Project ID#: eems024
Pillar: MDS

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

Market Acceptance of Advanced Automotive Technologies (MA3T) - Mobility Choice: Analyzing the Competition, Synergy, and Adoption of Fuel and Mobility Technologies

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Oak Ridge National Laboratory
2019 Vehicle Technologies Office Annual Merit Review
June 11, 2019

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

OVERVIEW

Timeline

Project start:	01 Oct 2017
Project end:	30 Sep 2019
Percent complete:	80%

Barriers

- Complex role of the human decision-making process in mobility systems
- Determining the value and productivity derived from new mobility technologies
- Computational difficulty of accurately modeling and simulating large- scale transportation systems

Budget

- Total project funding: $200K
  - DOE share:100%
- Funding for FY 2019: $0K

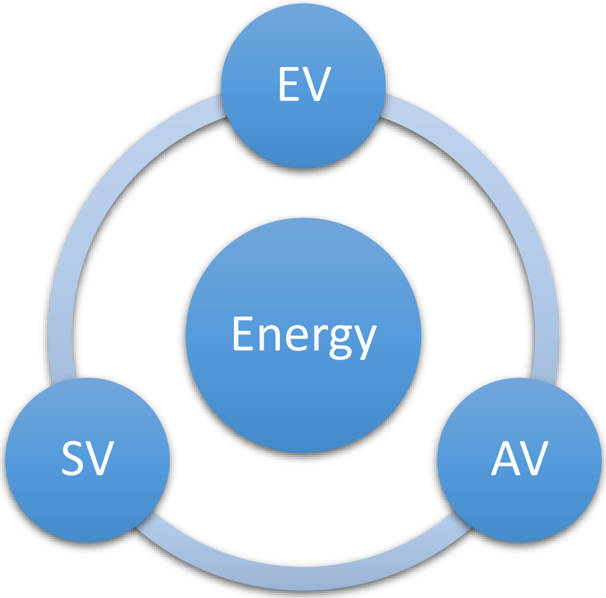
Partners

- Collaborations
  - Argonne National Laboratory
  - National Renewable Energy Laboratory
  - Lawrence Berkeley Laboratory
  - Vanderbilt University
- Project team: Zhenhong Lin (PI), Fei Xie

OBJECTIVES

- Understand behavioral factors and technological opportunities to accelerate transition to new mobility technologies such as automation and sharing.
- Model consumer mid-term and long-term consumer choices of vehicle and mobility technologies with a focus on energy implications.

  - Simulate long-term vehicle choices (buy new vehicles or not, buy human-driven or fully-automated vehicles, cooperative adaptive cruise control considered).
  - Simulate mid-term mobility choices (primarily using TNC (shared vehicles), public transit, or personal vehicles; TNC vehicles include human-driven and driverless vehicles).
  - Calibrate the behavioral parameters to SMART studies, historical and stated-preference data, including sales, TNC/mode choice demand, WholeTraveler observation and/or other surveys
  - Use MA3T-MC to generate scenario results to support SMART research



Research Questions

- Who are more likely to choose
  - Connected Automated Vehicles (CAV)
  - Shared mobility
  - Shared CAV
  - Plug-in Electric Vehicle (PEV)
  - PEV-CAV
  - Shared PEV
- Why, when and how many?
- What are the behavior and technological barriers?

...given relevant assumptions.

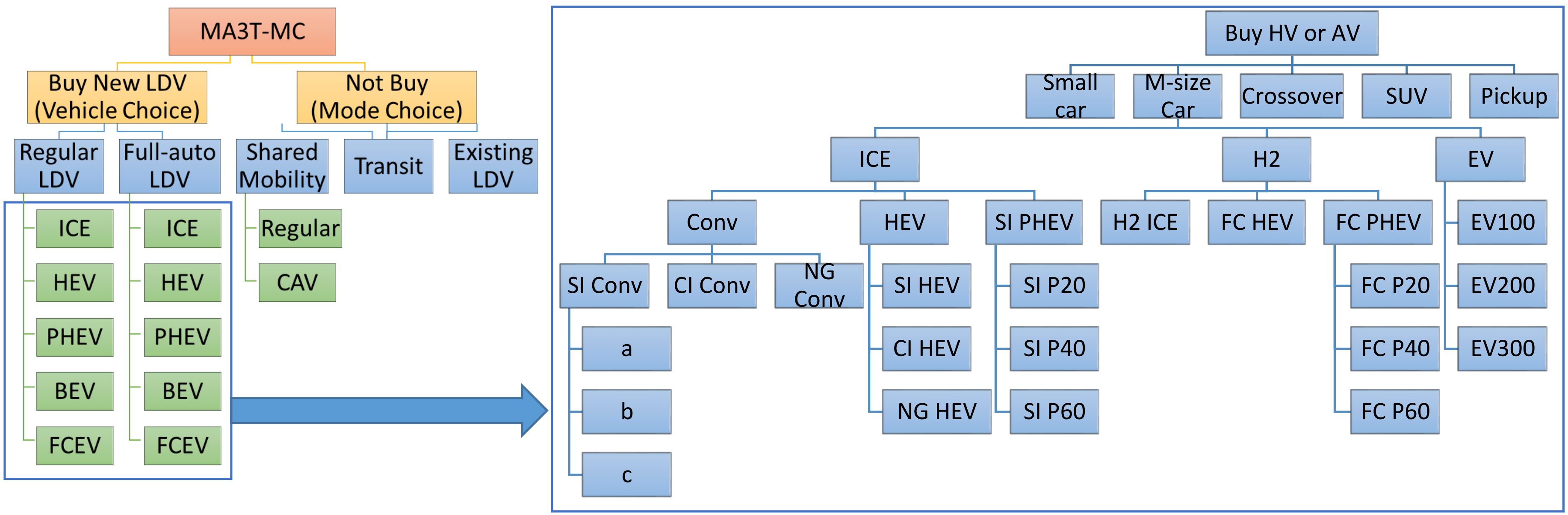
Therefore, it is for scenario analysis, not future prediction.

MILESTONES

Month/yeard	Description	Status
Jun 2019	Publishable scenario results on market penetration of CAV and shared mobility at national and local levels and by powertrain types, urban or rural, household type, and other demographic attributes.	On track

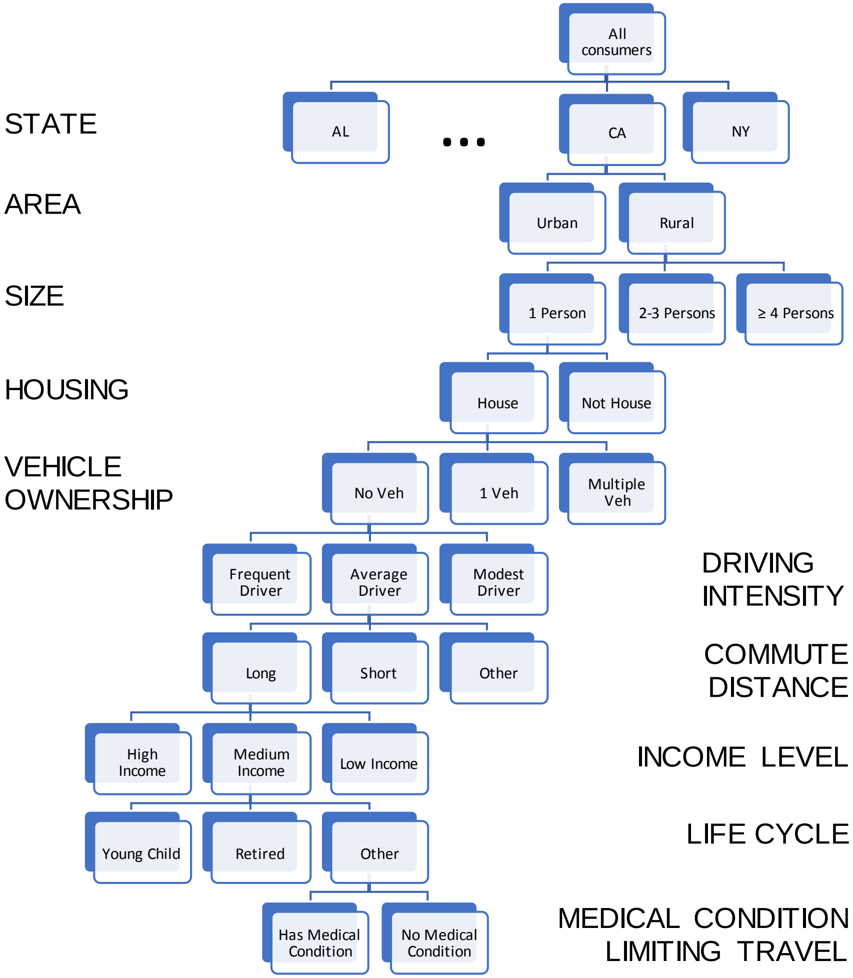
Nested multinomial logit theory with relevant vehicle and mobility technologies

- A natural expansion of powertrain-choice-only MA3T
- Cover VTO R&D technologies, highly-automated vehicles, shared mobility
- Technology synergy and co-leaning



Consumer segmentation for reflecting consumer heterogeneity and network externality

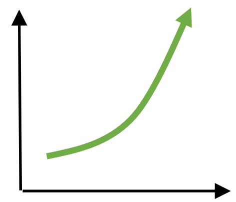
- Use NHTS 2017 data
- Household weighted K-Modes clustering based segmentation (implemented using Java)
- Automatically cluster >120,000 HHs into user defined segment groups (7238 in MA3T-MC)
- More depth in segmentation dimension without worry of exponential growth in size
- Future opportunity in evaluating impacts of segmentation accuracy on estimation of vehicle market



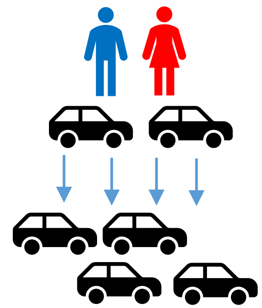
Systems dynamics between vehicle purchase and mode choice

- Decreasing return on investment (ROI) of vehicle purchase

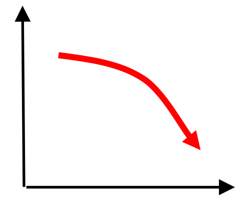
- Cost Reduction
- Better fuel efficiency
- Automation



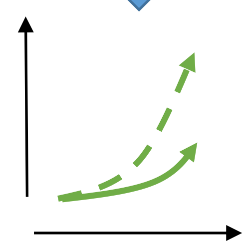
Increase in sales



Increase in vehicle ownership

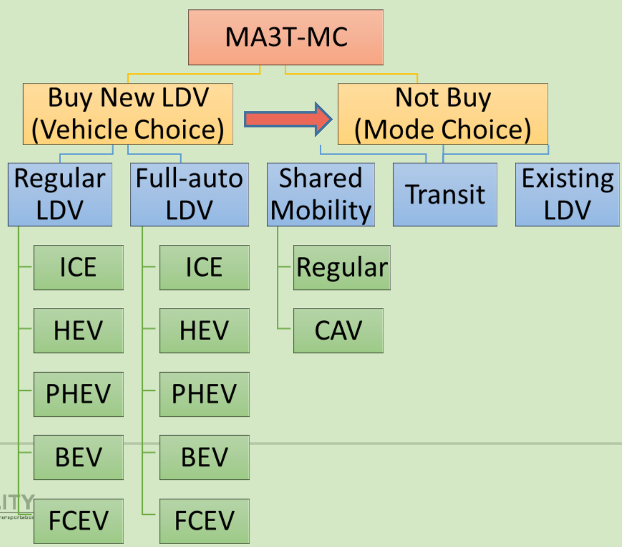


Decrease in Return on Investment of purchase



Resistance on Sales

- Connection between vehicle stocks and mode choice



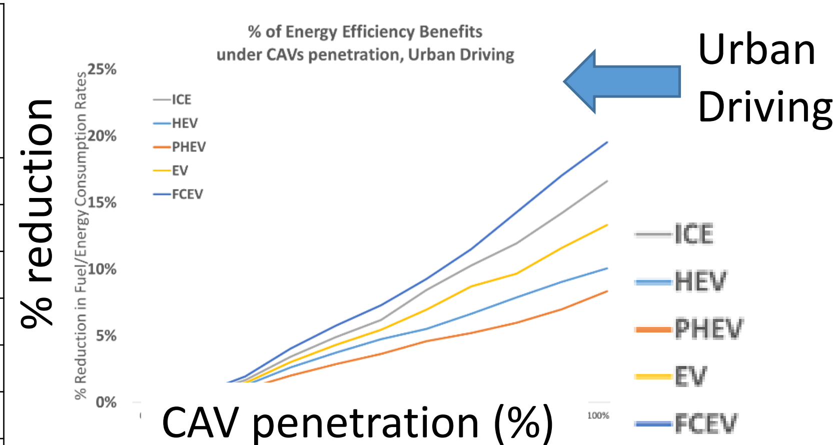
Feedback of changes in model attributes to mode choice (e.g. automation perfection)

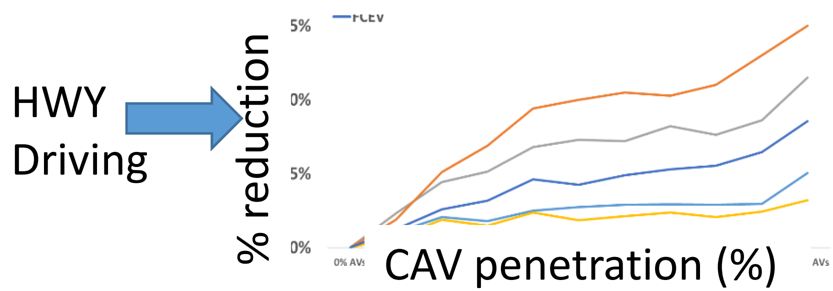
On-road CAV energy efficiency linked to fuel type and improved by on-road CAV penetration

- **Impacts of CAV sensor load** are processed based on data provided by ANL **Polaris/Autonomie**

Tech	CAV Load Assumption	Impact on fuel consumption (GGEPM)	Impact on electricity consumption (wh/mile)
Conv.	600 W	0.0014	-
	1000 W	0.0026	-
	2500 W	0.0081	-
HEV	600 W	0.0020	-
	1000 W	0.0033	-
	2500 W	0.0083	-
PHEV	600 W	-0.0002	23.14
	1000 W	-0.0002	40.66
	2500 W	-0.0002	108.28
BEV	600 W	-	25.91
	1000 W	-	45.09
	2500 W	-	117.06

- **CAV energy efficiency** are estimated by **SUMO/FASTSim** simulation





$$CAV\ fuel\ consumption = HV\ consumption \times (1 - Reduction\%) + CAV\ Load$$

Valuation of engagement in activities during travel, relevant to estimating travel time cost recovery with CAV and shared mobility

- Importance of being able to engage in activities

Assumption on valuation relationship

importance level	Valuation level
1	0%
2	50%
3	100%
4	150%
5	200%

WholeTraveler TRANSPORTATION BEHAVIOR STUDY

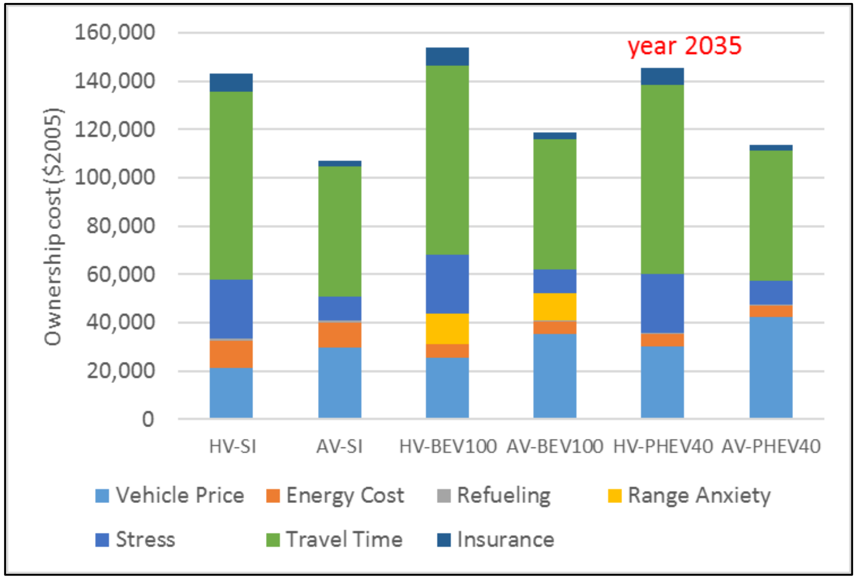
Income level	Child?	Importance level	valuation level
low	No	2.65	82.5%
low	Yes	3.13	106.3%
medium	No	2.74	87.0%
medium	Yes	2.63	81.7%
high	No	2.74	87.2%
high	Yes	3.06	103.1%

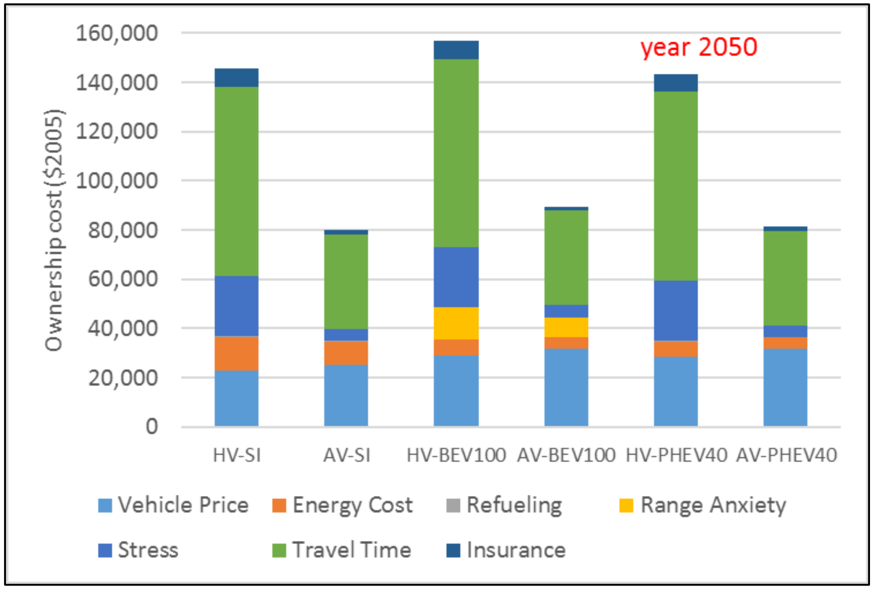
$$Travel\ Time\ Cost = TimeValue \times (1 - AutomationUF\% \times Perfection\% \times \boldsymbol{Valuation\ Level}\%)$$

Weighted average of work related and non-work-related time value

Travel time cost recovery, driving stress reduction and safety value are reasons for potential disruption

- Generalized ownership cost components explains disruption of automation
  - Reduction in insurance cost (likely underestimation for safety value)
  - Stress reduction
  - Less BEV range anxiety
  - Less energy cost, but less influential than other benefits





Induced Travel and Energy Rebound with CAV

- Elasticity on induced travel and energy rebound with CAV is based on a recent microeconomic study by University of Michigan (Taiebat et al., 2019)

Microeconomic model

Max Utility function

subject to

Monetary budget constraint

Time budget constraint

NHTS 2017 Travel Data

Elasticity by income level

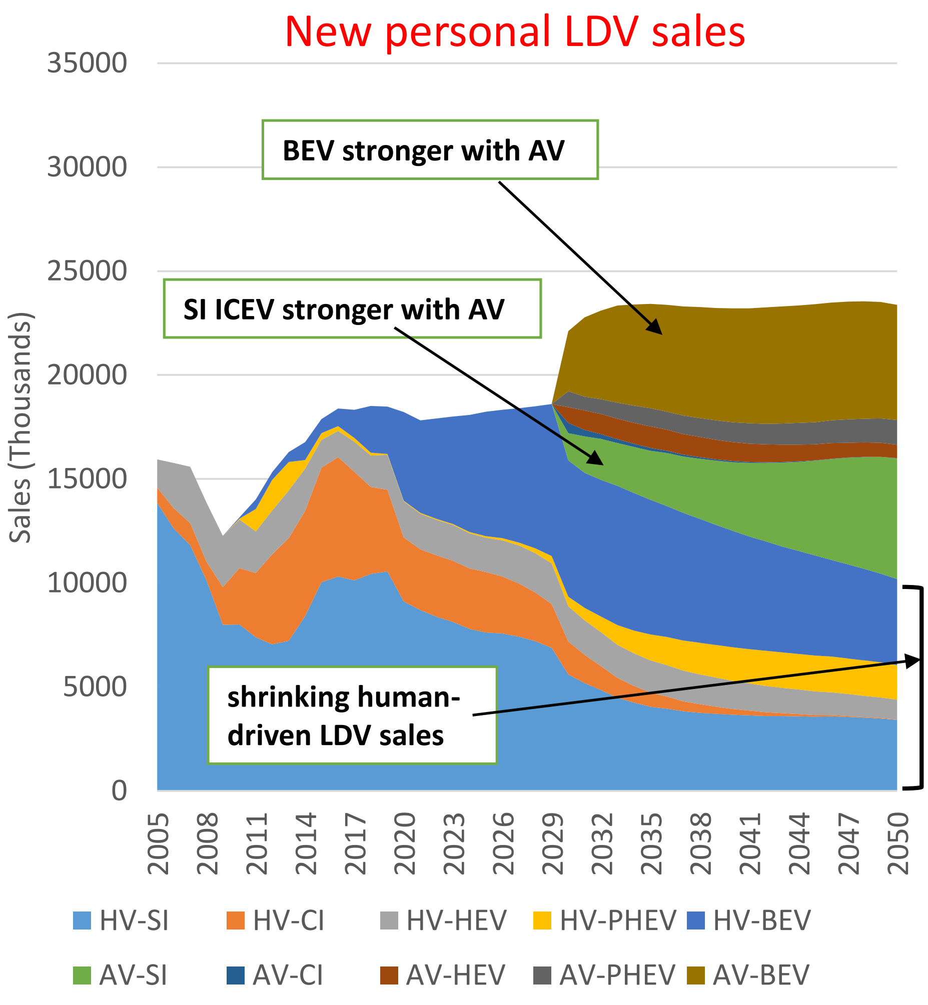
Income Level	Elasticity
Low	-30.4%
Medium	-42.3%
High	-42.1%

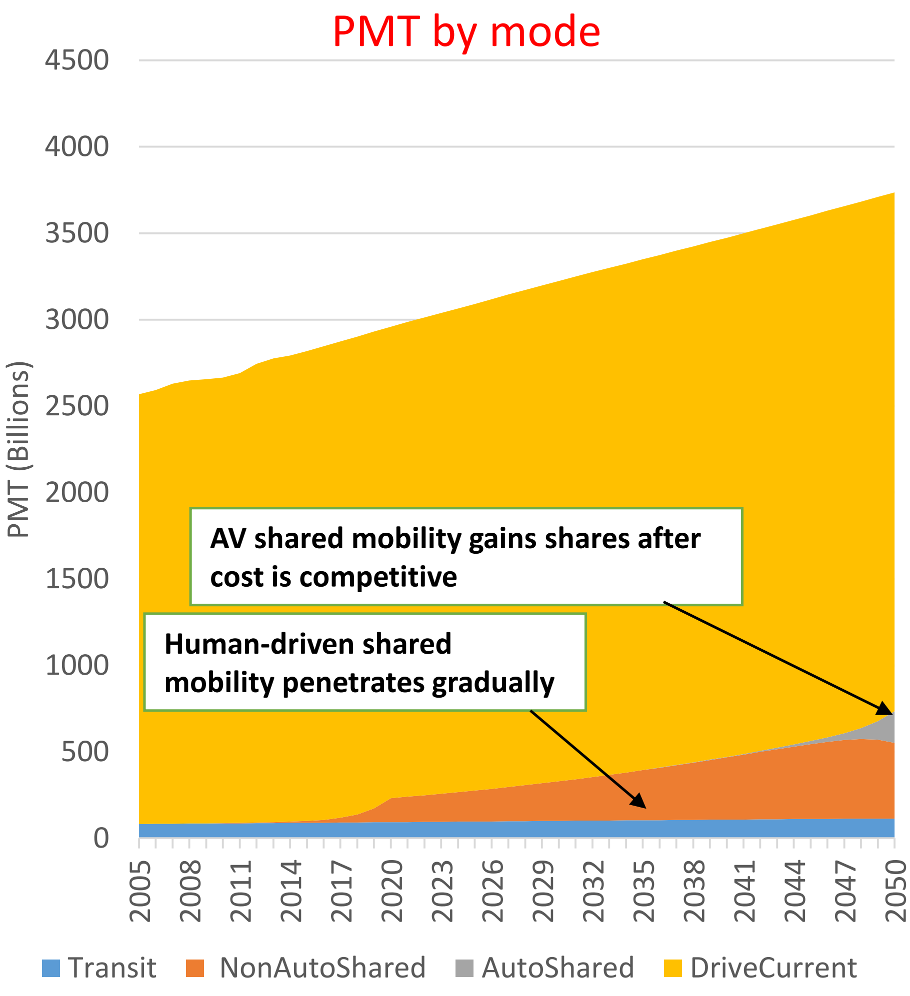
- **α%** change in monetary cost of vehicle ownership will result in **Elasticity× α%** change in PMT
- Example: for medium income, **1% decrease** in cost will results in **0.423% increase** in PMT

MA3T-MC result illustration – scenario definitions of 4 cases

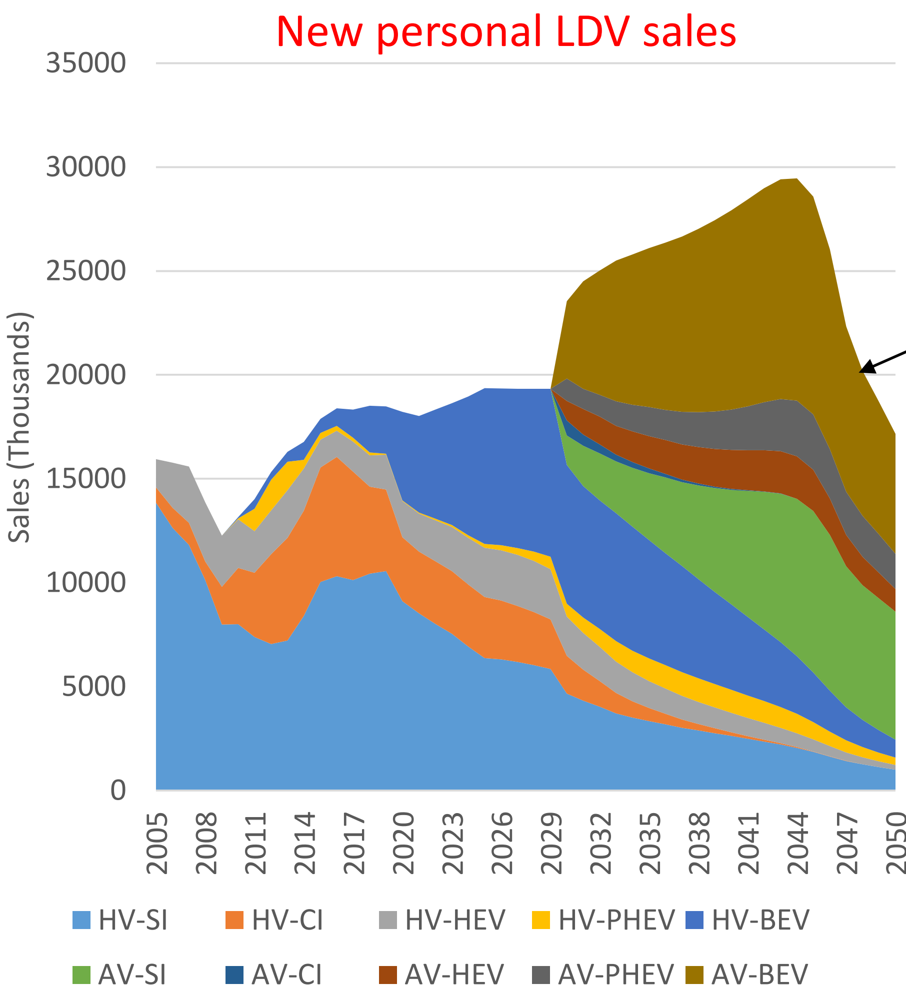
- Base
  - DOE BaSce study NoProgram case; AV and shared AV (SAV) starts in 2030 and improves overtime through 2050
- ProgramSuccess
  - BaSce study ProgramSuccess case; AV and SAV starts in 2030 and improves overtime through 2050
- ProgramSuccess & AV-Late
  - Personal AV enters market in 2040 (SAV still enters in 2030)
- ProgramSuccess & AV-Late & SAV-EarlierBetter
  - Personal AV enters market in 2040. SAV still enters in 2030, but with lower cost and better performance.

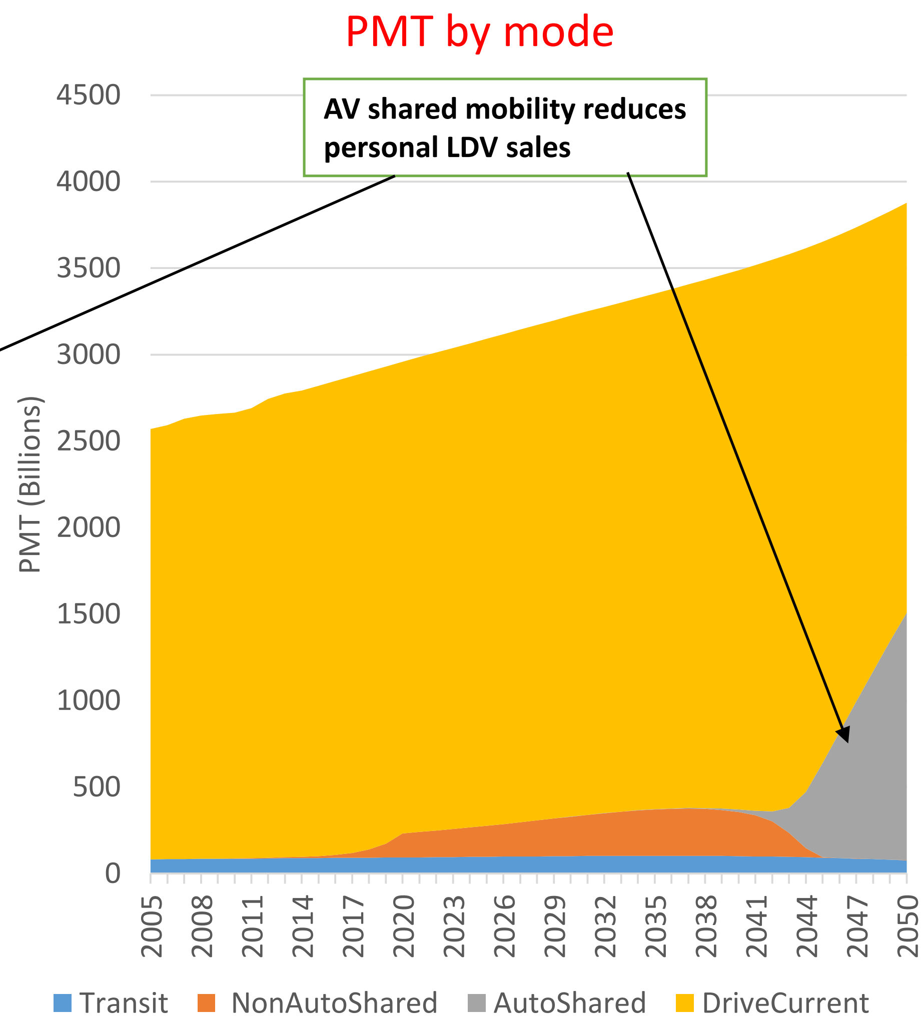
MA3T-MC results: Base



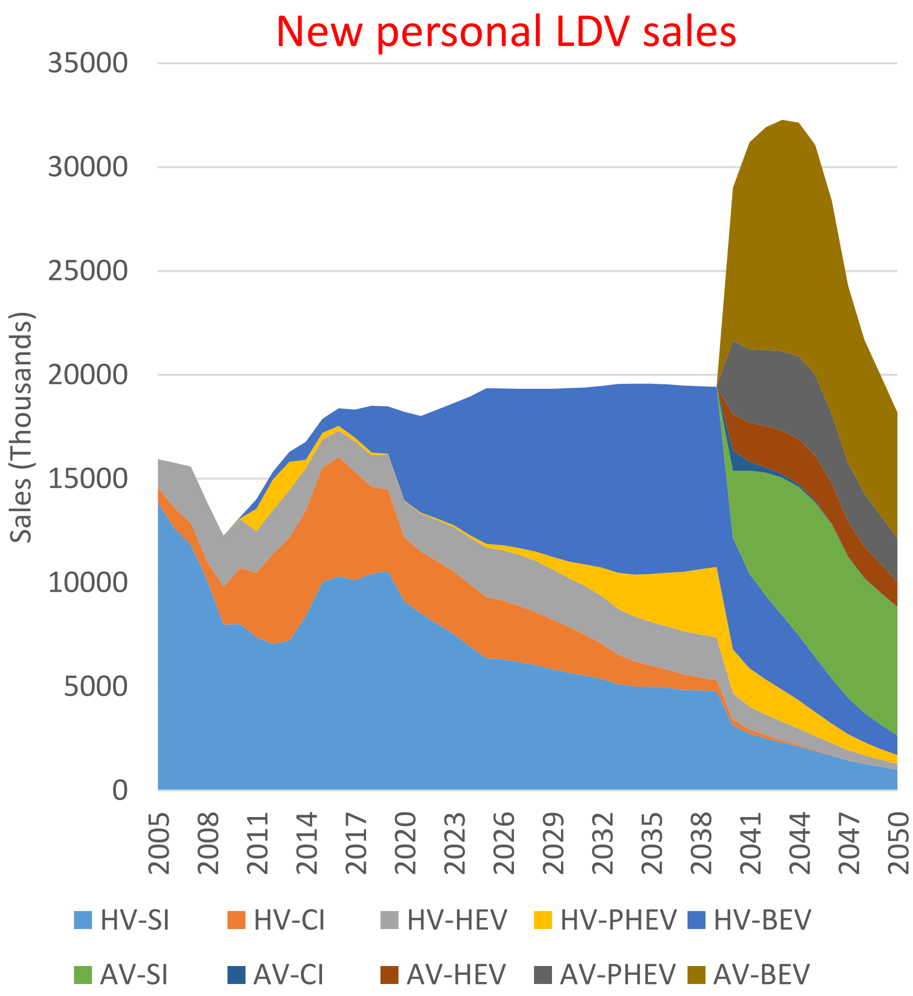


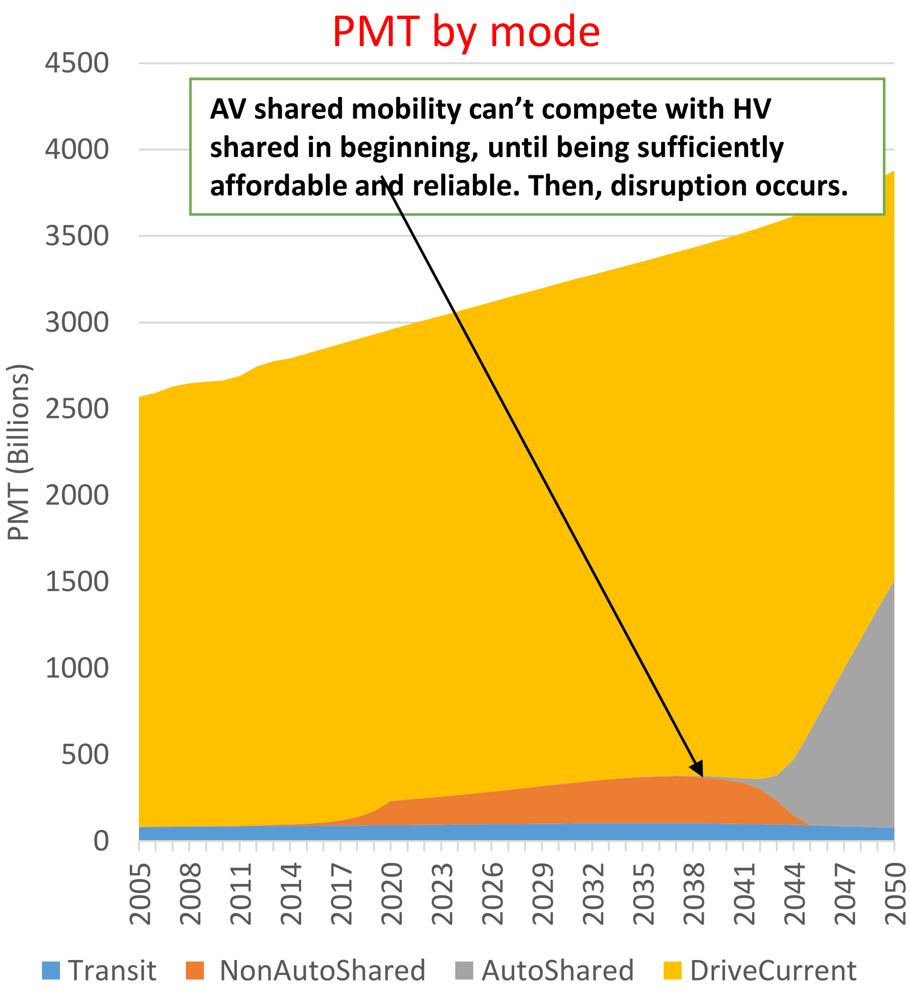
MA3T-MC results: ProgramSuccess



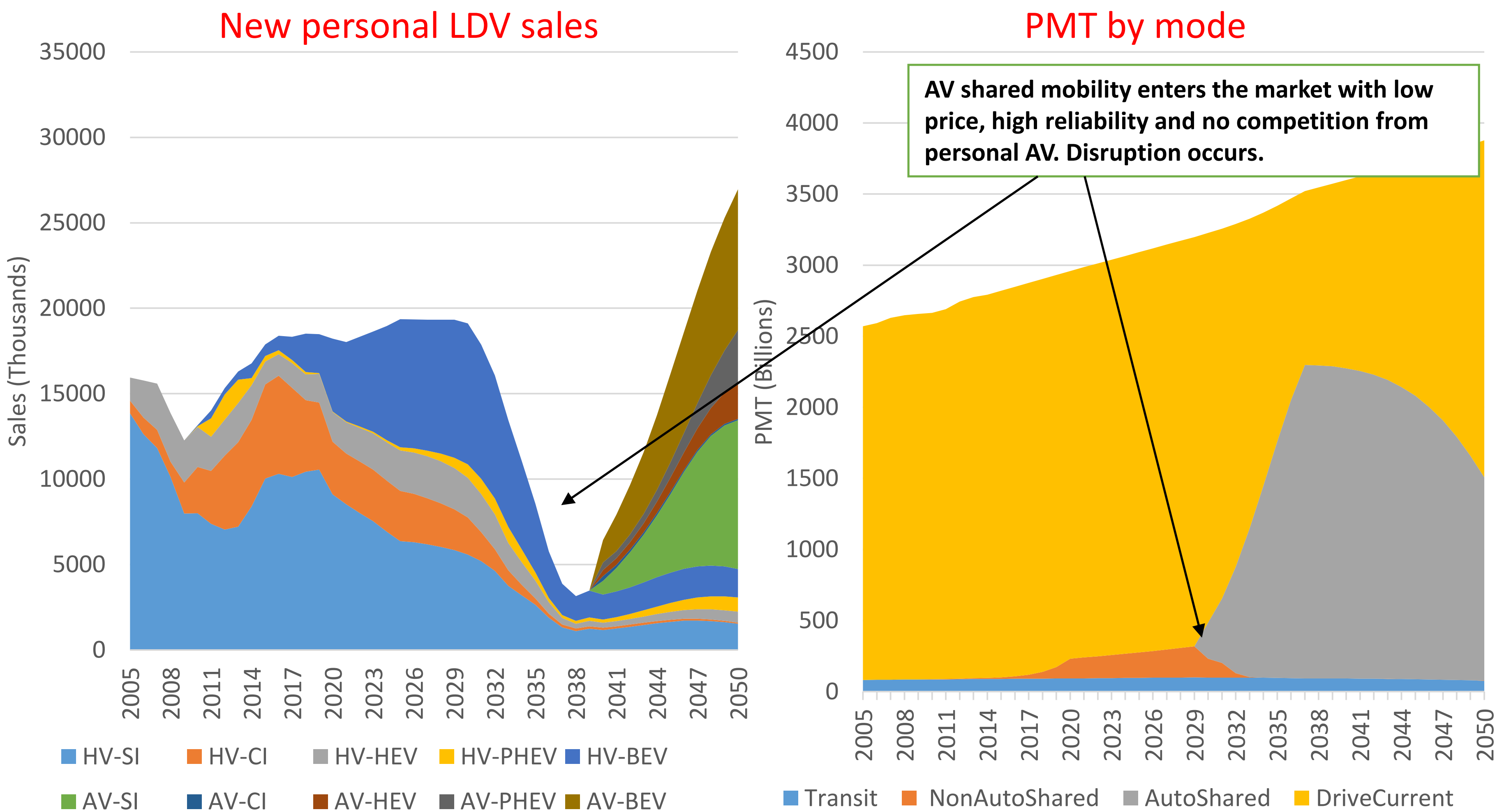


MA3T-MC results: ProgramSuccess & AV-Late



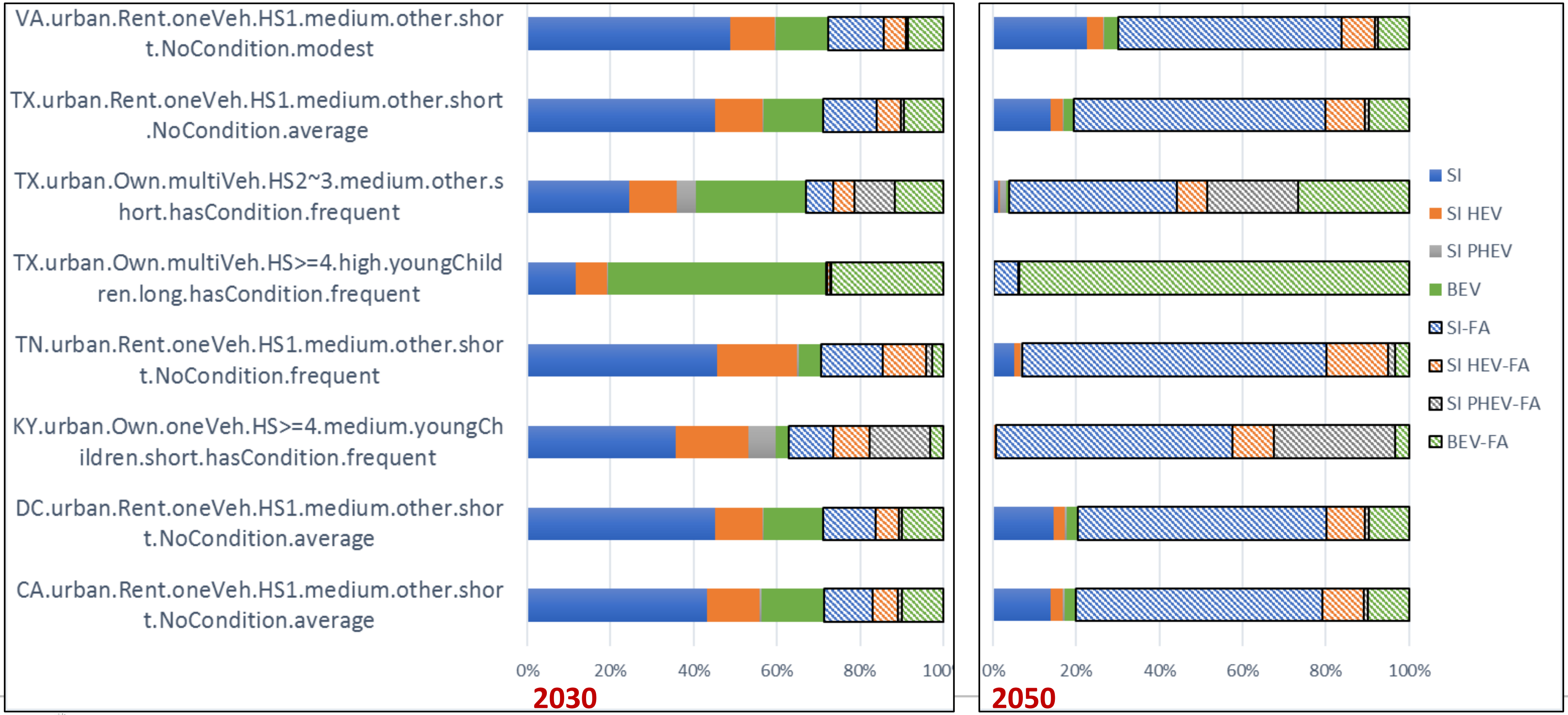


MA3T-MC results: ProgramSuccess & AV-Late & SAV-EarlierBetter



Which consumer group is likely to choose what?

- Notation–consumer segment label: state, area, home type (rent or own), vehicle ownership (1 or multi), household size (1, 2-3 or >4), income, family life (young child, retired or other), health condition, driving intensity. Results of only 8 segments among 7238 are shown.
- Notation—technology: SI (gasoline ICE), HEV (hybrid), FA (fully automated)

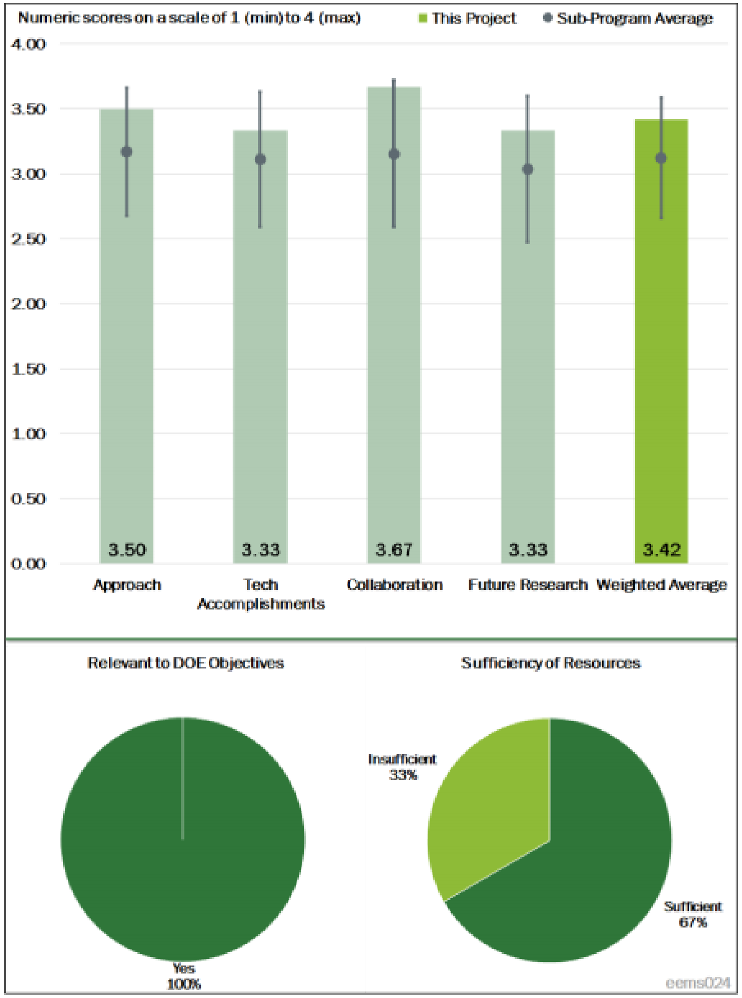


Impacts on CAV acceptance with energy implications?

- How the energy implications of CAV with different penetrations levels will in return affect CAV adoption?
  - Slower penetration at earlier phase due to high impact of sensor load?
  - Faster penetration at later phase due to more energy benefits of smooth driving?
  - Impacts of different sensor loads (600, 1000, or 2500W)
- Results are in preparation and will be presented during AMR meeting

Any proposed future work is subject to change based on funding levels.

RESPONSES TO PREVIOUS YEARS REVIEWERS COMMENTS



- The project at 2018 AMR received overall positive assessments by reviewers. Almost all comments are neutral or positive. No concerns were raised.
- The following comments are consistent with the research plan and thus are encouraging to the research team.
  - “understanding how consumers make choices about vehicle technologies is very relevant to DOE VTO goals as these technologies do not improve energy efficiency if consumers do not ultimately adopt them.”
  - “The project team has included a useful coordination/calibration aspect to its approach to take advantage of other EEMS research results.”
  - “The reviewer noted that the project leverages several years of previous development of the MA3T model and uses cost data from ANL”
  - “The reviewer said that the project team has presented several interesting plots of future fuel types, future market shares of various technologies, etc. The reviewer stated that these interesting results offer a nice preview of how transportation preferences may evolve in the future.”
  - “The future work to complete the development of the model and its planned functionality and refine the model as needed is logical.”
- Response
  - Continue the planned improvements of MA3T-MC
  - Continue coordination with other SMART tasks

Partnerships / Collaborations

MA3T-MC relies on inputs from diverse tasks of SMART Mobility among national labs

Consumer

- Demographics
- Lifestyle
- Land use
- Interaction
- Attribute stability
- WTP for tech attributes
  - Automation
  - Range
  - Fuel economy
  - Safety
  - Less refueling
  - Charging availability

X

Vehicle

- Fuel economy
  - By fuel type, by automation, by onroad tech mix
- Cost/price
- Range/uncertainty
- Space/design
- Connectivity/automation
- Component costs, learning by doing, co-learning

X

Infrastructure

- Fuel prices
- Charging availability
- Congestion/safety performance

X

Operation

- Vehicle ownership/lease
- Network flow coordination/optimization
- Pricing
- Mix of HV and AV
- Shared mobility pricing
- Charging infrastructure pricing

ANL, NREL, ORNL, LBL, INL, ISU, UTK, UT Austin, Vanderbilt, UC Davis

Remaining Challenges and Barriers

- Supply behavior of shared mobility
- Reliability of automated vehicles
- Latent travel demand of underserved population
- Travel demand: need, want, and time budget
- Network externality between AV and HV
- Contextual value of travel time

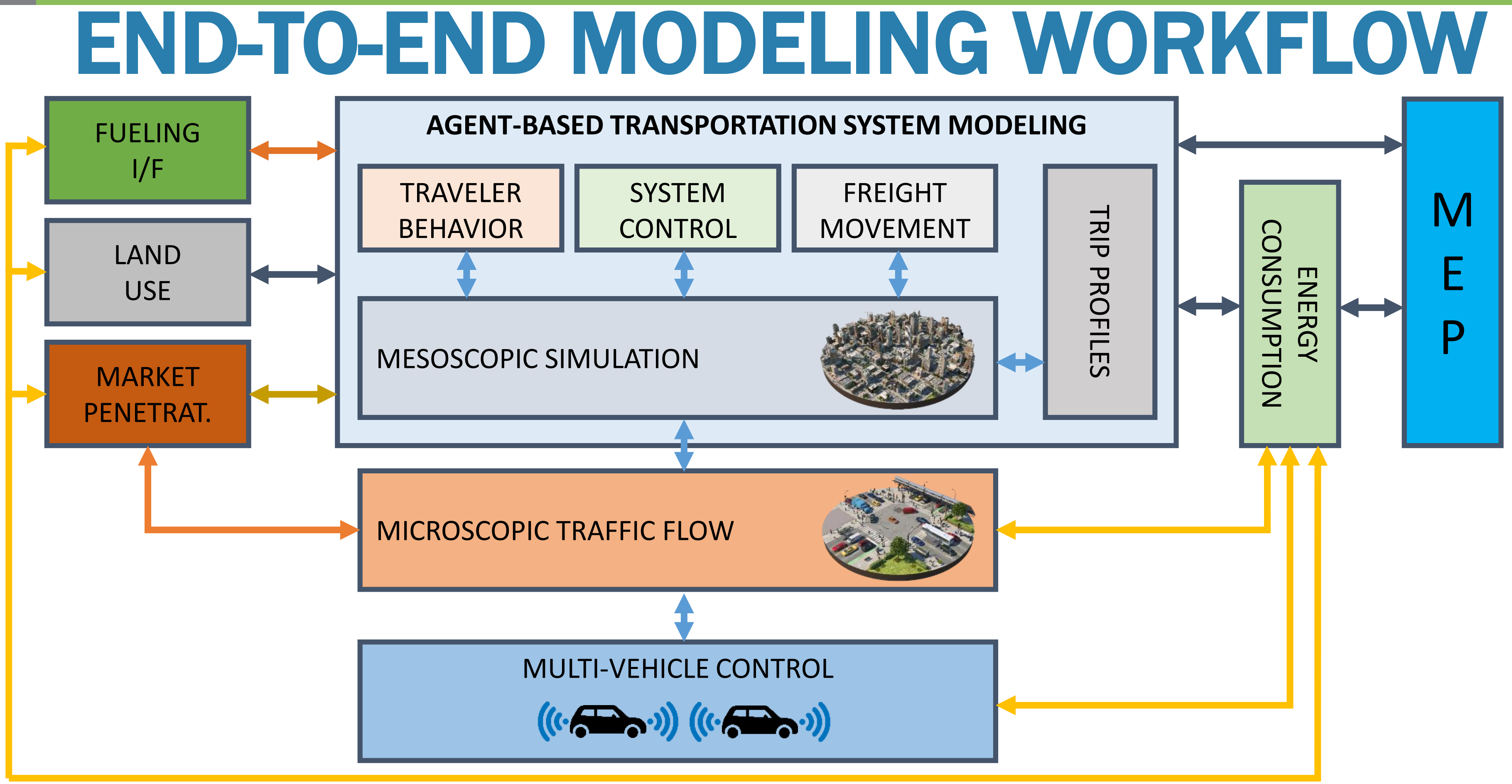
Any proposed future work is subject to change based on funding levels.

PROPOSED FUTURE RESEARCH

- What drivers may join force in supplying shared mobility?
- How to evaluate perceived reliability of automated vehicles?
- How to estimate latent travel demand of drivers and non-drivers?

Any proposed future work is subject to change based on funding levels.

MA3T-MC is directly relevant to the "market penetration" step of SMART workflow



SUMMARY

- Market penetration and dynamics of the 3-Revolution technologies (electrification, automation and sharing) are relevant to the EEMS mission…
- … and are addressed with the development of the MA3T-MC model.
- MA3T-MC consider diverse technologies, consumer heterogeneity, induced travel demand, and systems dynamics.
- Improvements are made on modeling with extensive collaboration with national labs and academia, including:
  - Incorporate importance of doing activities during travel (LBL)
  - Adopt elasticity on induced travel with CAV (University of Michigan)
  - Vehicle efficiency evolution with on-road penetration of automated vehicles (Vanderbilt University, ANL)
- Team is on schedule to provide publishable results to assist other SMART tasks.

Any proposed future work is subject to change based on funding levels.

ACKOWLEDGEMENTS

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QUESTIONS?