OCTOBER 22, 2020

U.S. DEPARTMENT OF ENERGY
SMARTMOBILITY
Systems and Modeling for Accelerated Research in Transportation

APPLYING THE SMART MOBILITY WORKFLOW FOR SCENARIO ANALYSES IN CHICAGO AND SAN FRANCISCO

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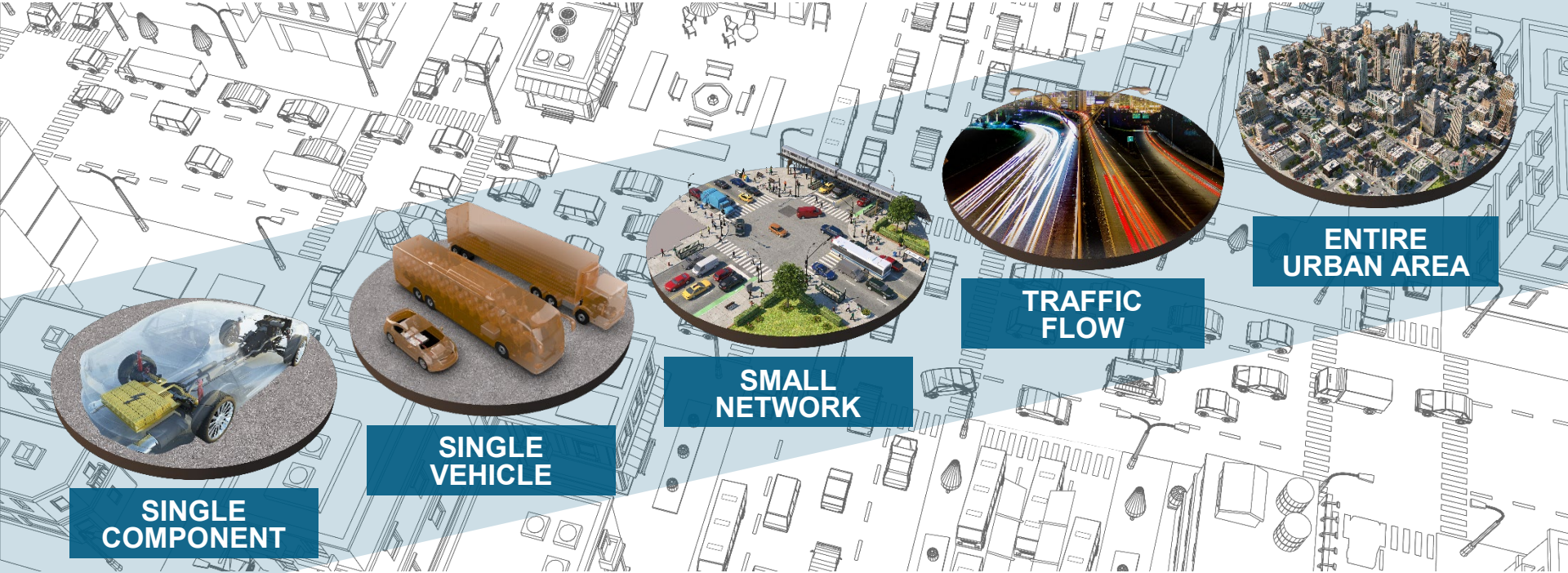
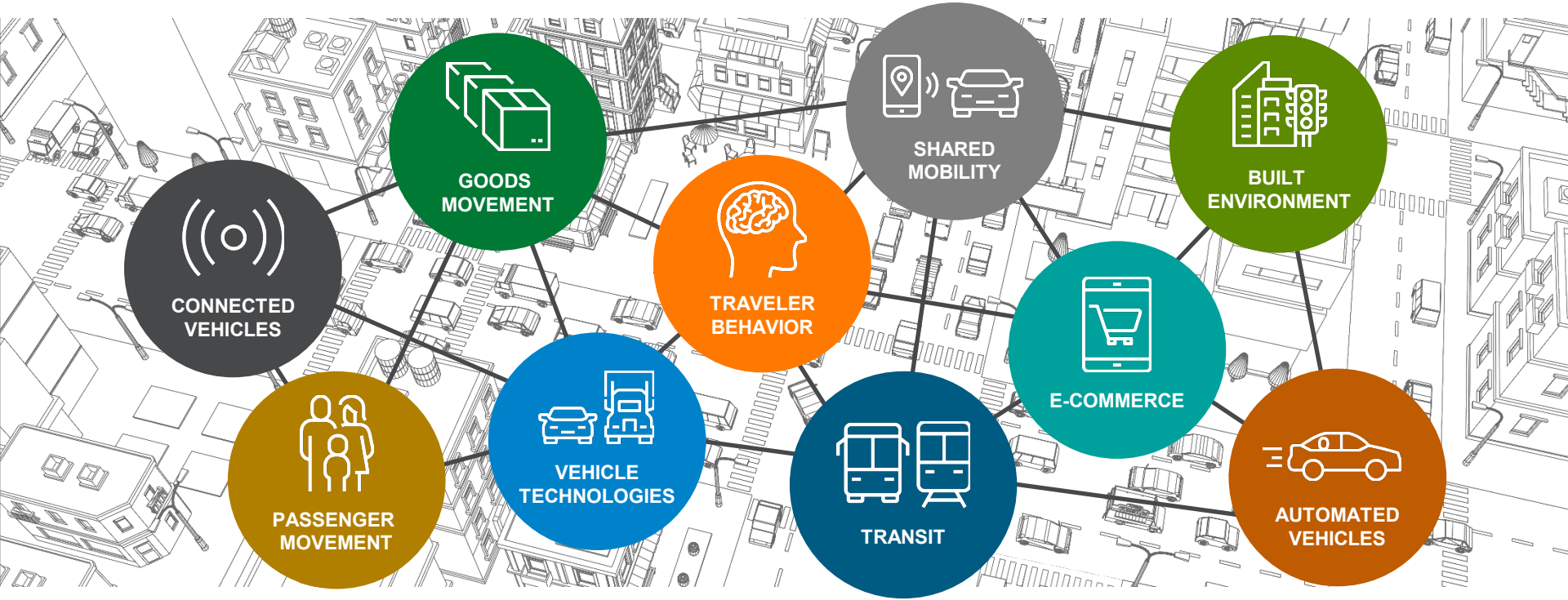
VTO SYSTEMS-LEVEL R&D



TRANSPORTATION IS A SYSTEM OF SYSTEMS



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.

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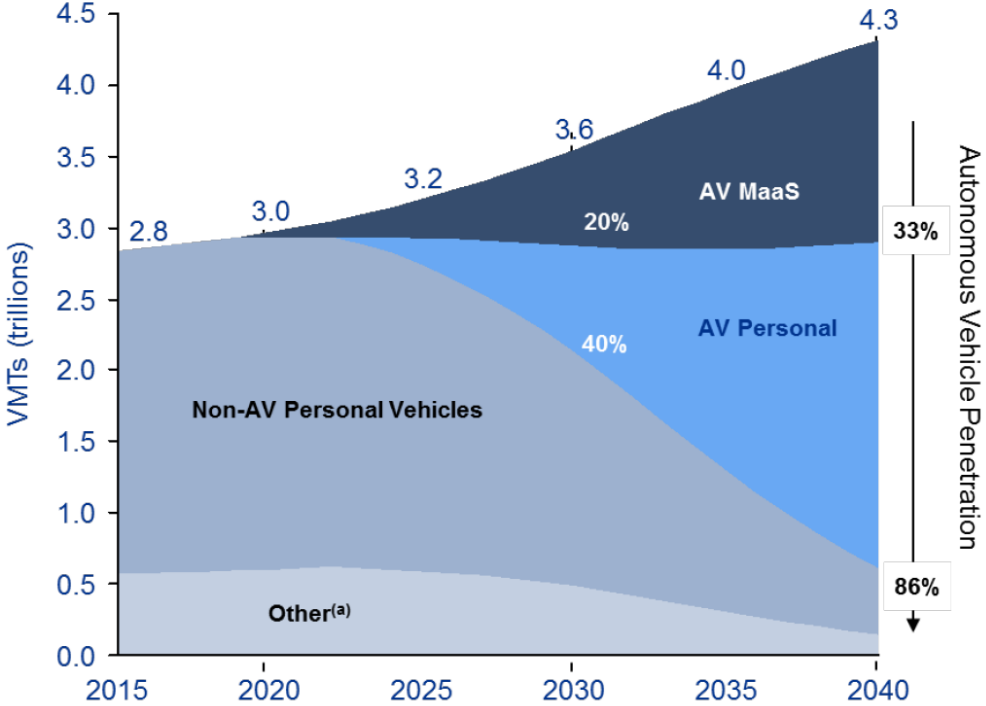
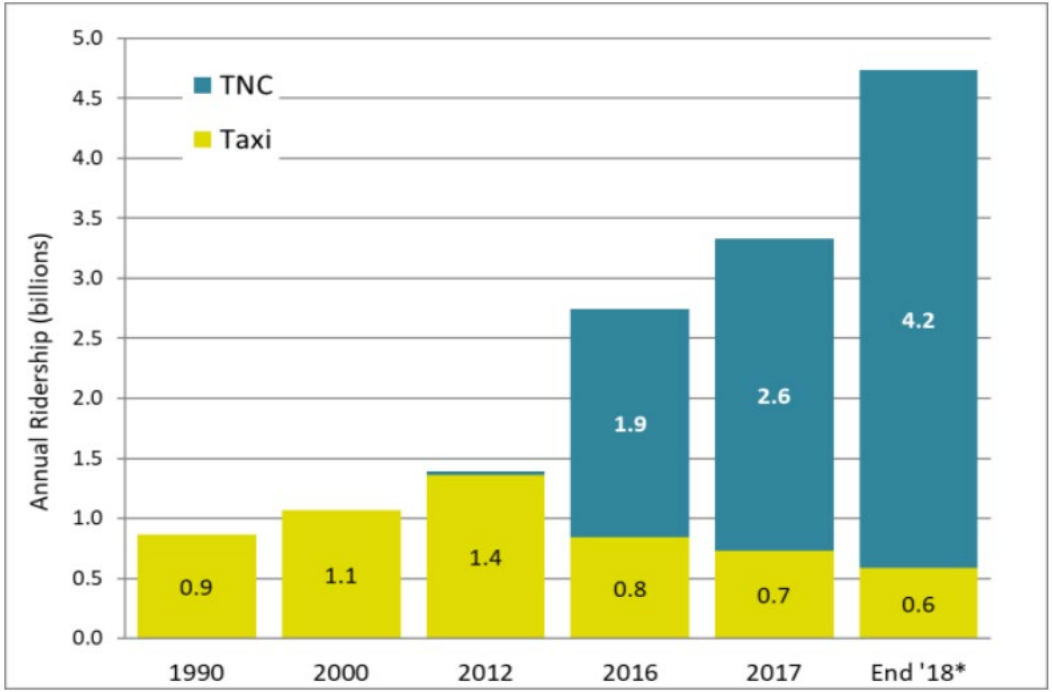
Vehicle Miles Traveled by Ownership Type & Mode

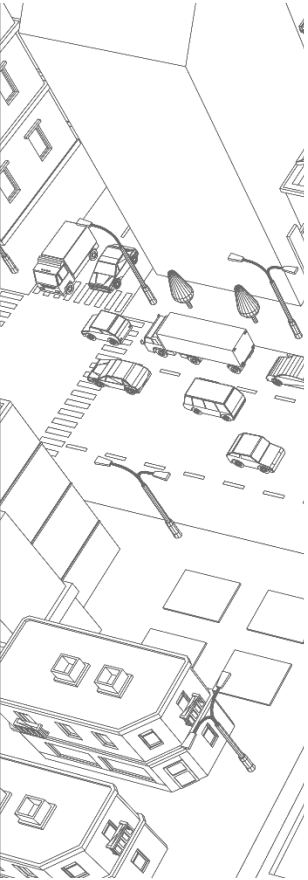
Source: J. Anderson, KPMG



TNC & Taxi Ridership in the U.S., 1990-2017

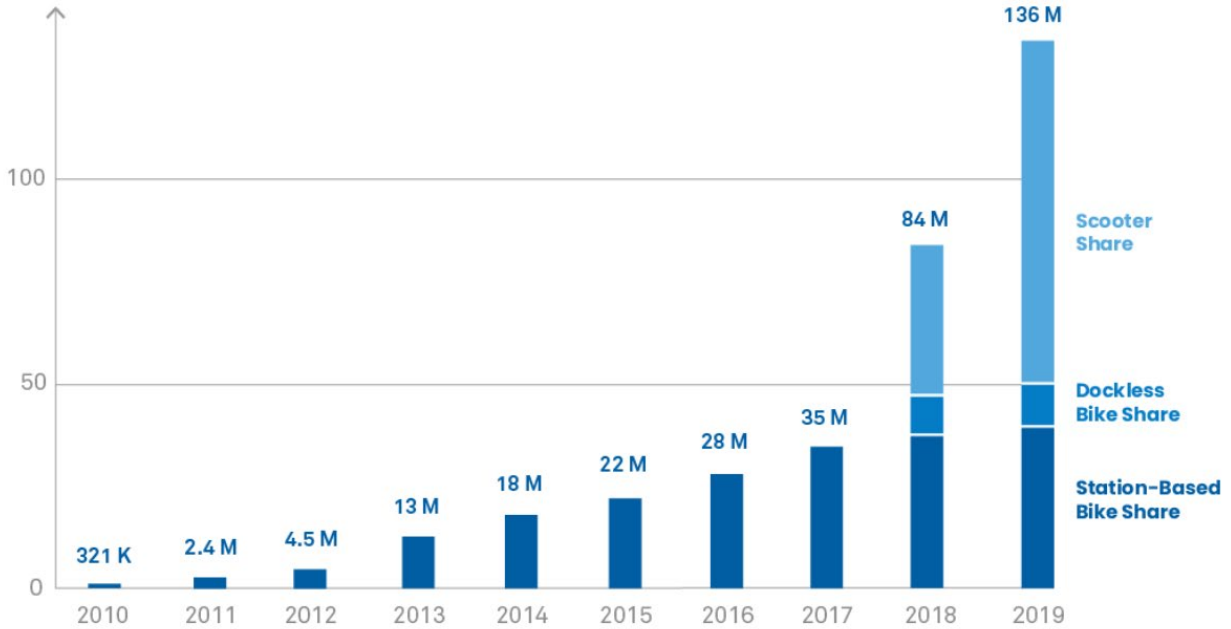
Bruce Shaller, Shaller Consulting

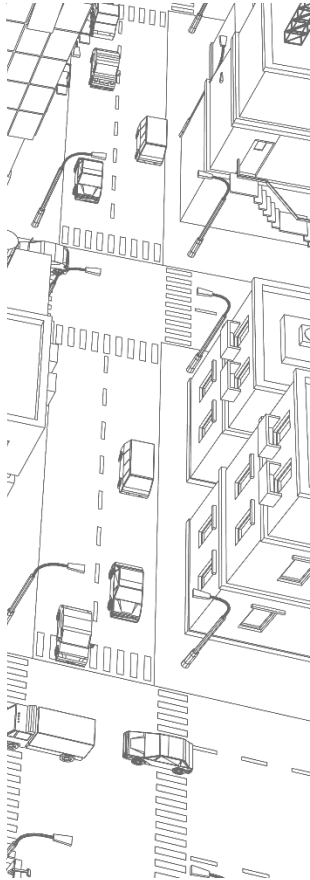




SHARED MICROMOBILITY RIDERSHIP GROWTH FROM 2010–2019, IN MILLIONS OF TRIPS

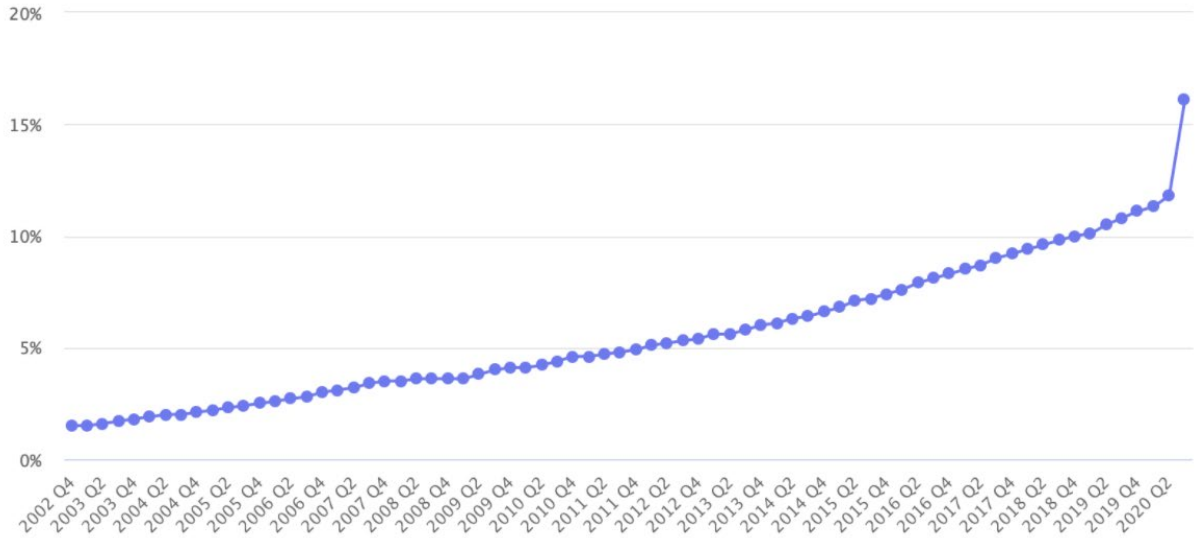
Source: NACTO





U.S. E-Commerce Sales as a Percent of Total Sales

Source: Marketplace Pulse, U.S. Department of Commerce



SMART MOBILITY MODELING WORKFLOW

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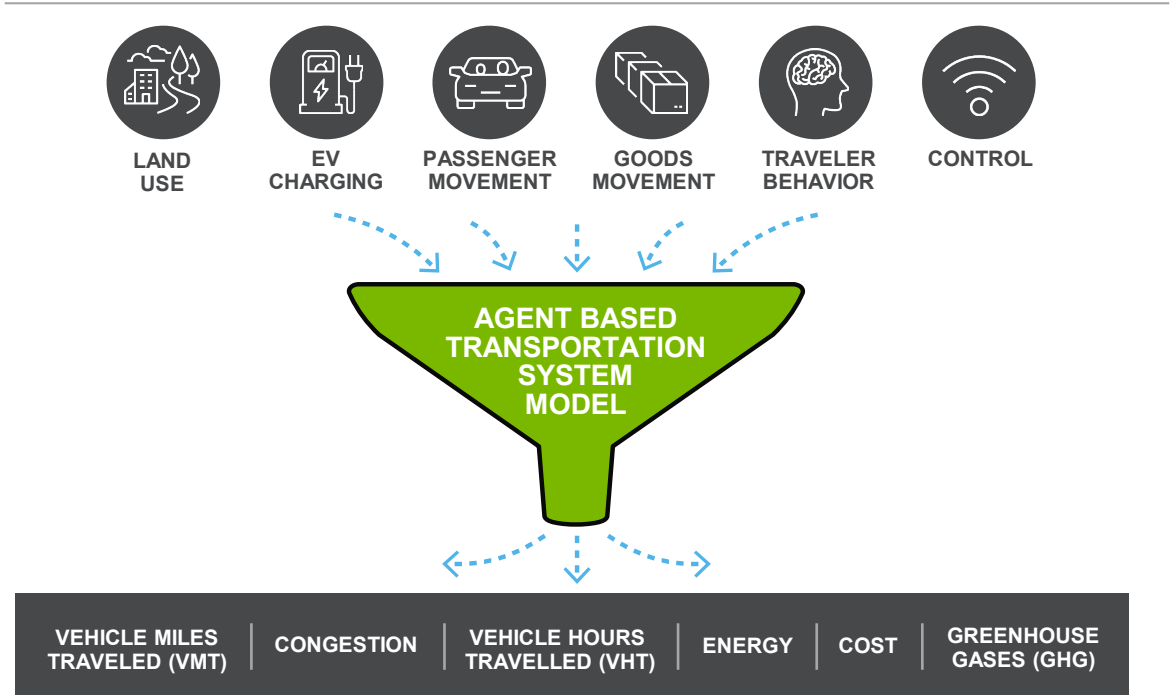
By creating a multi-fidelity end-to-end modeling workflow, SMART Mobility researchers advanced the state-of-the-art in transportation system modeling and simulation.



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MOBILITY FOR OPPORTUNITY

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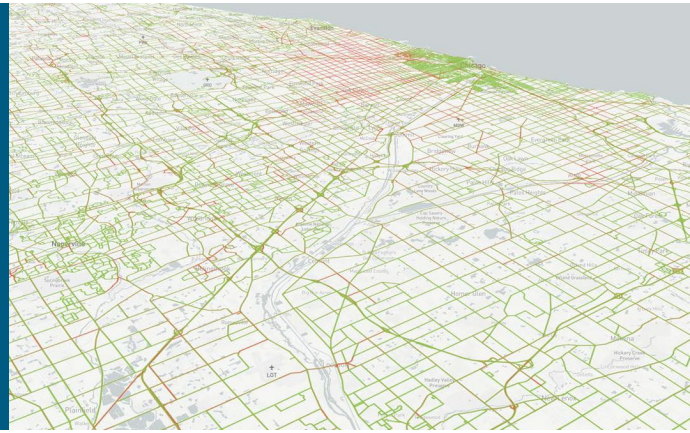
APPLYING THE POLARIS SMART MOBILITY WORKFLOW TO CHICAGO



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A COMPREHENSIVE APPROACH FOR COMPLEX QUESTIONS USING POLARIS

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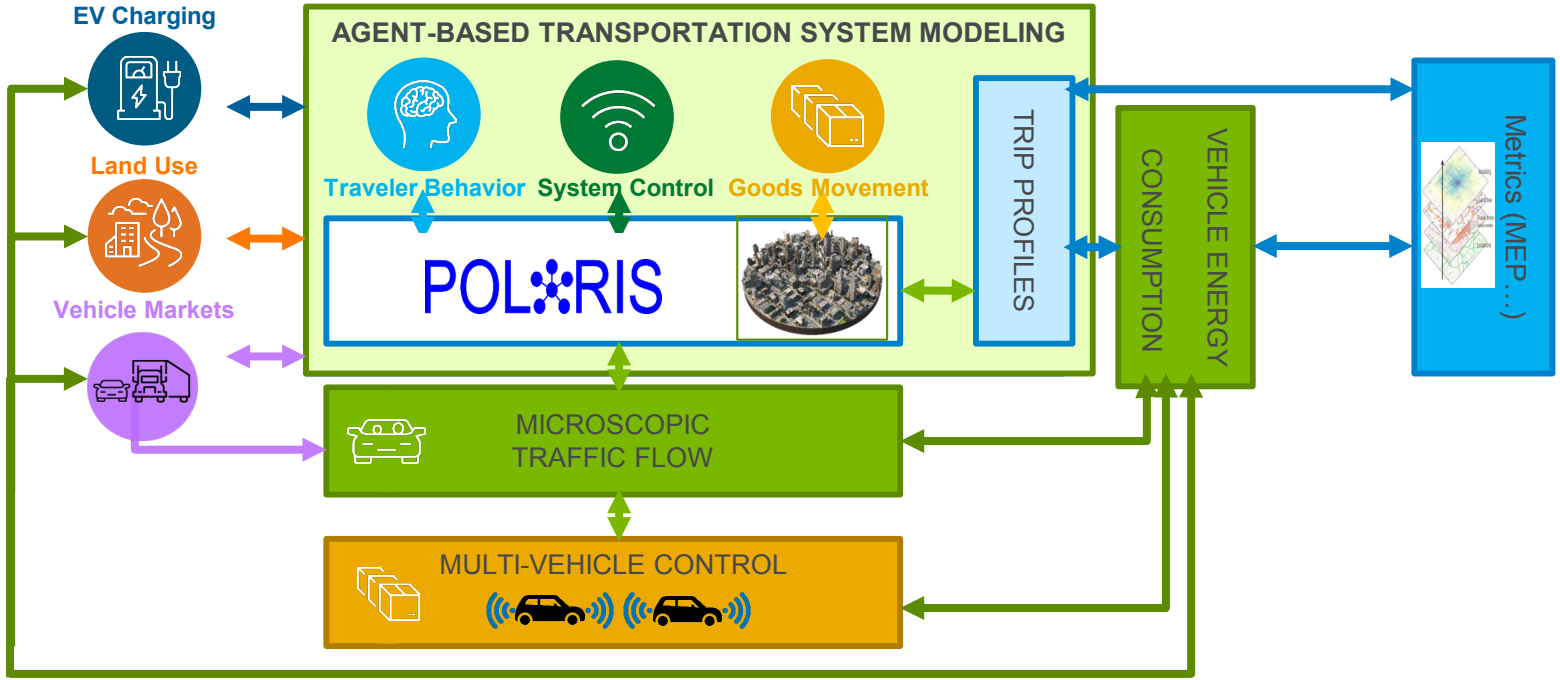

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WHY IS THE POLARIS WORKFLOW UNIQUE?

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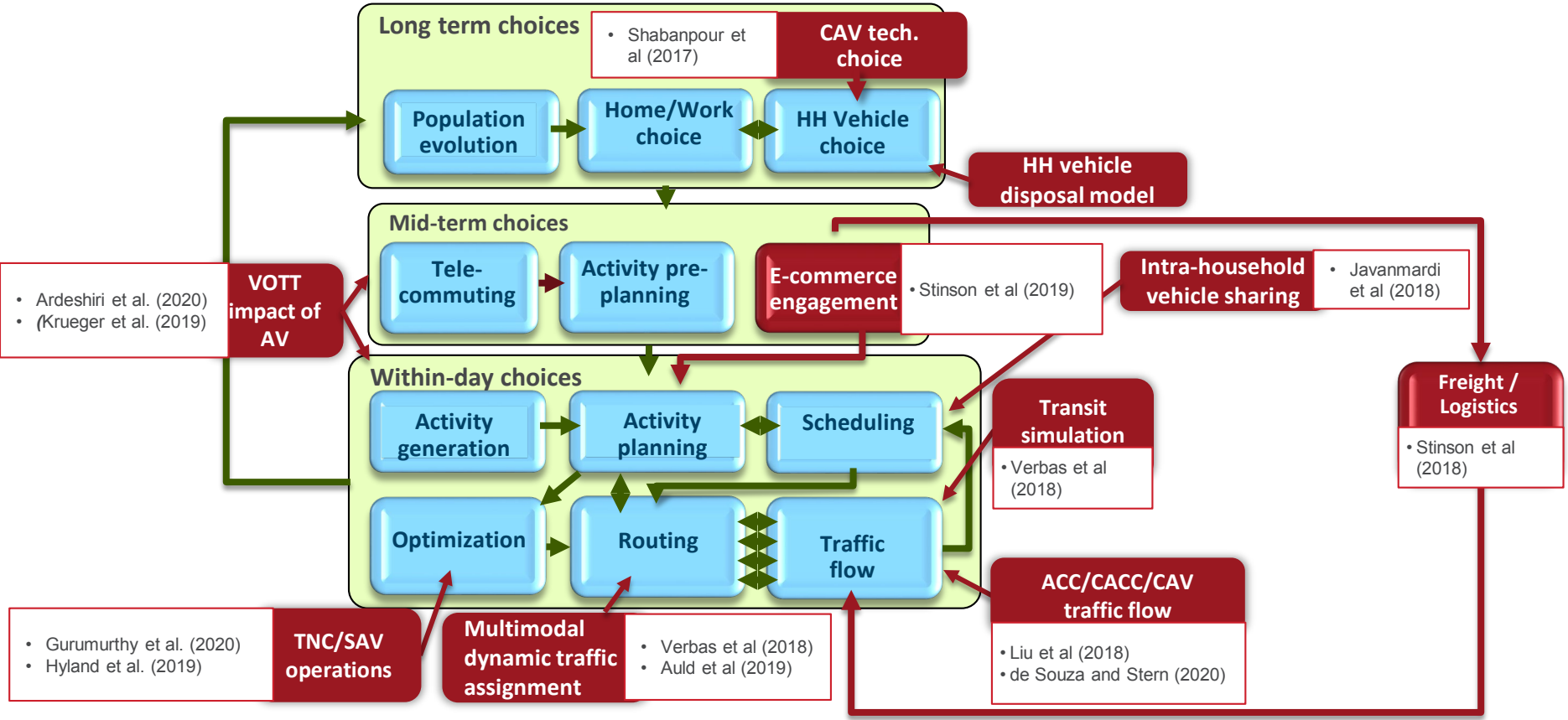
POLARIS

- **Key modeling features:**
  - Full-featured **activity-based** model
  - Includes **freight** shipments and local deliveries
  - High-fidelity **vehicle energy** consumption
  - **Integrated** demand, network assignment and traffic flow
  - **EV charging** and **grid** integration
  - Connection to **UrbanSIM** land use
  - Traveler behavior impacts of **VOTT** across many choices

Computational performance:

- Fully **agent-based**
- Integration with external **optimization** solvers (CPLEX, Gurobi, GLPK)
- High-performance **C++ codebase**
- Large-scale models with **100% of agents**
- **4-6 hr runtime** for up to 10 million agents
- Cross-platform implementation can run on Linux **HPC** clusters

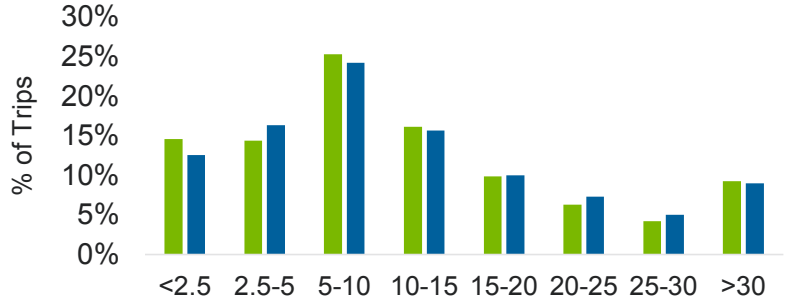
POLARIS ABM HAS BEEN SUBSTANTIALLY ENHANCED TO ACCOUNT FOR FUTURE MOBILITY



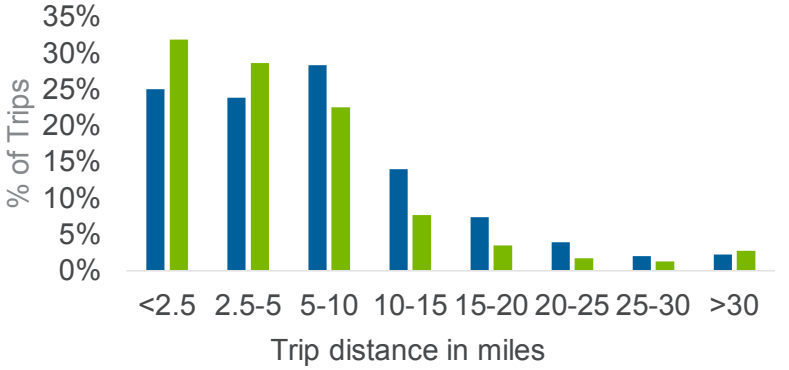
COMPREHENSIVE BASELINE VALIDATION

Ensures model representativeness

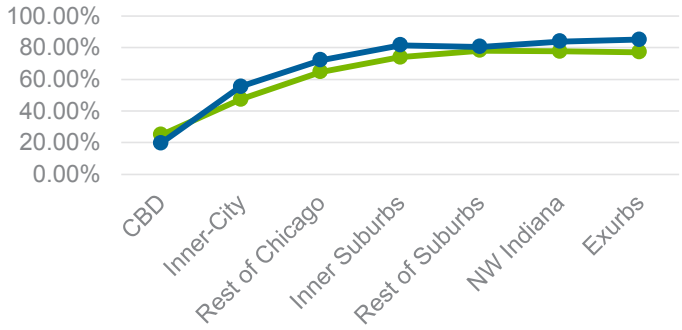
Work tours



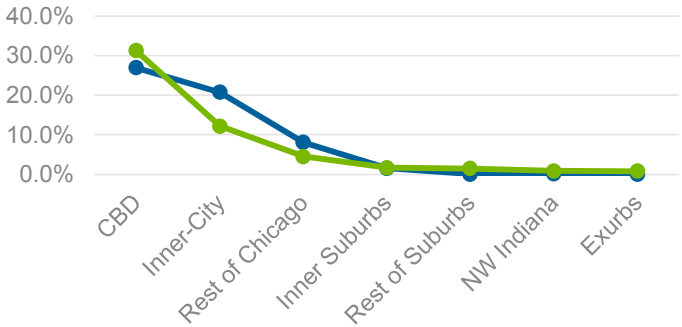
Other tours



Auto share



Transit share

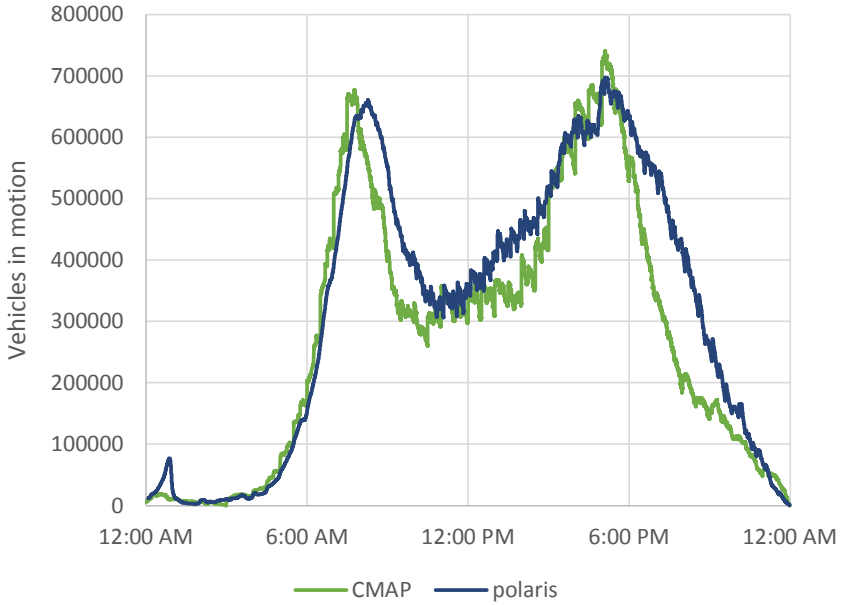


POLARIS CMAP

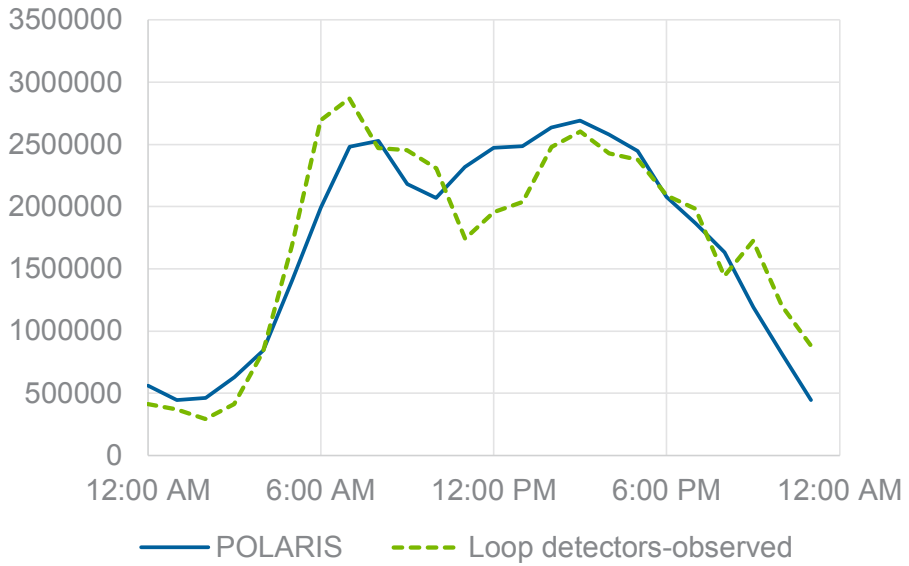
COMPREHENSIVE BASELINE VALIDATION

Matching vehicle movements and traffic counts

Vehicle in-network

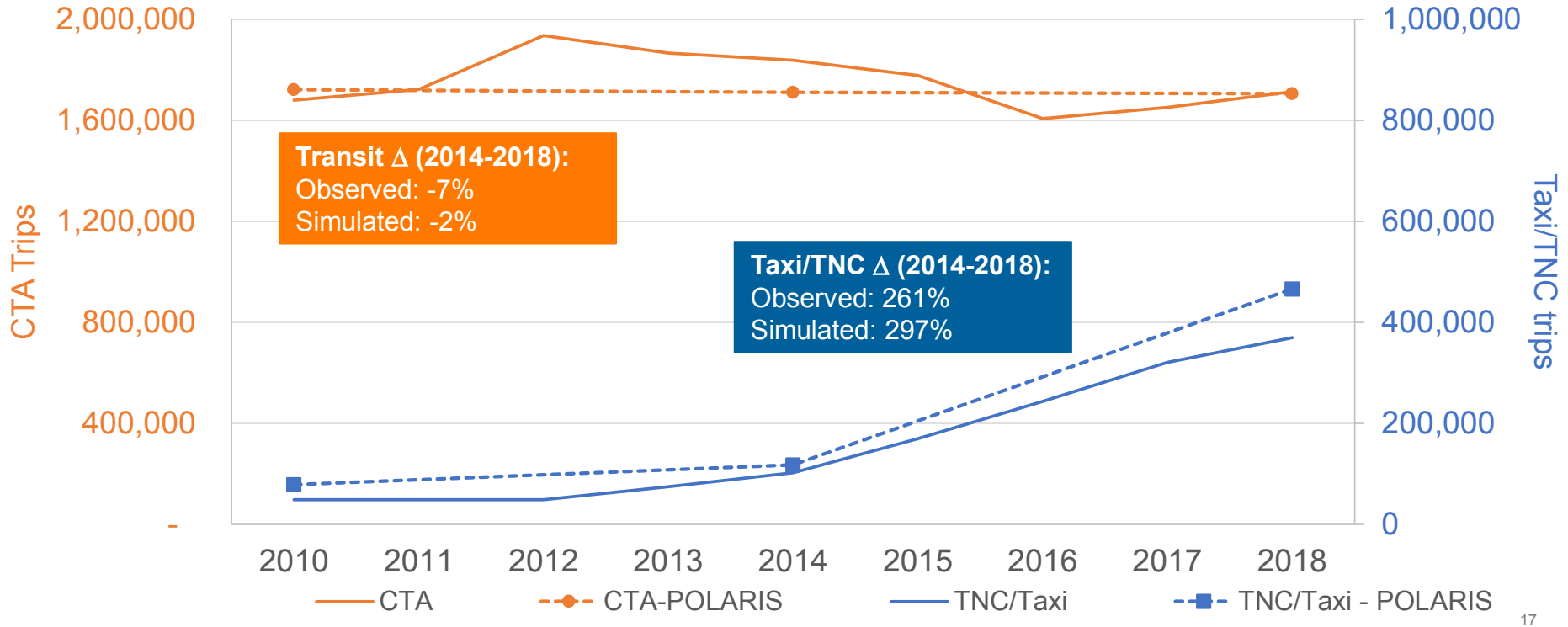


Highway Traffic Counts



BACK-CAST VALIDATION FOR TNC

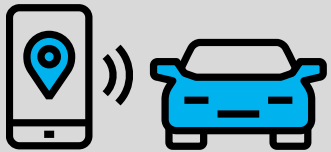
Ensure sensitivity of model and suitability for forecasting



SCENARIOS CONSIDERED

A world of

HIGH SHARING, PARTIAL AUTOMATION (Sharing)

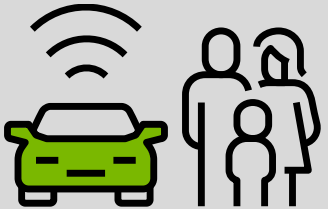


New technology enables people to significantly increase the use of **transit, ride-hailing** and **multi-modal travel. Partial automation** is introduced and is primarily used on the highway.

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.**

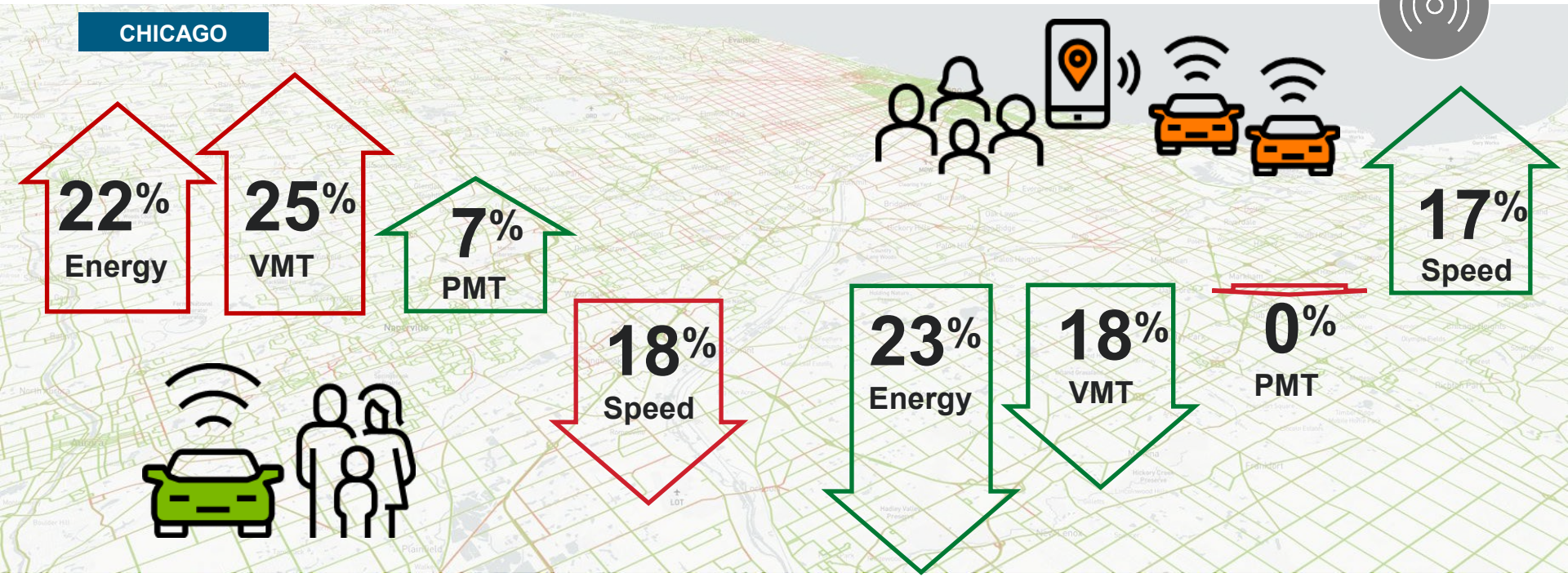
BASELINES Present Day

Base2 – **Medium-Term**, BAU Vehicles
Base3 – **Medium-Term**, Tech Success

Base5 – **Long-Term Future**, BAU Vehicles
Base6 – **Long-Term Future**, Tech Success

SHARED FLEET CAVS ENABLE HIGH SYSTEM EFFICIENCY

Compared to personally owned CAVs



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OPERATIONAL DIFFERENCES BETWEEN SAV AND PRIVATE AV ARE KEY

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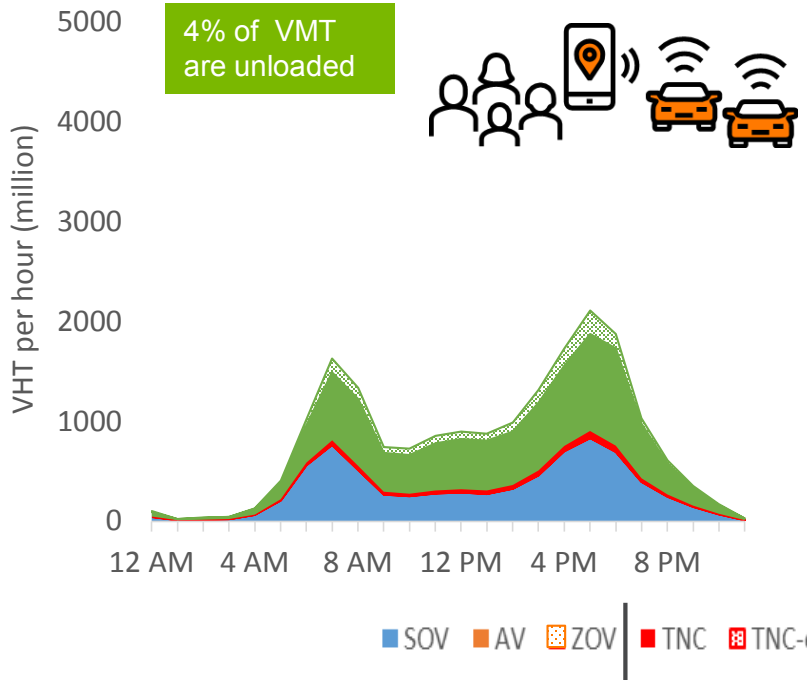
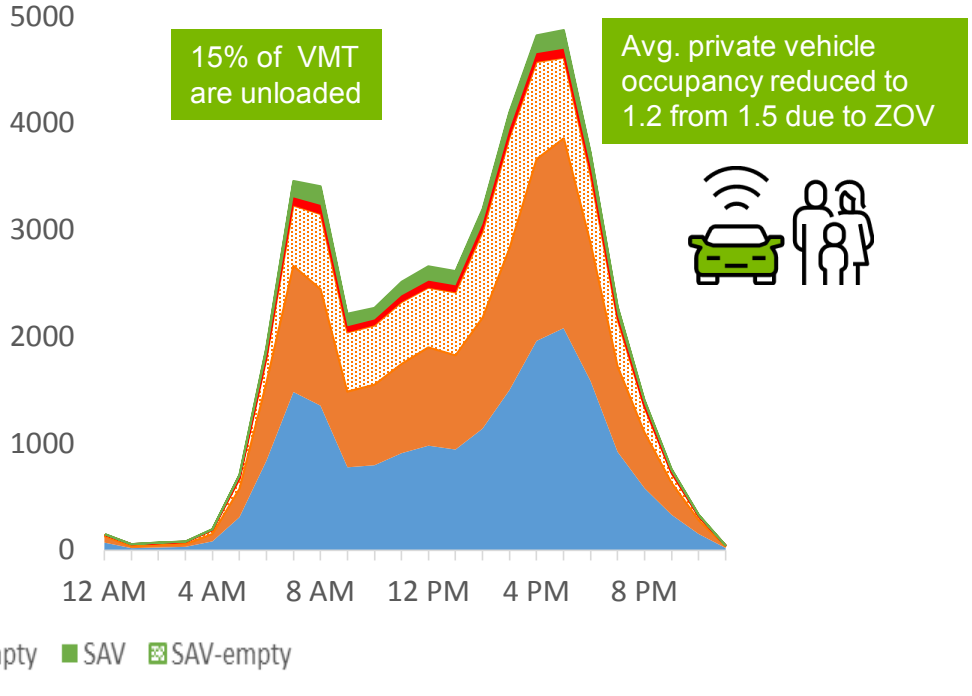
High-Sharing, High-Automation (SAV)



Low-Sharing, High-Automation (Private-AV)



SOV AV ZOV | TNC TNC-empty SAV SAV-empty

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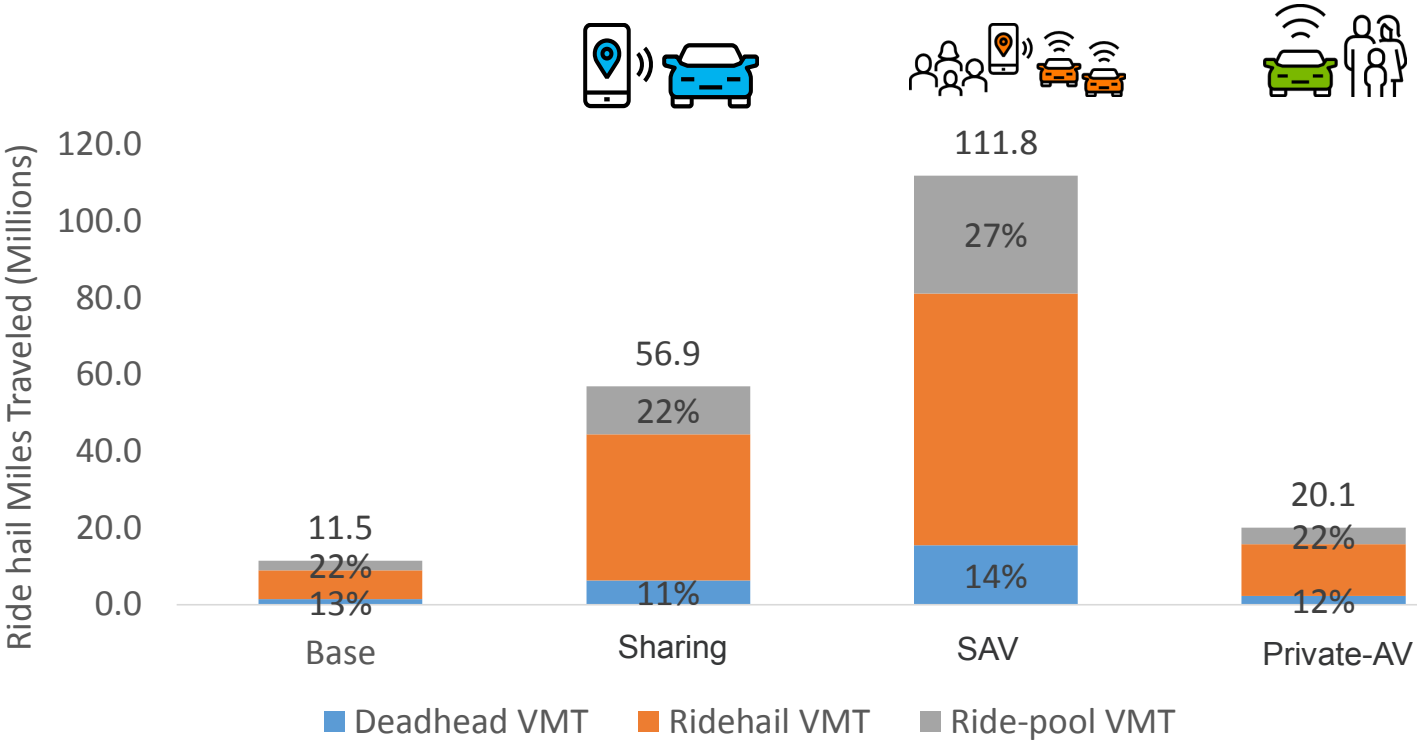
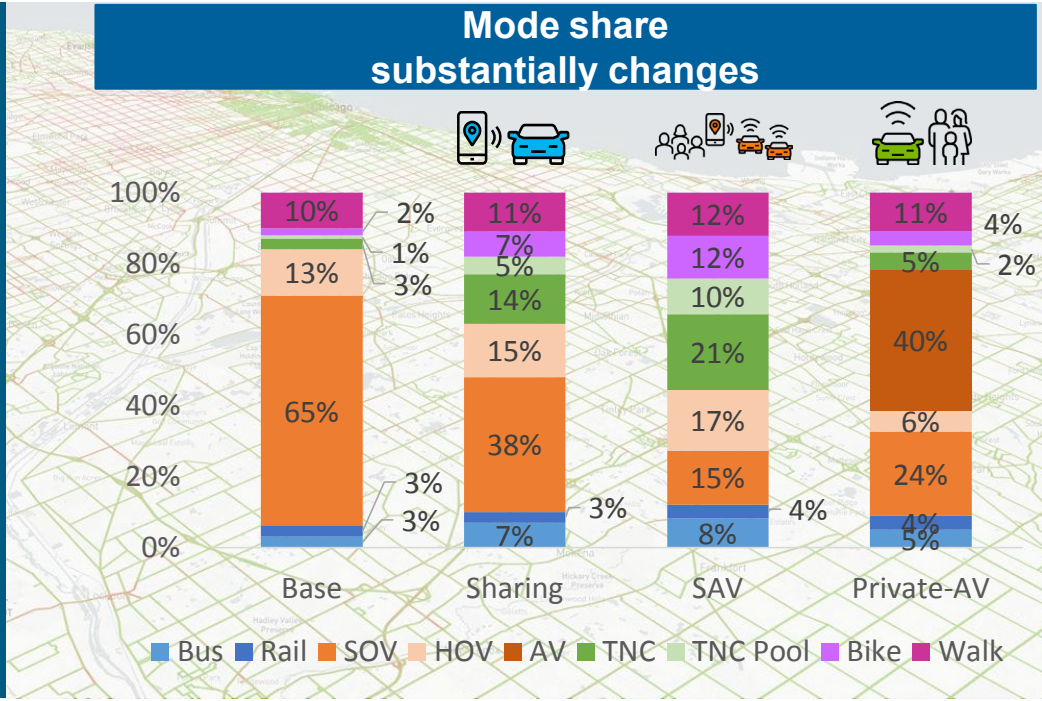
SHARING BENEFITS ENABLED BY EFFICIENT RIDE HAIL OPERATIONS



Avg. TNC occupancy:
Sharing: 1.04
SAV: 1.08
AV: 1.07

INDIVIDUAL TRAVEL BEHAVIOR CHANGES ALSO DRIVE 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

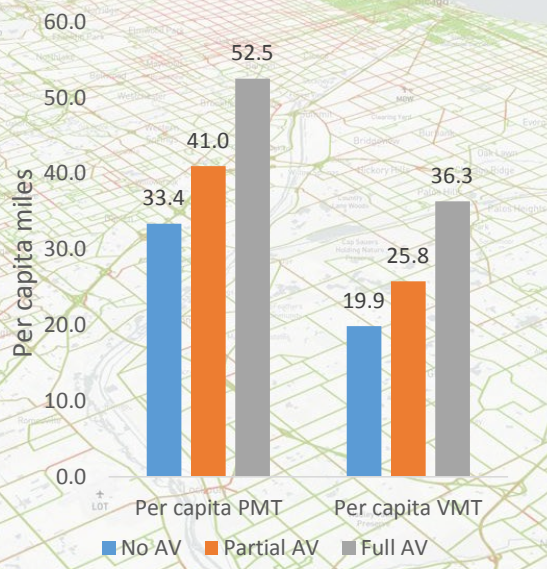


HOUSEHOLDS WITH AV BEHAVE MUCH DIFFERENTLY

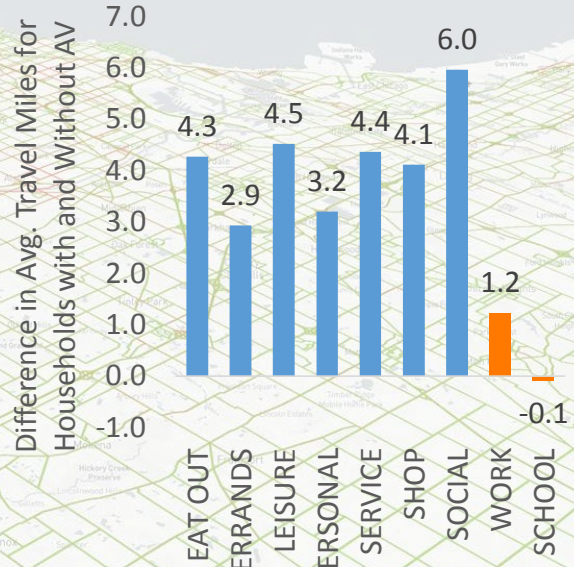
Up to 82% VMT increase in households owning an AV

- 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
- Consistent with (limited) empirical studies

Households with AV drive more than others



Driven by increased travel to discretionary activities

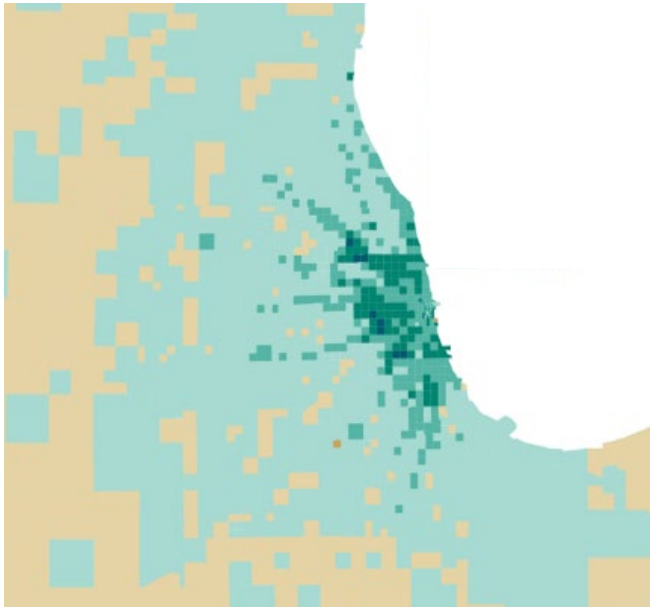


TRANSIT AND RIDE-HAIL CAN BE COMPLEMENTARY

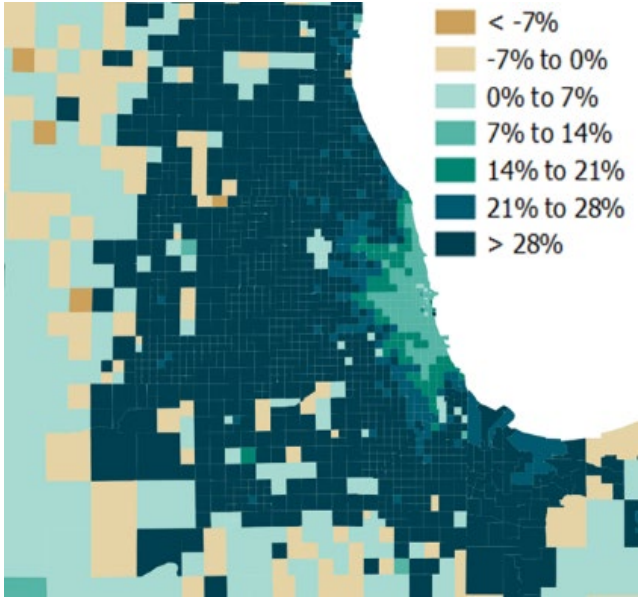
Transit is key mobility in urban core, TNC serves suburbs

- 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

Transit Mode Share change



TNC Mode share change



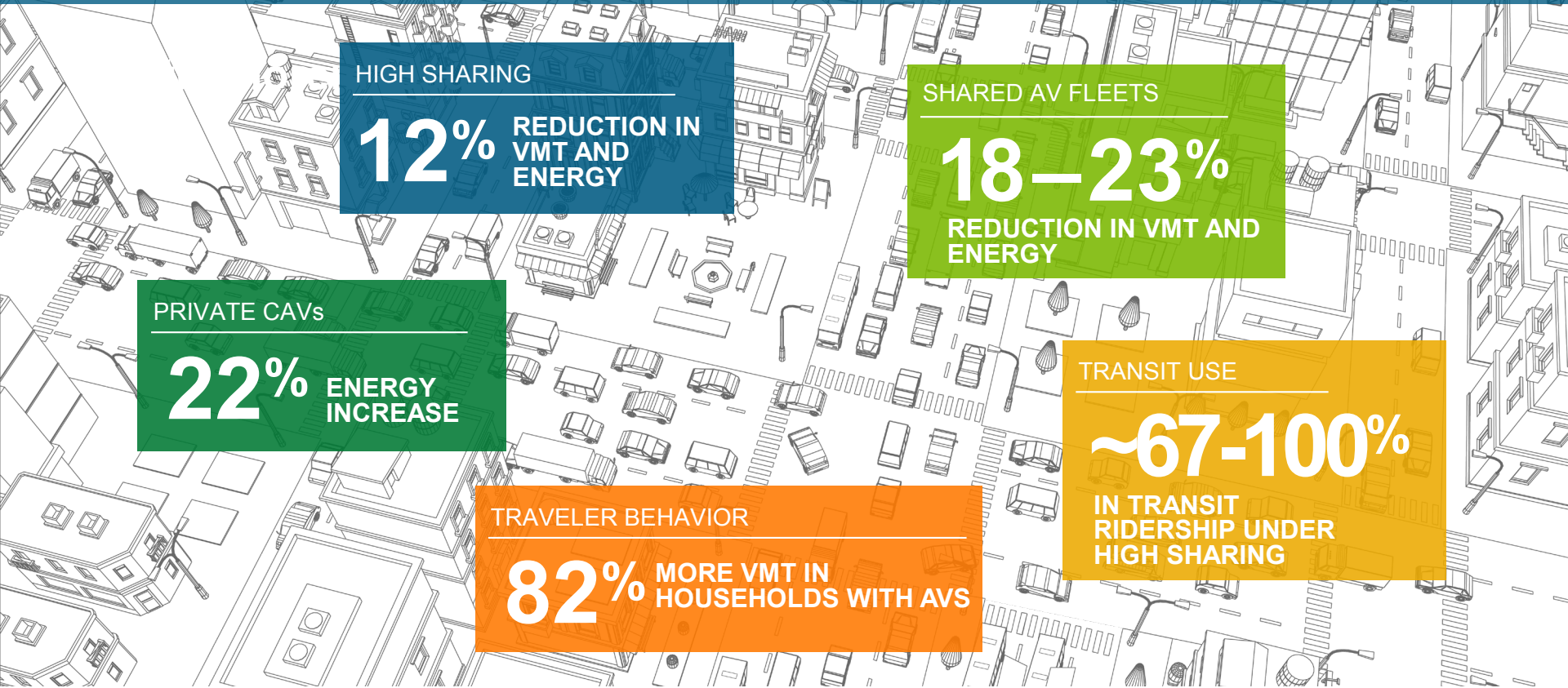
HIGH LEVEL SCENARIO RESULTS

Mobility and Energy Impact

	Sharing		SAV		Private-AV	
						
Factor	**BAU[3]**	**VTO[4]**	**BAU[3]**	**VTO[4]**	**BAU[3]**	**VTO[4]**
VMT	-12%	-12%	-18%	-18%	4%	25%
PMT[1]	-1%	-1%	-2%	0%	-1%	7%
Avg. Speed[2]	11%	12%	16%	17%	-1%	-16%
Vehicle Energy	-12%	-13%	-18%	-23%	2%	22%
MEP	34%	34%	51%	76%	23%	10%

1. Productive miles of travel: Auto drive miles + passenger miles (by all modes) + freight miles – unloaded vehicle miles
2. Proxy measure for congestions; 3. PEV: Plug-in Electric Vehicles (PHEV + BEV) – Scenario Inputs
3. Business-as-usual vehicle technology development
4. DOE VTO program success vehicle technology development

KEY FINDINGS



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HIGH SHARING

12% REDUCTION IN VMT AND ENERGY

SHARED AV FLEETS

18–23% REDUCTION IN VMT AND ENERGY

PRIVATE CAVs

22% ENERGY INCREASE

TRANSIT USE

~67-100% IN TRANSIT RIDERSHIP UNDER HIGH SHARING

TRAVELER BEHAVIOR

82% MORE VMT IN HOUSEHOLDS WITH AVS

For any questions, please contact:
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REFERENCES

- **Integrated modeling and agent-based modeling techniques:**
  - J. Auld, F. Souza, A. Enam, M. Javanmardi, M. Stinson, O. Verbas, A. Rousseau (2019). Exploring the mobility and energy implications of shared versus private autonomous vehicles. Proceedings of the 2019 IEEE Intelligent Transportation Systems Conference (ITSC), Pages 1691-1696
  - Auld, J., Verbas, O., Javanmardi, M., Rousseau, A., (2018). Impact of Privately-Owned Level 4 CAV Technologies on Travel Demand and Energy. Procedia Computer Science, The 9th International Conference on Ambient Systems, Networks and Technologies (ANT 2018), 914–919.
  - Auld, J., Hope, M., Ley, H., Sokolov, V., Xu, B., and Zhang, K. (2016). POLARIS: Agent-based modeling framework development and implementation for integrated travel demand and network and operations simulations. Transportation Research Part C: Emerging Technologies 64, 101–116.
- **Activity-based modeling and traveler behavior:**
  - Ardeshiri, A., T. Rashidi, J. Auld (2020). The Impact of Autonomous Vehicles and Multitasking on Value of Travel Time. Presentation at the 99th Annual Meeting of the Transportation Research Board. Washington, D.C., Jan 12-16, 2020.
  - Krueger, R., T. Rashidi, J. Auld (2019). Preferences for travel-based multitasking: Evidence from a survey among public transit users in the Chicago metropolitan area. Transportation Research Part F: Traffic Psychology and Behaviour 65, 334-343
  - Javanmardi, M., J. Auld, O. Verbas (2018). Analyzing Intra-household Fully Autonomous Vehicle Sharing. Presentation at the 97th Annual Meeting of the Transportation Research Board. Washington, D.C., Jan 12-16, 2018.
  - Shabanpour, R., Golshani, N., Tayarani, M., Auld, J., Mohammadian, A.K., (2018). Analysis of telecommuting behavior and impacts on travel demand and the environment. Transportation Research Part D: Transport and Environment 62, 563–576.
  - Golshani, N., Shabanpour, R., Auld, J., and Mohammadian, A. (2018). Activity start time and duration: incorporating regret theory into joint discrete–continuous models. Transportmetrica A: Transport Science, 1–19.
  - Auld, J., and Mohammadian, A. (2009). Framework for the development of the agent-based dynamic activity planning and travel scheduling (ADAPTS) model. Transportation Letters 1, 245–255.
- **Network and traffic flow modeling:**
  - Felipe Paper – TRB 2020
  - Auld, J., Verbas, O., Stinson, M., (2019). Agent-Based Dynamic Traffic Assignment with Information Mixing. Procedia Computer Science, The 10th International Conference on Ambient Systems, Networks and Technologies (ANT 2019), 864–869.
  - Souza, F. de, Verbas, O., Auld, J., (2019). Mesoscopic Traffic Flow Model for Agent-Based Simulation. Procedia Computer Science, The 10th International Conference on Ambient Systems, Networks and Technologies (ANT 2019), 858–863.
  - Verbas, Ö., Auld, J., Ley, H., Weimer, R., Driscoll, S., (2018). Time-Dependent Intermodal A* Algorithm: Methodology and Implementation on a Large-Scale Network. Transportation Research Record 2672, 219–230.
- **Freight Modeling**
  - Stinson, M., A. Enam, J. Auld, A. Moore (2020). Assessing the e-commerce effect: parcel delivery vs. household shopping. Presentation at the 99th Annual Meeting of the Transportation Research Board. Washington, D.C., Jan 12-16, 2020.
  - Stinson, M.; Auld, J.; and Mohammadian (2019). An Agent-based Model of Freight Transportation with Emerging Trends in POLARIS. A. Pre-print of Proceedings from the VREF Urban Freight Conference, Gothenburg, Sweden in October 2018, 2019.
- **TNC / SAV Modeling**
  - Gurumurthy, K.M., F. de Souza, A. Enam, J. Auld (2020). Large-scale Simulation of Shared Autonomous Vehicles: Integrating the Supply and Demand Perspectives. Presentation at the 99th Annual Meeting of the Transportation Research Board. Washington, D.C., Jan 12-16, 2020.

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APPLYING THE BEAM SMART MOBILITY WORKFLOW TO SAN FRANCISCO

MODELING INTEGRATED MESOSCALE URBAN SYSTEMS WITH THE BEAM MODEL

ZACHARY NEEDELL
Lawrence Berkeley National Laboratory

This presentation does not contain any proprietary, confidential, or otherwise restricted information.

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WHY MODEL FUTURE TRANSPORTATION SYSTEMS?

What is the problem?

- Automation, electrification, and other changes will transform transportation systems
- Behavioral change will be just as important

→ how do they interact?

What is needed?

- Decisions must be made, despite uncertainty
- Technologies being developed now will be used in a world that is very different from today
  - Differences in context can be as or more important than differences in performance

MODELING TRANSPORT SYSTEMS

What are the important factors to consider?

Supply

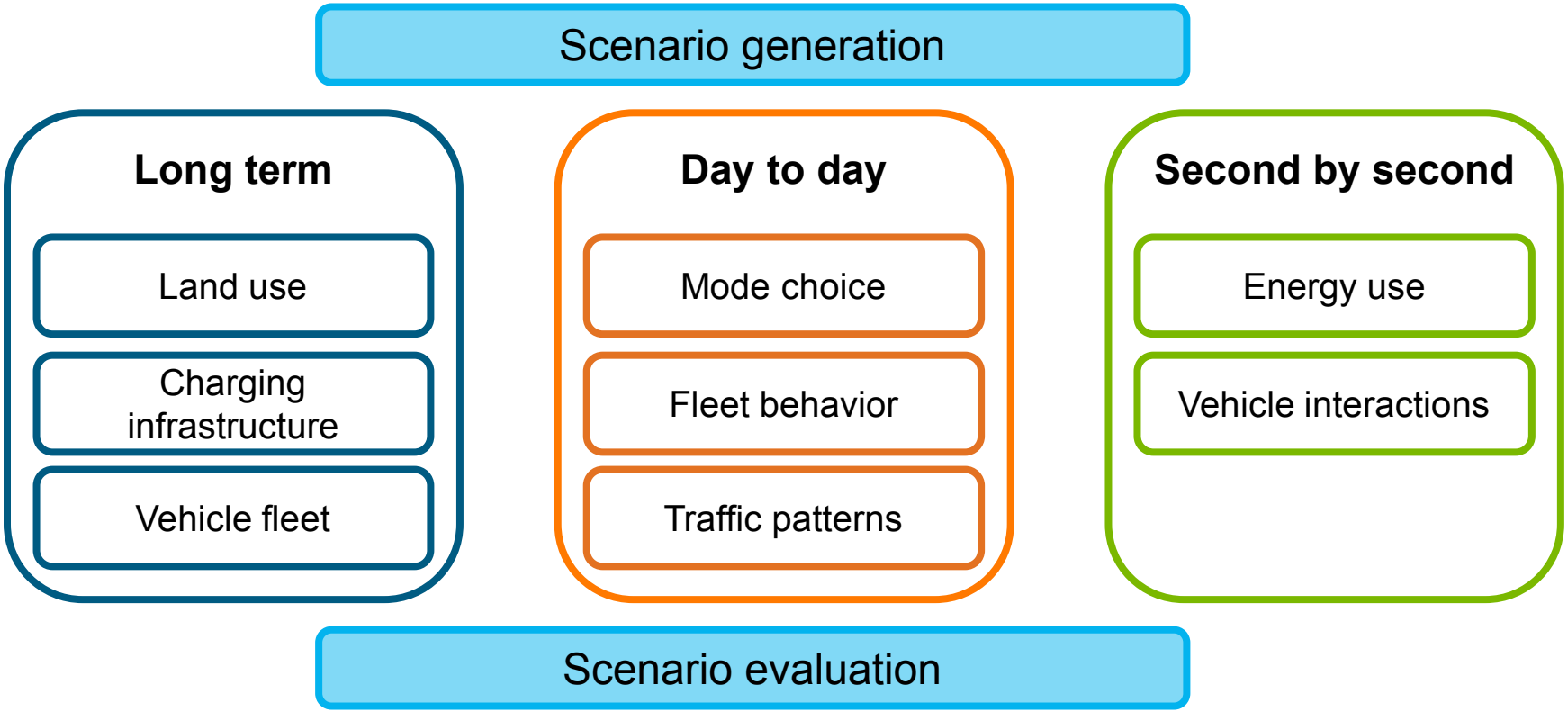
- What are the travel speeds on the road network?
- How crowded are the buses?
- What are wait times for TNCs?
- How plentiful are empty parking spaces?

Demand

- How many trips do people take?
- What mode do they use?
- What route do they take?
- What vehicle types are purchased?
- Where do businesses locate?

- Needed for understanding big changes to the transportation system
- Allows for feedbacks, where supply and demand interact
  - Induced demand, land use change, new technologies and mobility services

MODELING ACROSS TIME SCALES



MODELING ACROSS TIME SCALES

BERKELEY LAB — Whole Traveler / POLARIS coordination — Argonne NATIONAL LABORATORY

Long term

- Berkeley — UrbanSim
- NREL — EVI-Pro, FCSPlan — Berkeley
- NREL — ADOPT

Day to day

BEAM

Second by second

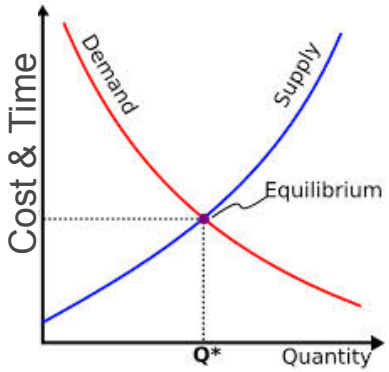
- NREL — Route-E / FastSim
- AIMSUN — BERKELEY LAB

NREL — MEP

BEAM RESOURCE MARKETS

- Road Capacity
- Vehicle Capacity
- Ride Hail Availability
- Parking/Refueling Access

- Supply:
  - Ride Hail
  - Vehicle sharing
  - Driving
  - Transit
  - Parking
  - Charging Infrastructure
  - Biking, Walking

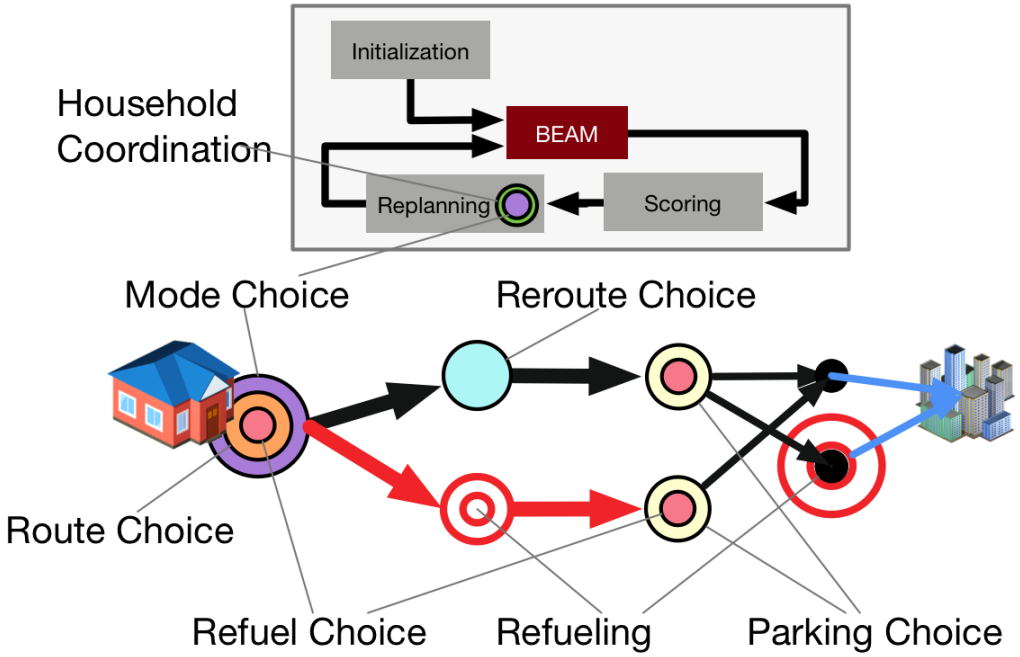


- Demand:
  - Mode Choice
  - Route Choice
  - Rerouting
  - Park Choice
  - Refuel Choice

BEHAVIORAL MODELING IN BEAM

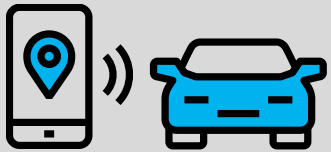
Hybrid of before-day and within-day planning.

Mode, trip, and route planning dynamic (on-the-fly)… enabling faster convergence toward user equilibrium.



SCENARIOS

HIGH SHARING, PARTIAL AUTOMATION (Sharing)



Medium-Term Future

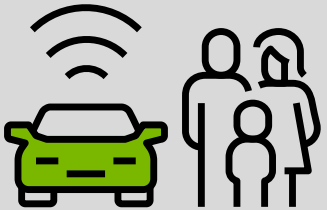
A2 - Business-as-usual vehicles
A3 - DOE vehicle technology success

HIGH SHARING, HIGH AUTOMATION (SAV)

Long-Term Future

B5 - Business-as-usual vehicles
B6 - DOE vehicle technology success

LOW SHARING, HIGH AUTOMATION (Private AV)



Long-Term Future

C5 - Business-as-usual vehicles
C6 - DOE vehicle technology success

BASELINES

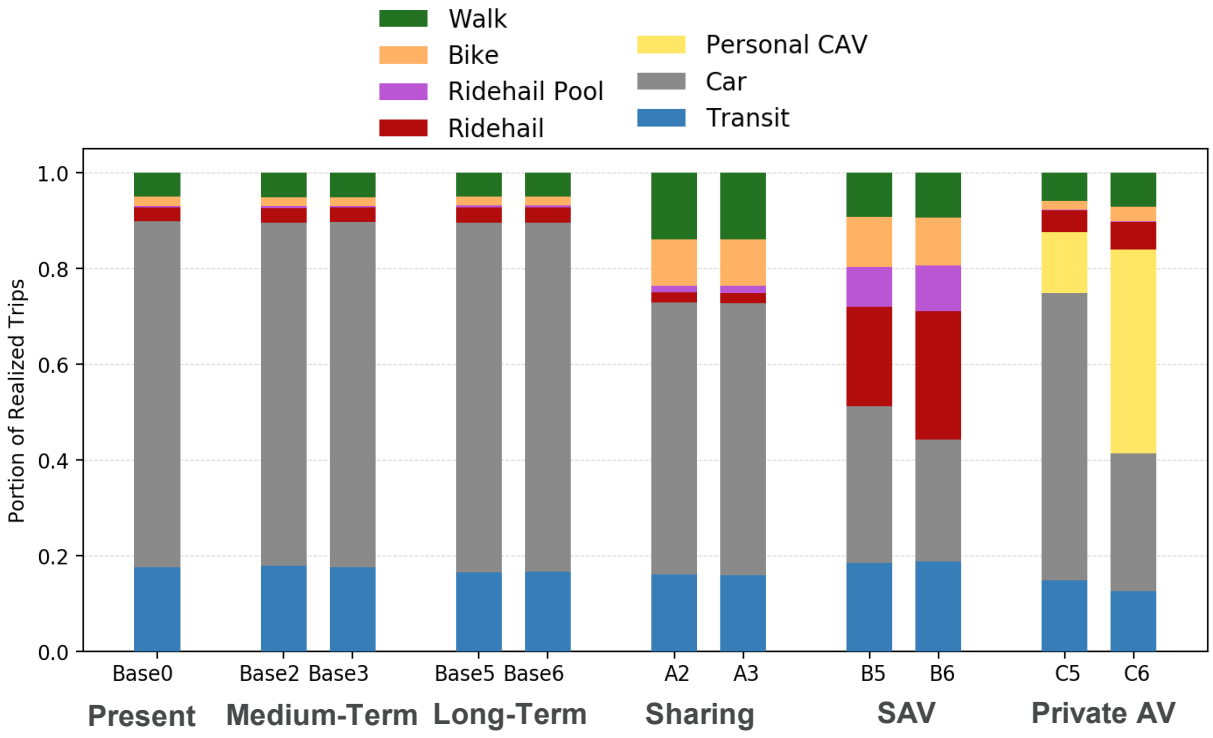
Base0 – Present Day

Base2 – **Medium-Term**, BAU Vehicles
Base3 – **Medium-Term**, Tech Success

Base5 – **Long-Term Future**, BAU Vehicles
Base6 – **Long-Term Future**, Tech Success

MODAL SPLITS

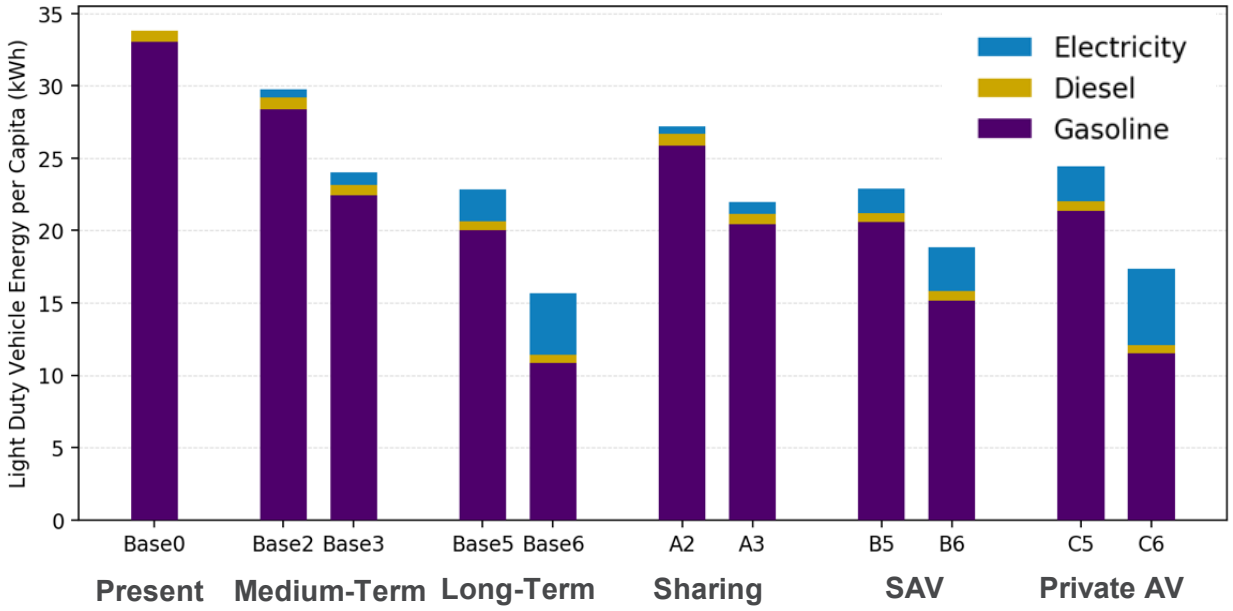
Household vehicle ownership assumptions and different valuations of travel time are main drivers of variation in commuting mode share across scenarios; changes to both are required to replace private car travel



Modal Market Shares for commute in San Francisco Bay Area across Scenarios

LIGHT DUTY VEHICLE ENERGY

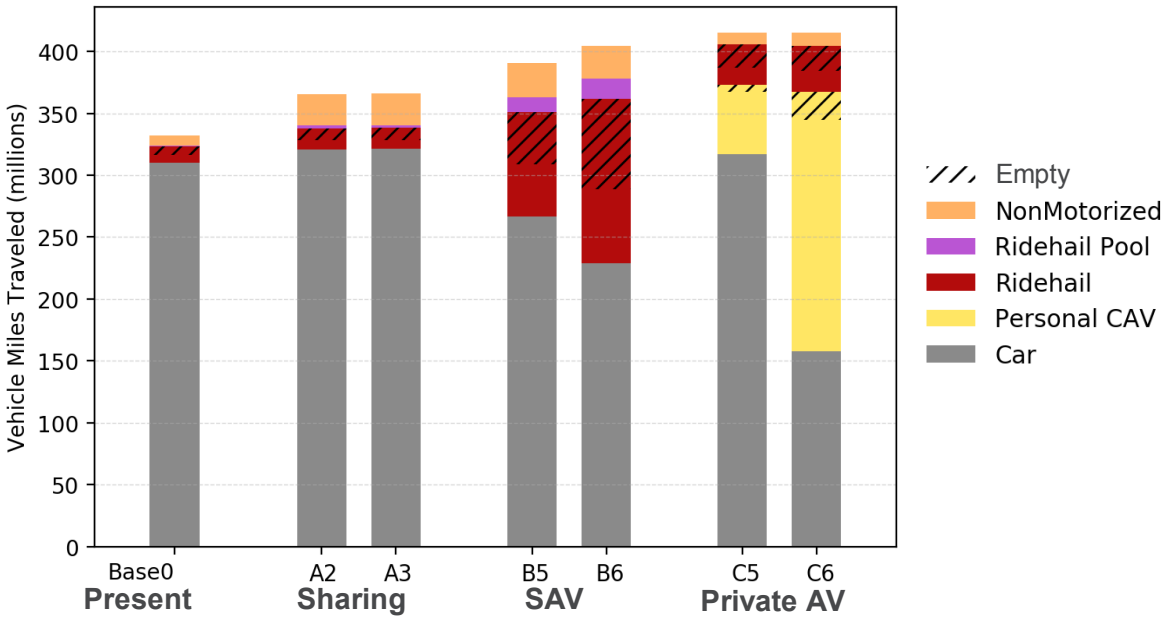
Advanced powertrain technologies, including electrification, remain the primary factor influencing future transportation energy use, having a greater impact than either vehicle sharing or automation



Per capita light duty vehicle energy consumption by fuel type for the San Francisco Bay Area

VEHICLE MILES TRAVELED (VMT)

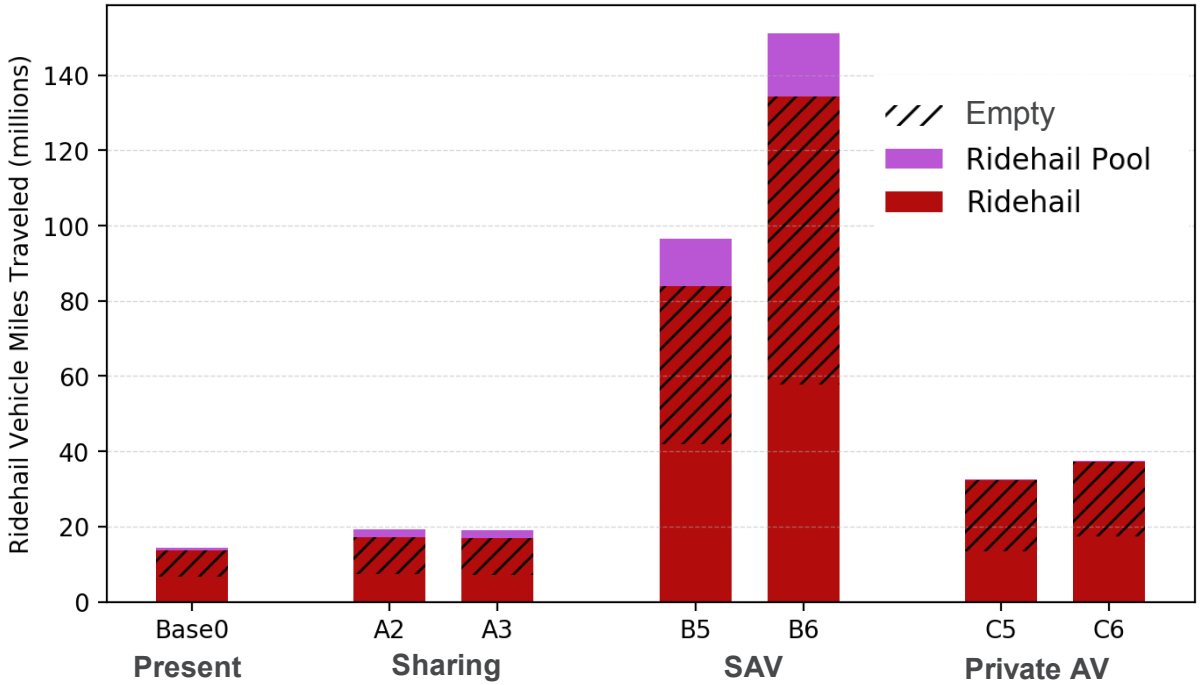
Neither preference for walking, biking, and shared modes (Shared) nor moderate personal vehicle retirement rates (Private AV) replace personal car travel as majority commute mode (including transit which is not shown here)



Total light duty vehicle miles traveled for commuting by mode for the San Francisco Bay Area.

RIDE HAIL VMT

Increasing ride hail occupancy while maintaining high enough quality service to attract travelers is a fundamentally difficult problem.

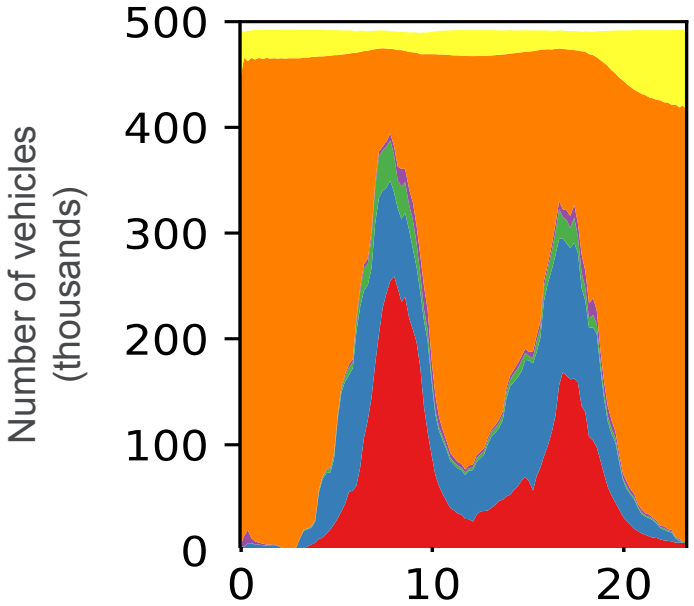


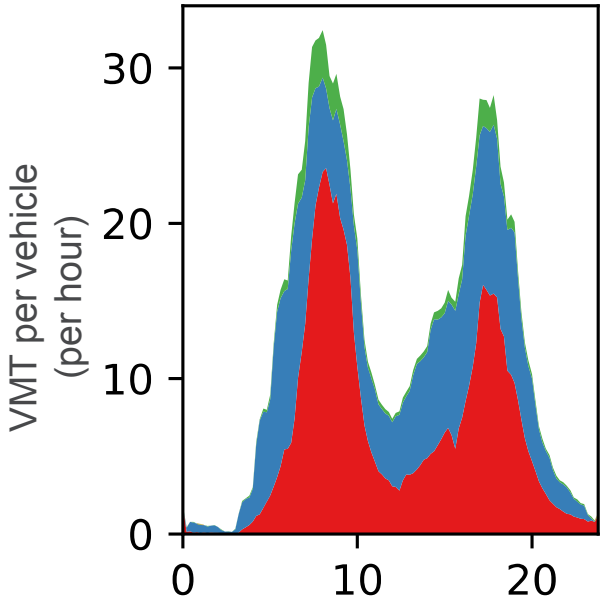
Vehicle miles traveled by ride hail for the San Francisco Bay Area, differentiating between empty vehicle (hatched) and multiple passengers (purple) miles

RIDE HAIL FLEET OPERATIONS

With Passenger
Repositioning
Deadheading
Charging
Idle
Offline

SAV Scenario with VTO Technology

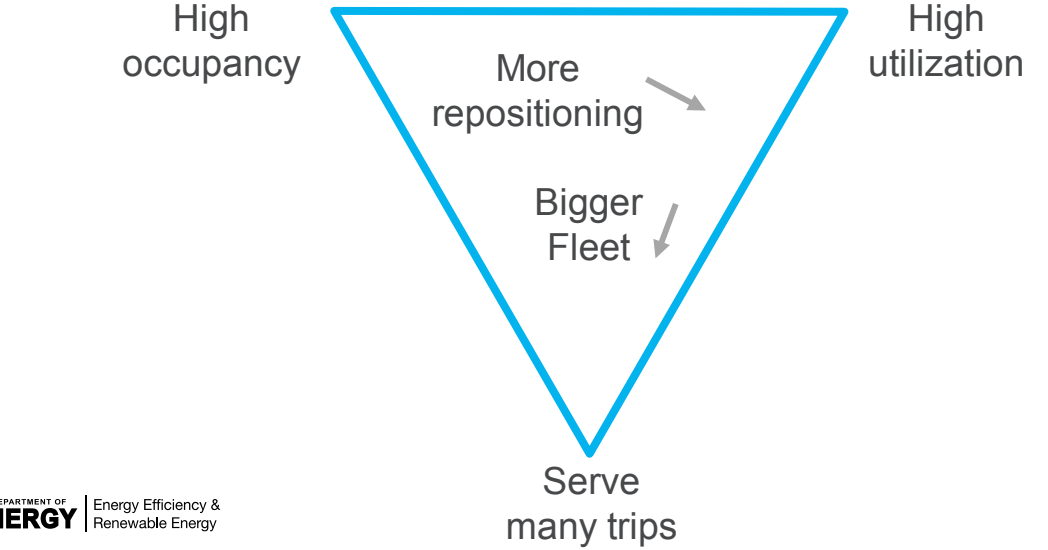




RIDE HAIL SENSITIVITY ANALYSIS

Assumptions about ride hail fleet operations are very important

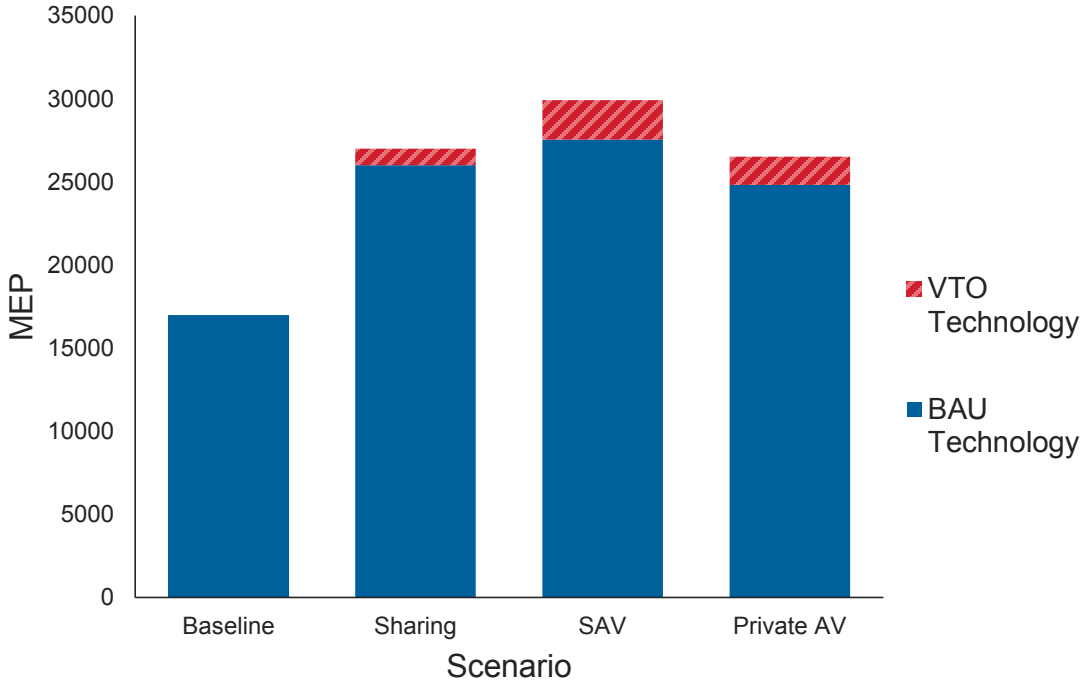
Elasticity of WRT	Wait Time	VMT	Occupancy	Total Trips	Rides / Vehicle
Fleet Size	-0.14	0.48	-0.35	0.28	-0.72
Repositioning	-0.04	0.22	-0.22	0.002	0.002



- Empty VMT from ride hailing drove major differences between scenarios
- Assumptions about fleet size and repositioning are important
- Reveals important trade-offs in fleet management

MOBILITY ENERGY PRODUCTIVITY

MEP scores are higher than baseline for shared mobility scenarios (Sharing and &SAV), but are lower for the privately owned automobile scenario (Private AV); suggests that shared mobility can augment vehicle technology improvement



SF Bay Area MEP values across the workflow scenarios

LONG TERM VISION

Next steps for BEAM

- Fuller representation of all the actors in the transportation system
  - Freight and deliveries
  - Curb space use and management
- Consistent representation of agents and decisions across time scales
  - More model sensitivity and predictive power
- Modeling process that is responsive and accessible to stakeholders
  - More modularity → meet interested parties where they are
  - Faster model → more runs and full exploration of parameter space

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MOBILITY FOR OPPORTUNITY

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BERKELEY LAB

INL Idaho National Laboratory

NREL NATIONAL RENEWABLE ENERGY LABORATORY

OAK RIDGE National Laboratory