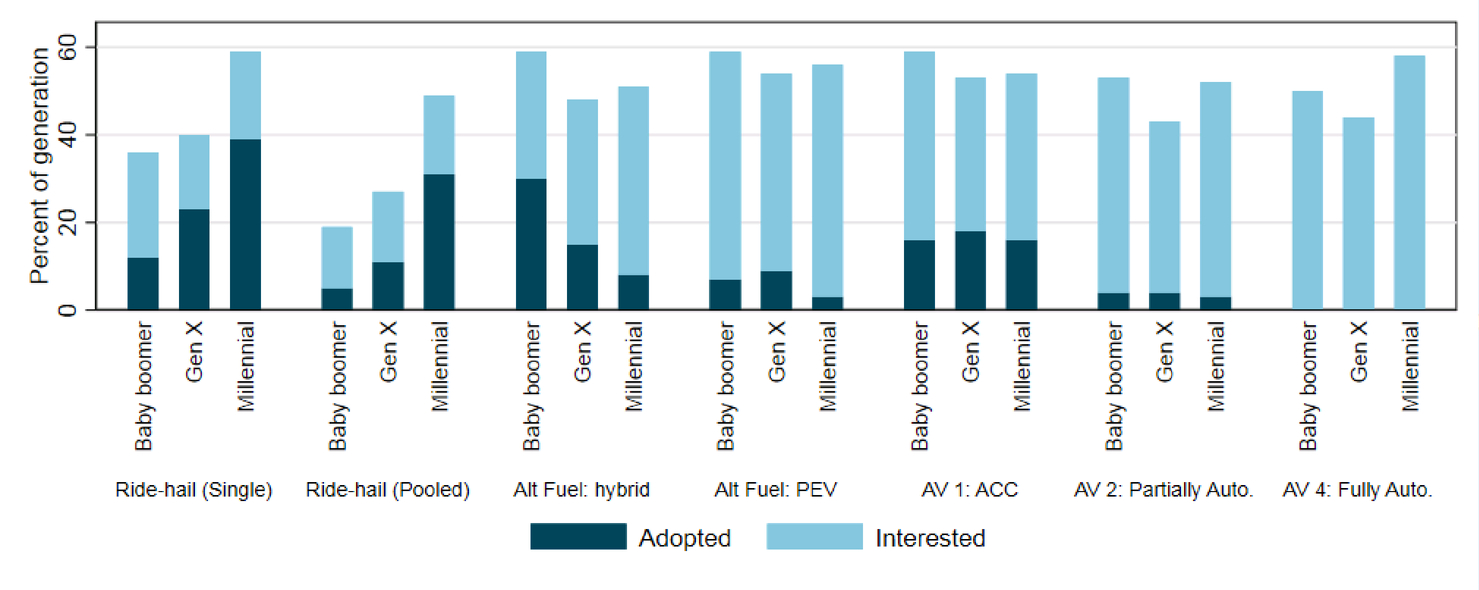
WholeTraveler TRANSPORTATION BEHAVIOR STUDY

SAN FRANCISCO



Spurlock et al. (2019)

VEHICLE TECHNOLOGY PREFERENCES OF OLDER GENERATIONS MATTER FOR ENERGY

Vehicle-dependence increases with age

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WholeTraveler TRANSPORTATION BEHAVIOR STUDY

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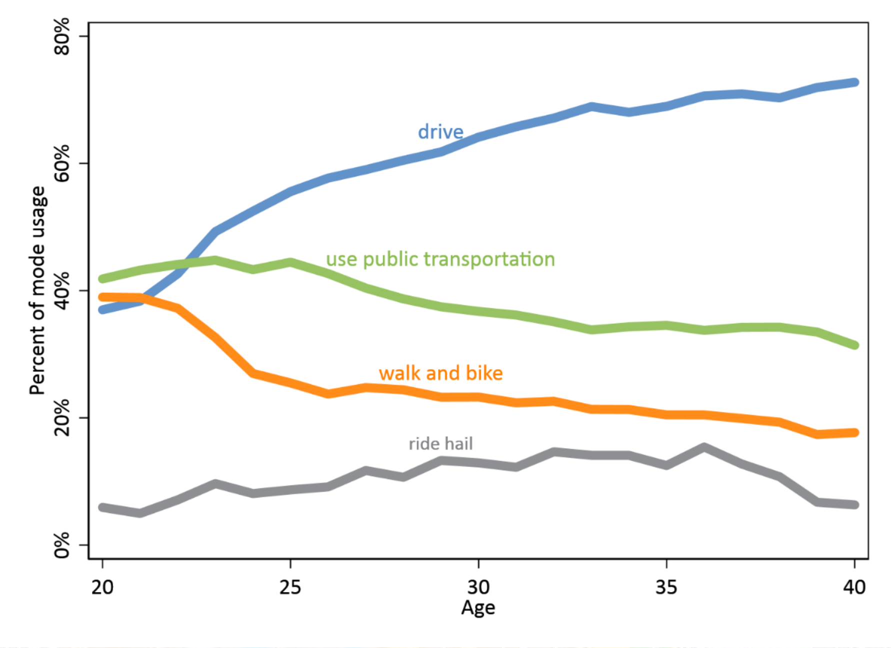

CRITICAL DRIVERS OF VEHICLE DEPENDENCE

Lifecycle patterns evolve..

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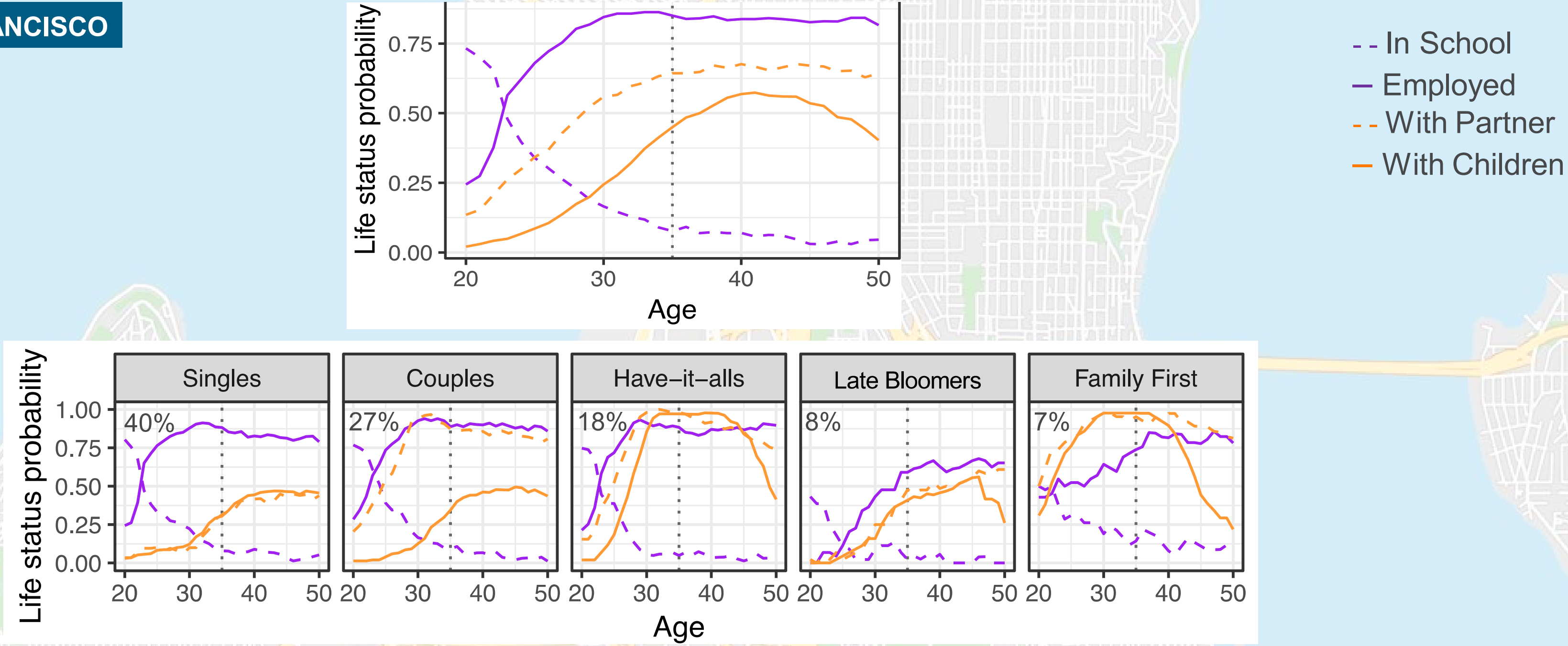


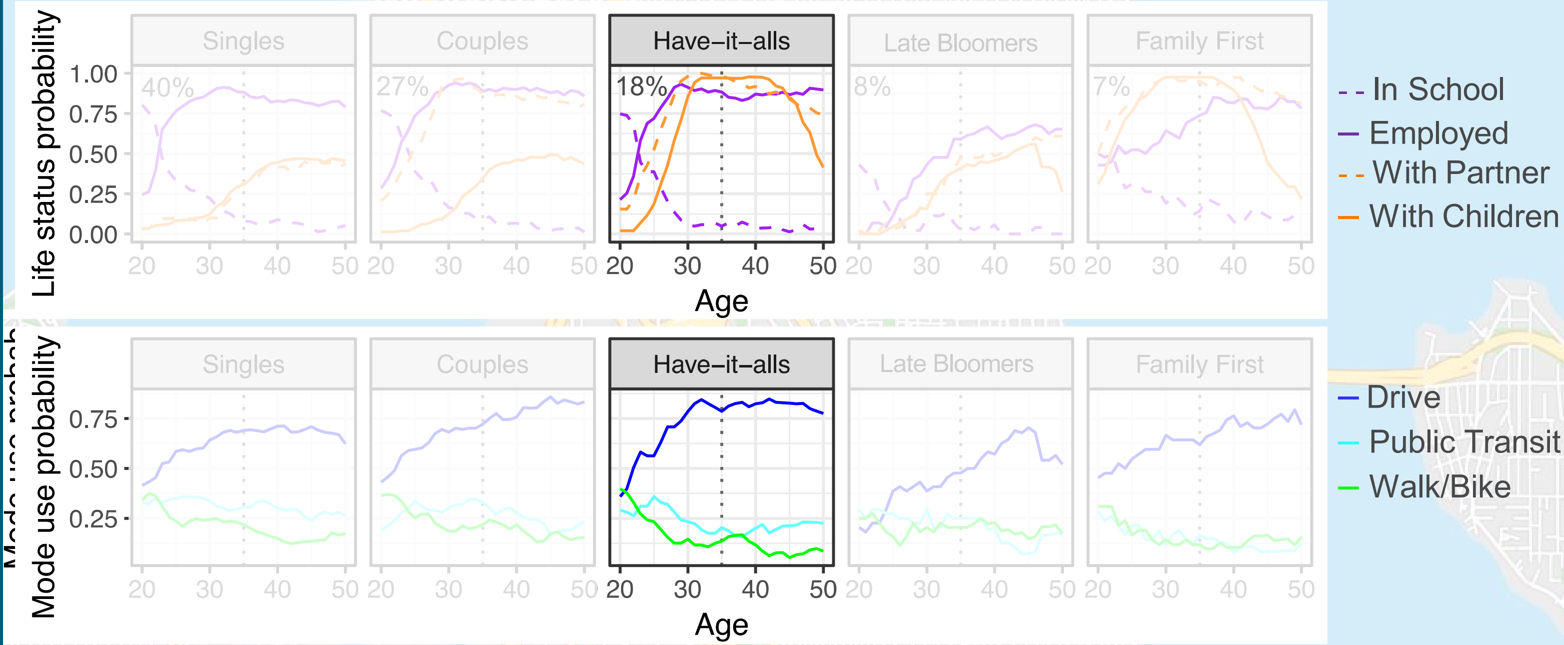
Jin et al. (2020)

CRITICAL DRIVERS OF VEHICLE DEPENDENCE

Timing and order of life events impact on mode use

SAN FRANCISCO

"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

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WholeTraveler TRANSPORTATION BEHAVIOR STUDY

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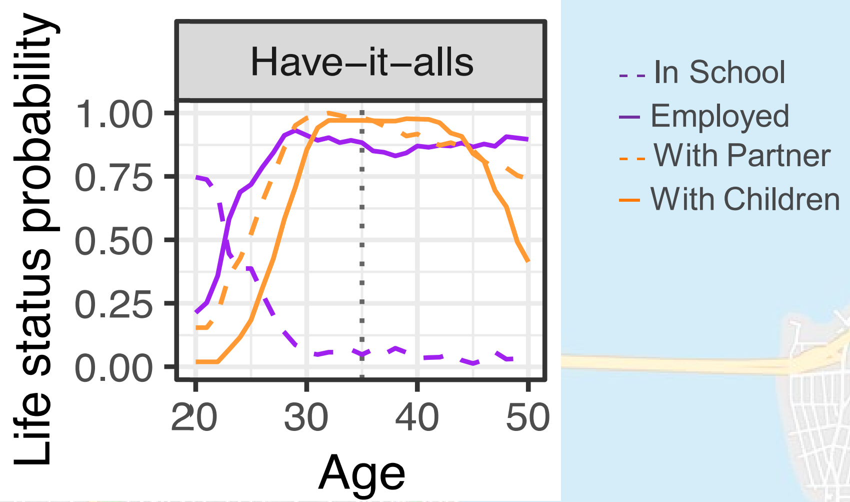
When preparing for/having children Have-it-all women, more than men:

- 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



BARRIERS TO ELECTRIC VEHICLE ADOPTION

Explaining the Gender Gap

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WholeTraveler TRANSPORTATION BEHAVIOR STUDY

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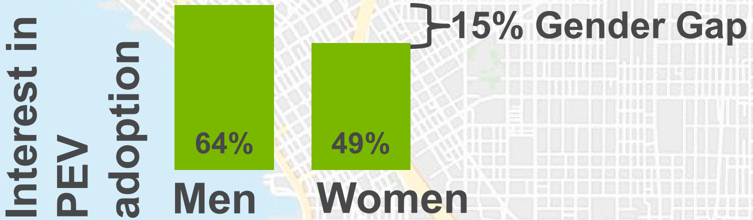

What underlying factors drive this gender gap?

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

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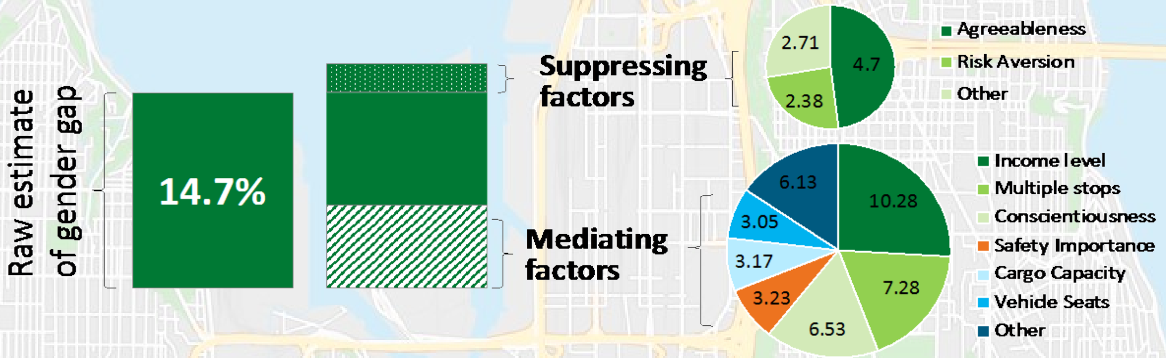
WholeTraveler TRANSPORTATION BEHAVIOR STUDY

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%



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EMPIRICAL STUDIES ANALYZING THE REAL-WORLD IMPACT OF RIDE-HAILING

Behavior of ride-hail drivers has an impact

UNITED STATES

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.

EMPIRICAL STUDIES ANALYZING THE REAL-WORLD IMPACT OF RIDE-HAILING

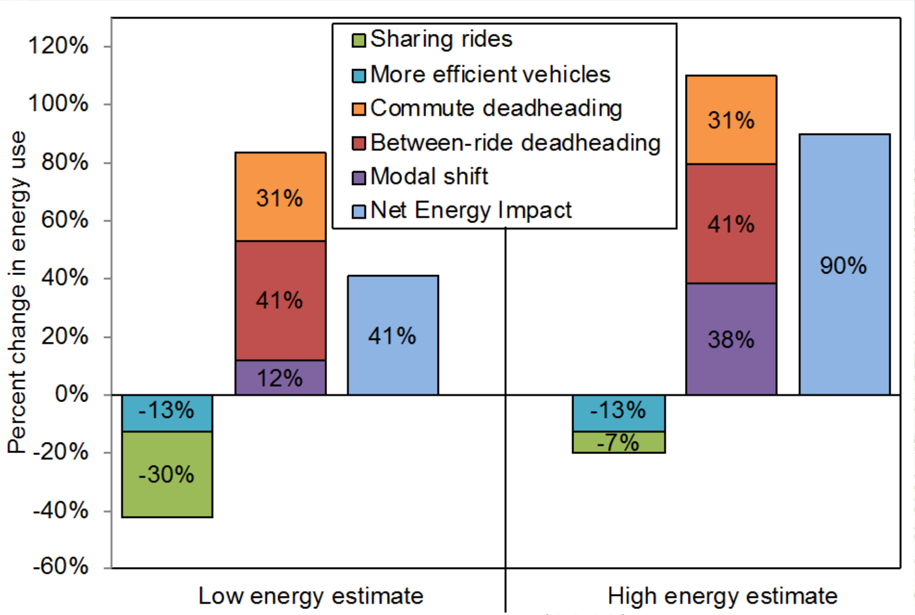
Behavior of ride-hail drivers has an impact

AUSTIN

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

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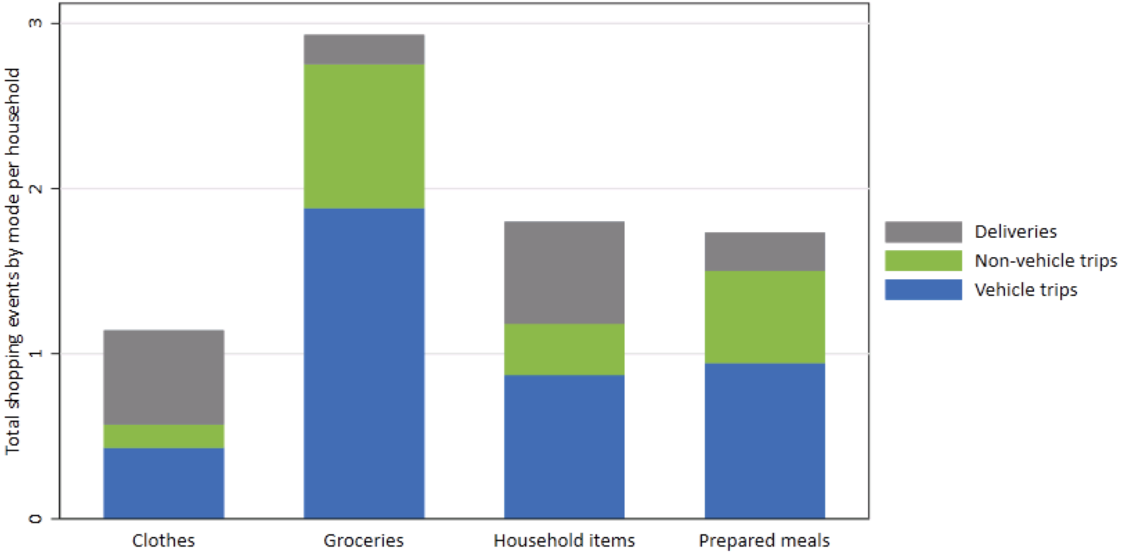
Deliveries substitute for, and are in addition to, shopping trips

WholeTraveler
TRANSPORTATION BEHAVIOR STUDY

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



E-COMMERCE AND DELIVERY IMPACT ON SYSTEM ENERGY USE

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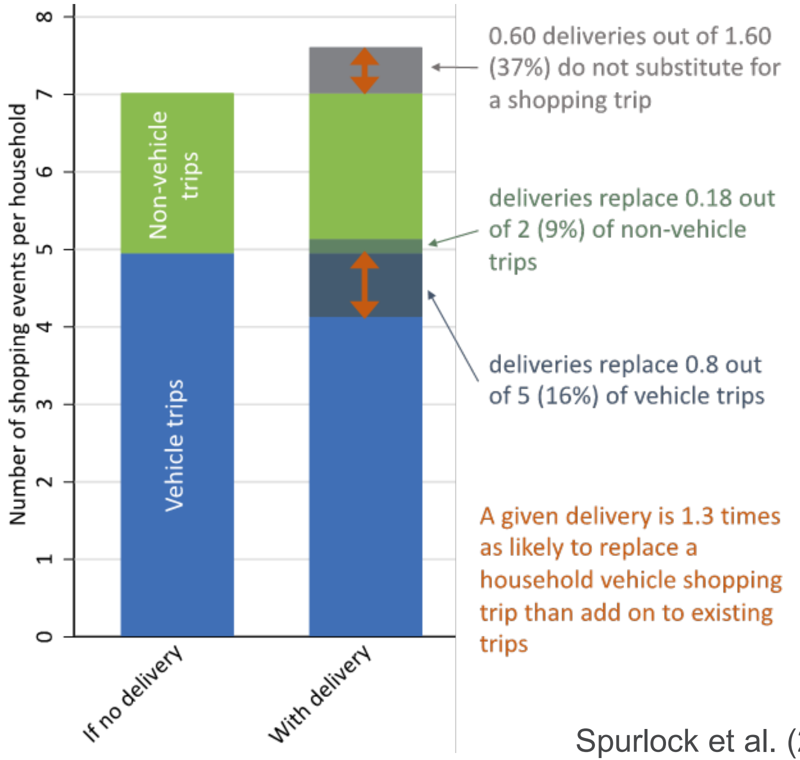
Systems and Modeling for Accelerated Research in Transportation

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

WholeTraveler
TRANSPORTATION BEHAVIOR STUDY

SAN FRANCISCO

- 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.



Spurlock et al. (2020)

BEHAVIORAL FINDINGS THROUGH SIMULATION MODELING

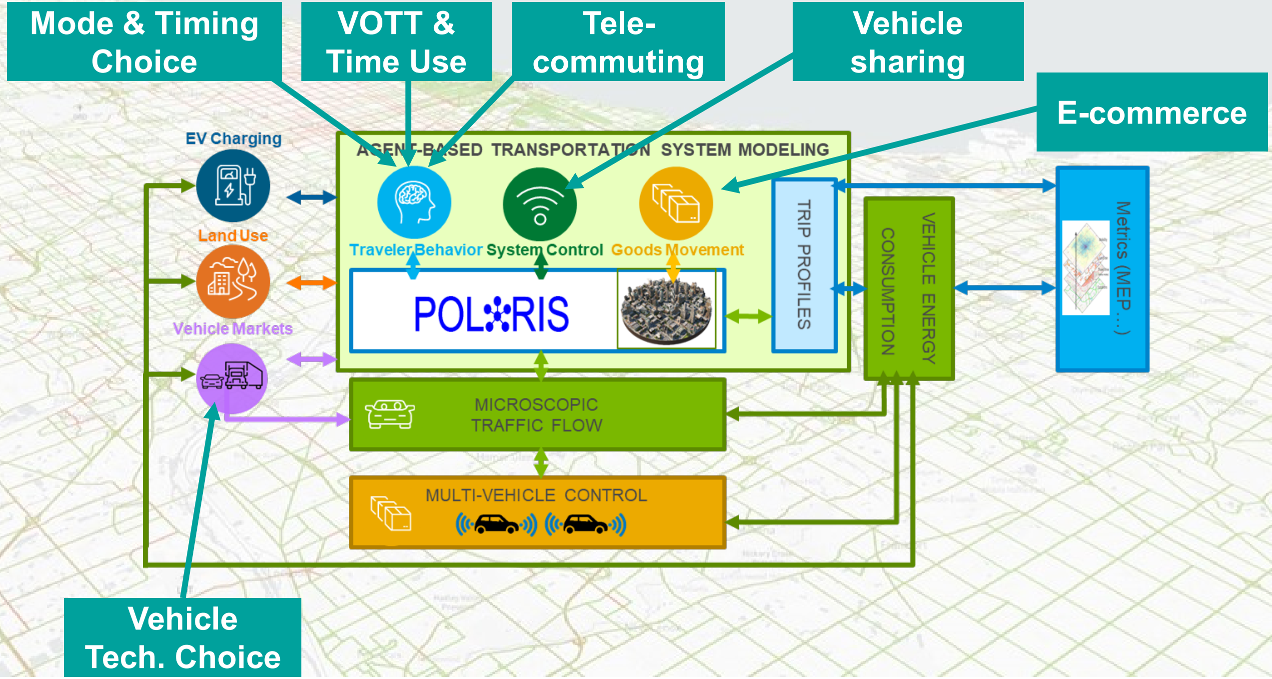
POLARIS

BEAM

BEHAVIORAL RESEARCH IMPROVES AND EXTENDS THE SMART MOBILITY WORKFLOW

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

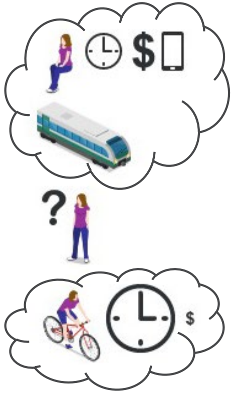
- Substantial research on a broad range of demand behaviors led to many new models
- Incorporated in SMART Workflow and impacts evaluated
- Evaluation of sensitivity of overall model to each component were performed
- Key findings published in multiple journal articles



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**

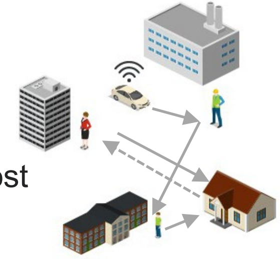


Mode and Timing Choice (Golshani et al 2018)

- 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



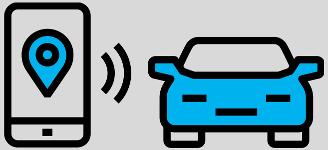
E-Commerce (Stinson et al 2019)

- 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)

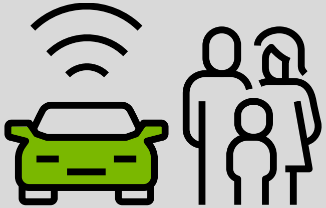


New technology enables people to significantly increase the use of **transit, ride-hailing** and **multi-modal travel. Partial automation** is introduced and is primarily used on the highway.

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**.

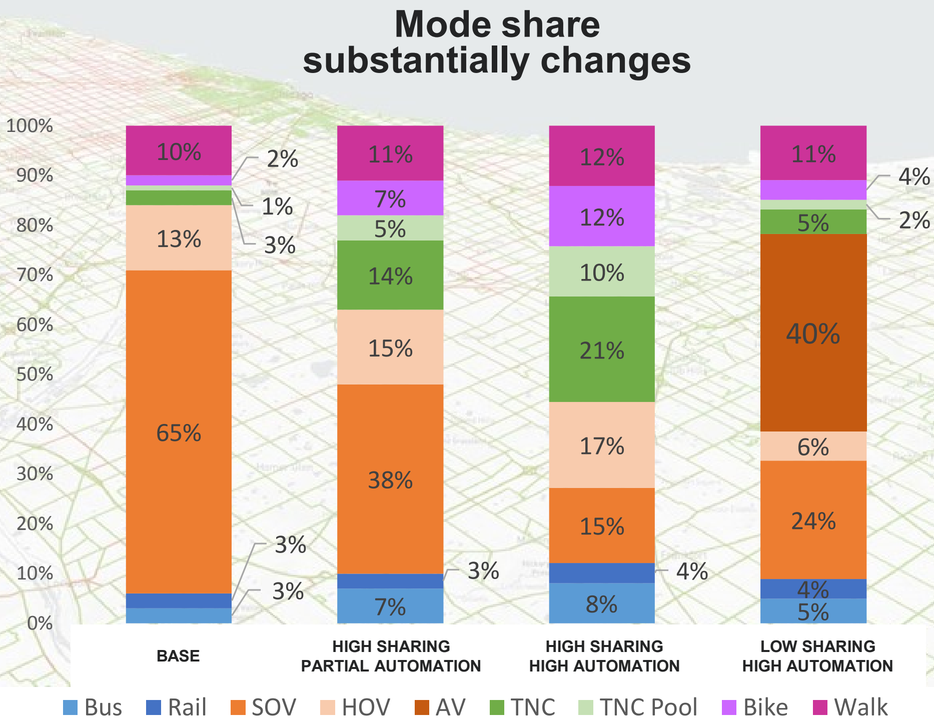
LOW SHARING, HIGH AUTOMATION (Private-AV)



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



LOWER VOTT HAS GREATER IMPACT IN LOW-DENSITY ACTIVITY AREAS

Sensitivity of urban residents to VOTT is low

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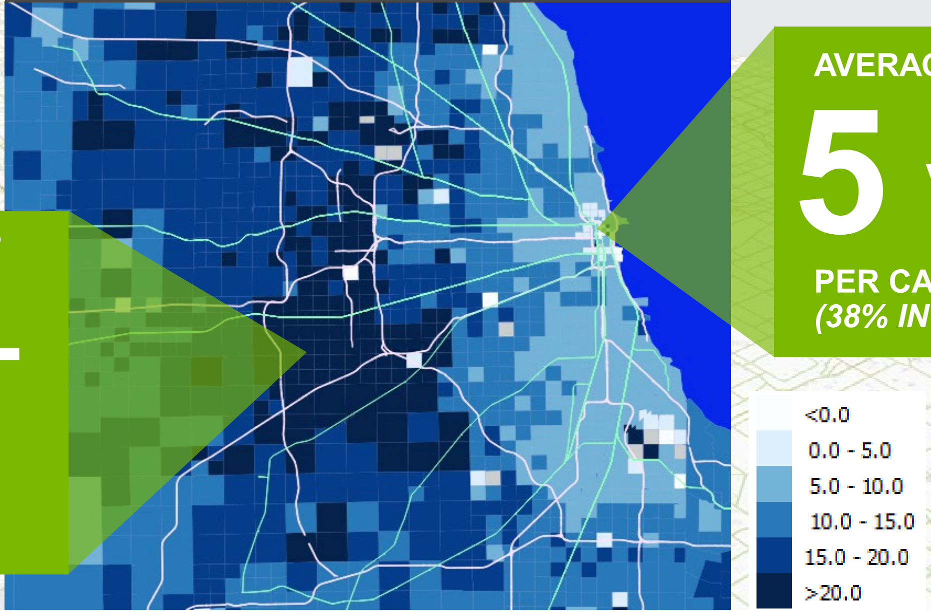
VOTT: Value of Travel Time
Monetary cost I would be willing to pay to avoid an hour of travel; differs by mode, income, location

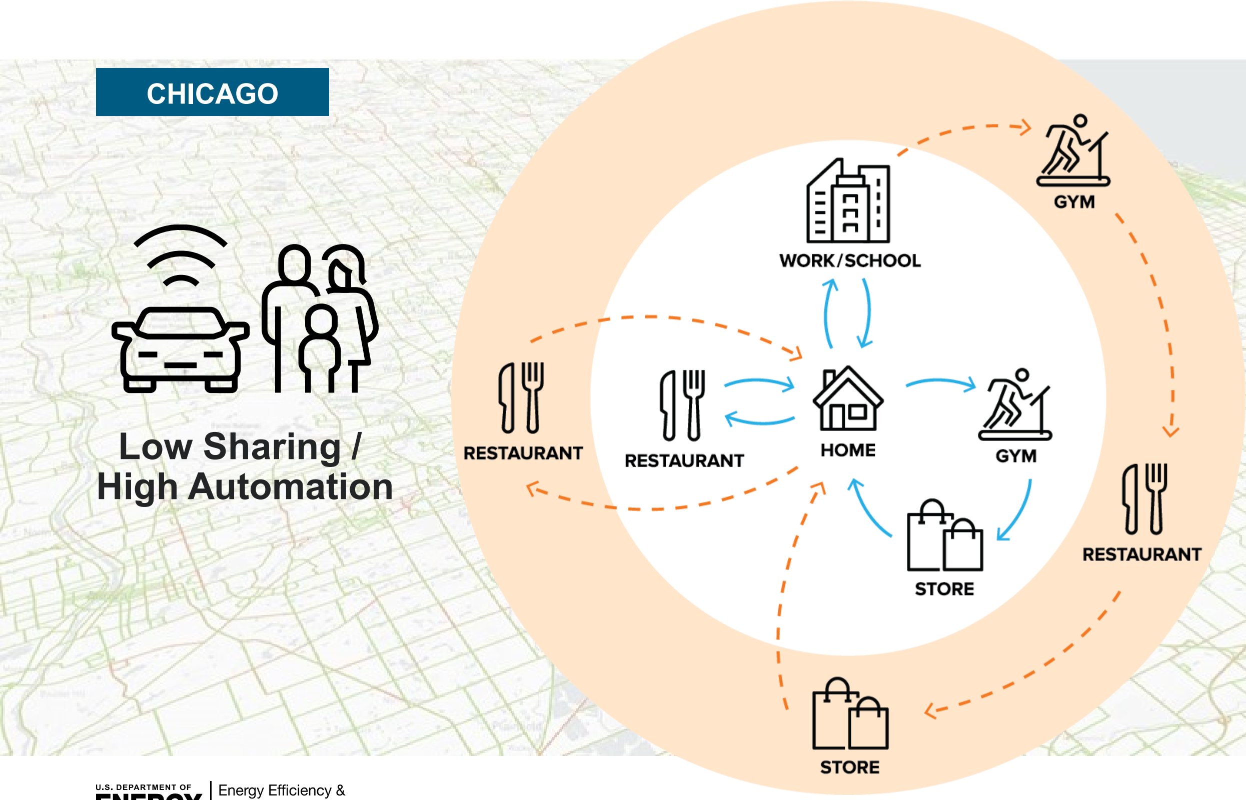
When VOTT is reduced by 50%...

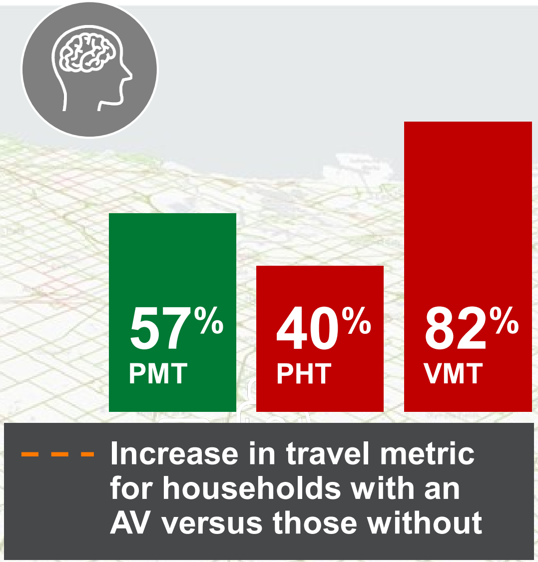


AVERAGE INCREASE OF
14 VMT
PER CAPITA IN CORE SUBURBAN AREAS
(52% INCREASE)

AVERAGE INCREASE OF
5 VMT
PER CAPITA DOWNTOWN
(38% INCREASE)

AUTOMATED VEHICLES HAVE MAJOR EFFECT ON TRAVEL BEHAVIOR





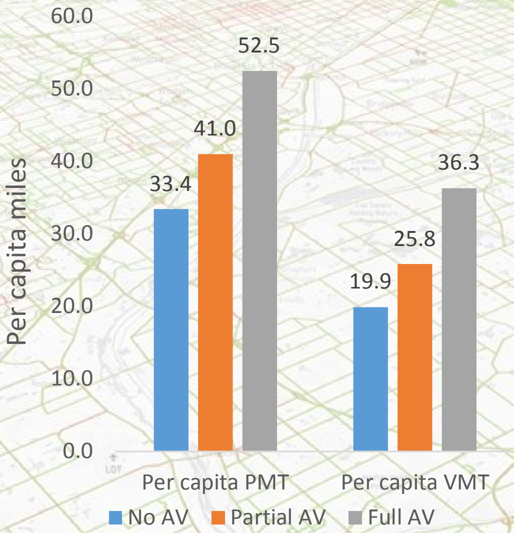
HOUSEHOLDS WITH AV BEHAVE MUCH DIFFERENTLY

Up to 82% VMT increase in households owning an AV

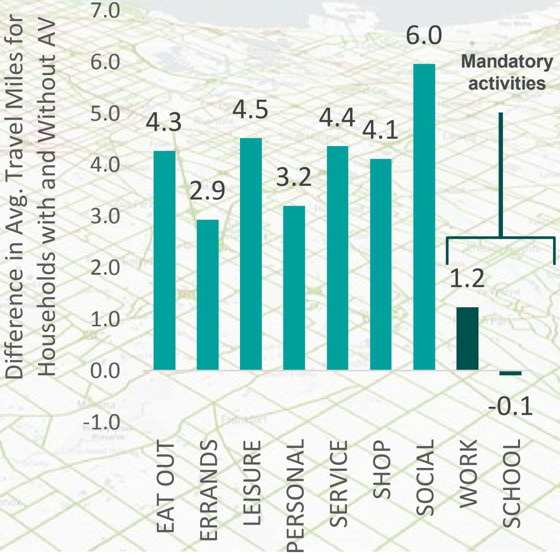
Chicago

- 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

Households with AV drive more than others



Driven by increased travel to discretionary activities

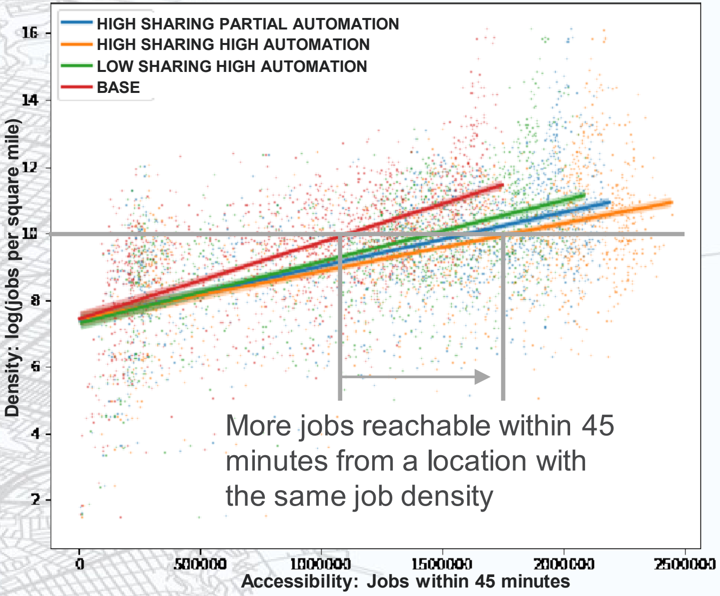


LOWER SUBJECTIVE TRAVEL COSTS AFFECT DEMAND FOR LAND OUTSIDE THE URBAN CORE

High accessibility via lower travel costs can induce sprawl

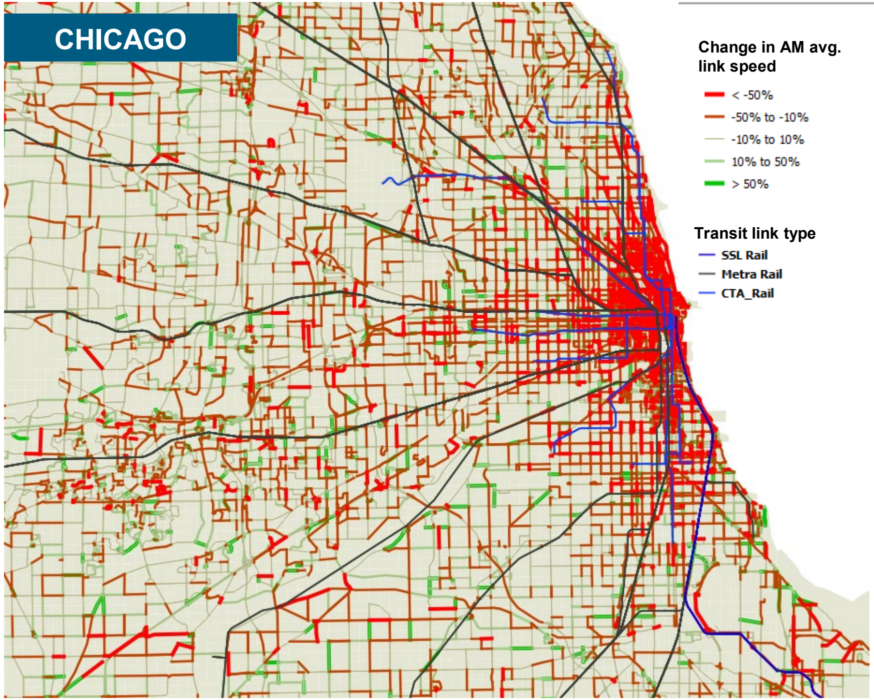
San Francisco

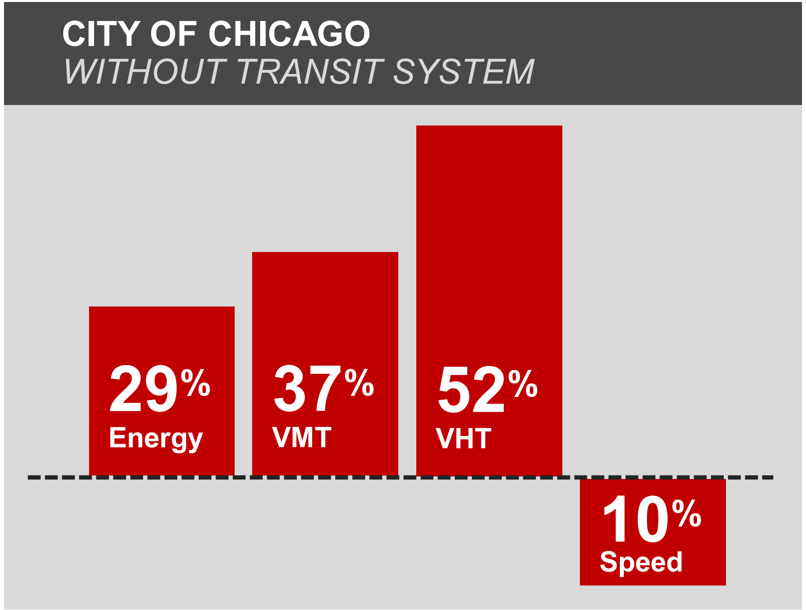
- All scenarios increase **accessibility**
- More demand to shift residence and businesses further from the urban core
- This was most prevalent in the **high-sharing with high-automation scenario**
    - lowest generalized travel cost
    - people willing to travel further
    - highest increase in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



TRANSIT IS CRITICAL TO MOBILITY

Absent transit, energy use and congestion increase





TRANSIT AND RIDE-HAIL CAN BE COMPLEMENTARY

Transit provides key mobility in city, TNC serves suburbs

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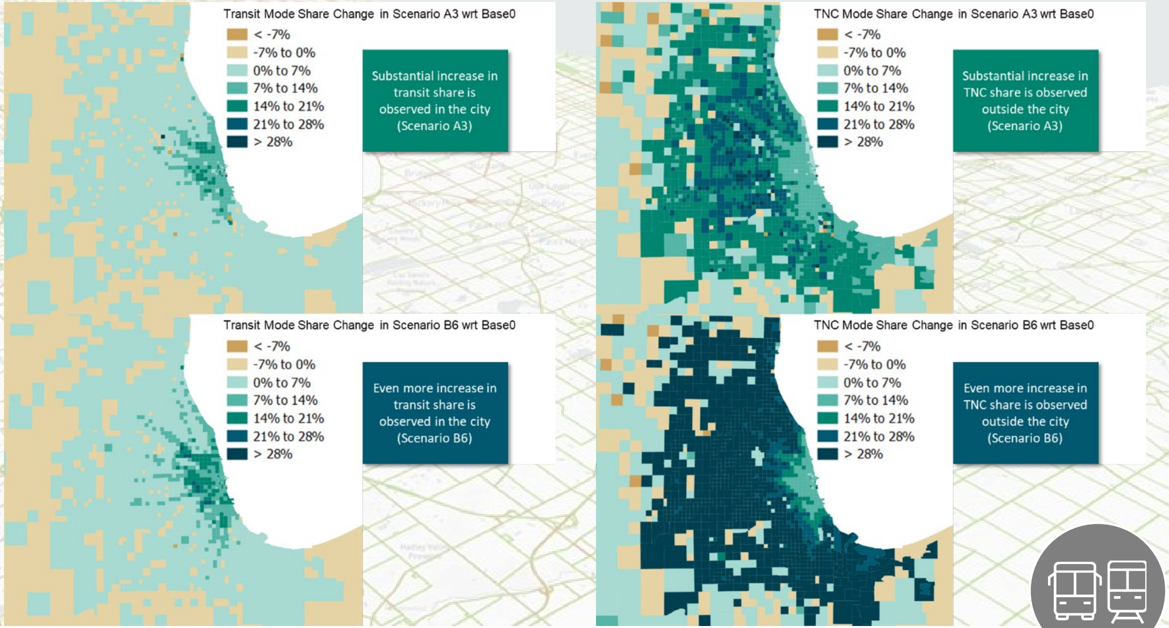
CHICAGO

- **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

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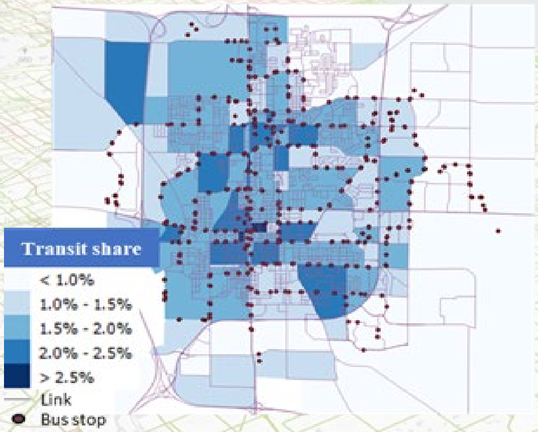
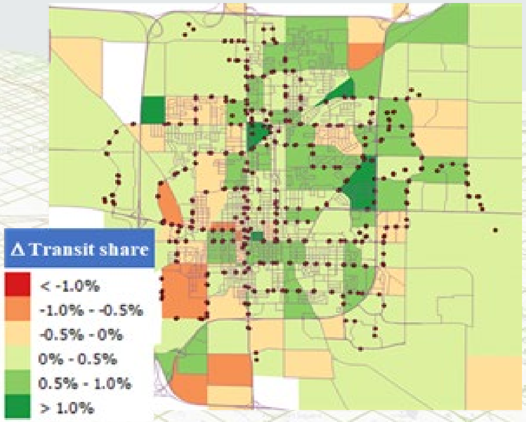
BLOOMINGTON, IL

- 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%

Baseline transit mode share (%)



Δ in transit share

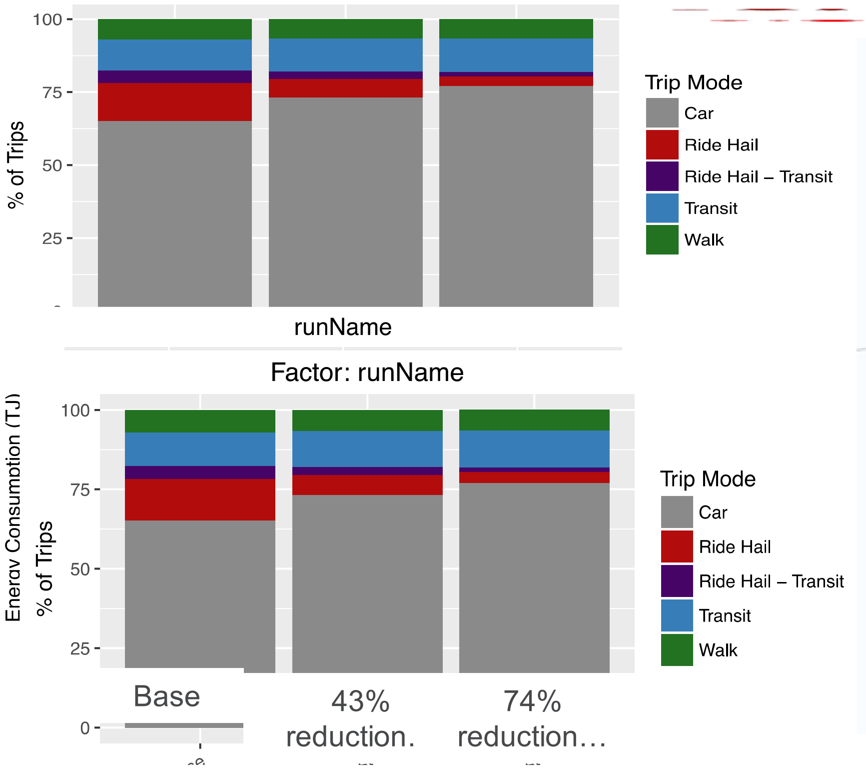


	Total VMT	TNC-to-transit VMT	Transit mode %	Total fuel (kg)
Baseline	2,265,786	1,805	1.30%	232,320
TNC access	2,232,961	5,737	1.50%	229,669
% change	**-1.40%**	**217.80%**	**10.90%**	**-1.10%**

REDUCING RIDE-HAIL USAGE EFFECTS TRANSIT RIDERSHIP AND TOTAL ENERGY

San Francisco

- 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



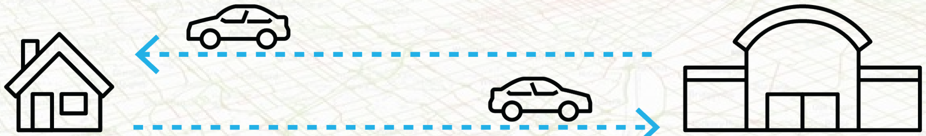
INCREASE IN E-COMMERCE LOWERS OVERALL SYSTEM VMT AND ENERGY

Fewer shopping trips, more deliveries

POLARIS

CHICAGO

SHOPPING TRIP = 7 to 8 miles, one way



DELIVERY TRIP

1 ADDED STOP = 0.4 mile

TAKEAWAYS

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

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