Project ID# EEMS017
Pillar: CAV

U.S. DEPARTMENT OF ENERGY

SMARTMOBILITY

Systems and Modeling for Accelerated Research in Transportation

Impact of Connected and Automated Vehicle (CAV) Technologies on Travel Demand and Energy

Joshua Auld
Argonne National Laboratory
2019 Vehicle Technologies Office Annual Merit Review
June 12, 2019

Argonne NATIONAL LABORATORY
INL Idaho National Laboratory
BERKELEY LAB
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PROJECT OVERVIEW

Timeline	Barriers
• Project start date : Oct. 2016 • Project End date : Sep. 2019 • Percent complete : 90%	• High uncertainty in technology deployment, functionality, usage, impact at system level • Computational models, design and simulation methodologies • Lack of data on individual behaviors relating to CAV adoption, usage • Integration of many model frameworks: land use, demand, flow, vehicles, grid, economy

Budget	Partners
• FY17-FY19 Funding: $2,010,000 • FY17 Funding Received: $635,000 • FY18 Funding Received : $625,000 • FY19 Funding Received : $750,000	• Argonne (Lead), LBNL • Texas A&M, University of Texas – Austin • University of Illinois at Chicago

Project Relevance

- Vehicle adoption
- CACC traffic impact
- Value of travel time

- Household (HH) scheduling & optimization
- Vehicle allocation
- Platoon coordination

- Shared fleet scheduling & repositioning
- HH decision making under AV
- Mixed AV traffic flow impact
- System optimization

FY17 | FY18 | FY19

Challenges:

- Much uncertainty at DOT, MPO, OEM,… regarding impact of future mobility on planning
- Complex adaptive system: many agents competing for resources
- Limited data: CAV design, operations of other future mobility technologies
- Highly dependent systems: decision-making, traffic flow, Smart Mobility technologies

Objectives and Relevance:

- Quantify the regional energy impact of SMART mobility deployment
- Consider **multiple interrelated** factors: traffic flow, traveler behavior, system operations
- Bridge research gaps between **vehicle technology** and **transport system design**
- Quantify travel demand impact on **VTO R&D portfolio**
- Assess regional **mobility energy productivity** for potential future mobility scenarios

Milestones

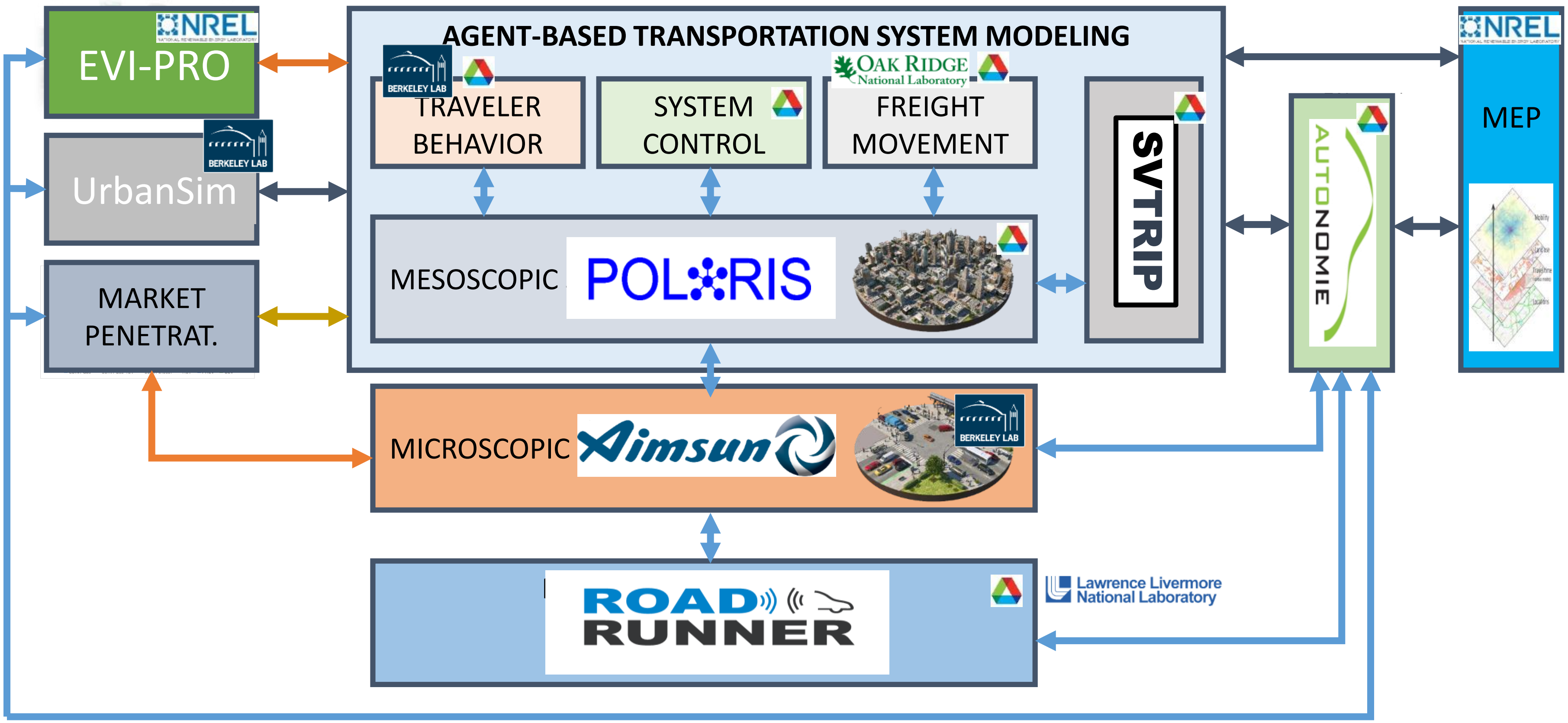
18Q3 | 18Q4 | 19Q1 | 19Q2 | 19Q3 | 19Q4

- 18Q3 — QPM: Study on regional energy impact of coordinated platooning
- 18Q4 — Annual: Study on joint effects of platooning and vehicle sharing at regional scale
- 19Q2 — QPM: Quantify impact of connectivity and automation on traffic flow fundamental diagrams and energy
- 19Q3 — QPM: Quantify energy, mobility and MEP impact of individually owned AVs including car sharing
- 19Q4 — Annual: Impact on energy, mobility and MEP of SAV fleet with geofencing, repositioning, and various fleet sizes

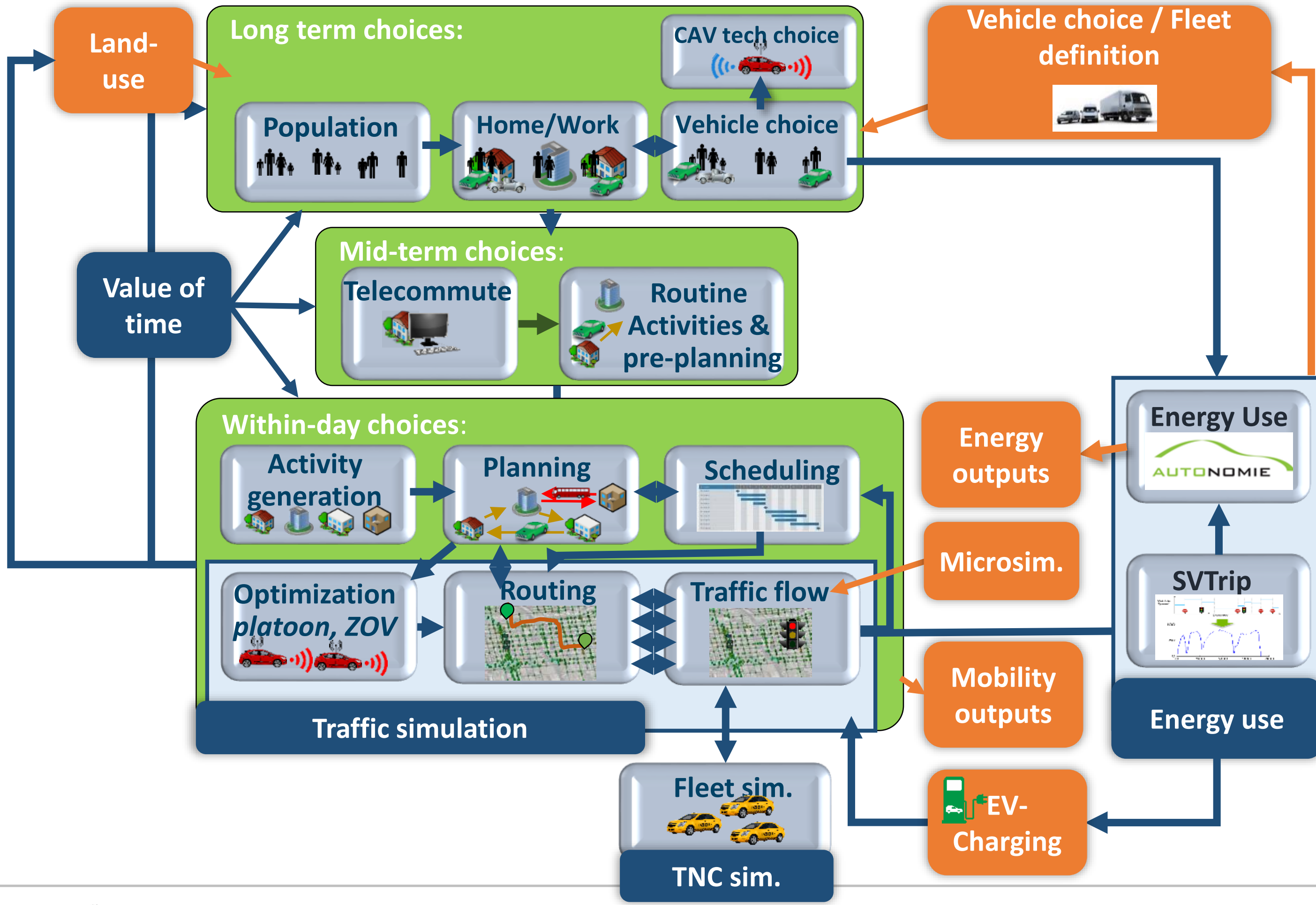
Legend:
- Task completed
- In progress
- On track

APPROACH

APPROACH - SMART WORKFLOW
A COMPREHENSIVE APPROACH TO ANSWER COMPLEX QUESTIONS



POLARIS: AGENT-BASED ACTIVITY-TRAVEL SIMULATION MODEL SIMULATES REGIONAL MOBILITY



Polaris Highlights:

- Simulate **regional** mobility
- Provides detailed travel information by each **agent**
- Fully **integrated** demand, dynamic traffic assignment, and simulation
- Integrated with **energy** model for regional energy analysis
- **Open-source** C++ for Windows/Linux
- Supports **HPC**
- 4-8 hr for 10M agents

Inputs from:	EEMS016, EEMS023, EEMS024, EEMS035, EEMS075
Used in:	EEMS013, EEMS017, EEMS058, EEMS060, EEMS077,EEMS078
Output to:	EEMS026, EEMS035, EEMS057, EEMS068

POLARIS INCLUDES DETAILED REPRESENTATION OF MULTIMODAL TRANSPORTATION SUPPLY AND DEMAND

Transit network

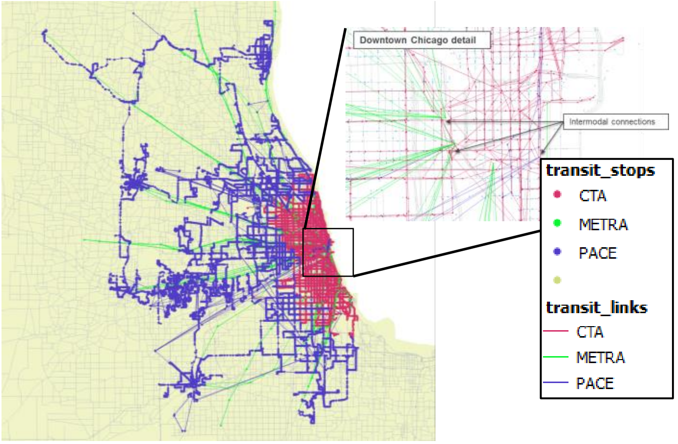
- 35,077 nodes (CTA, PACE, METRA)
- 217,119 links
- 344 transit routes with 2,098 transit patterns
- 28,138 transit vehicle trips
- Intermodal and walking connections

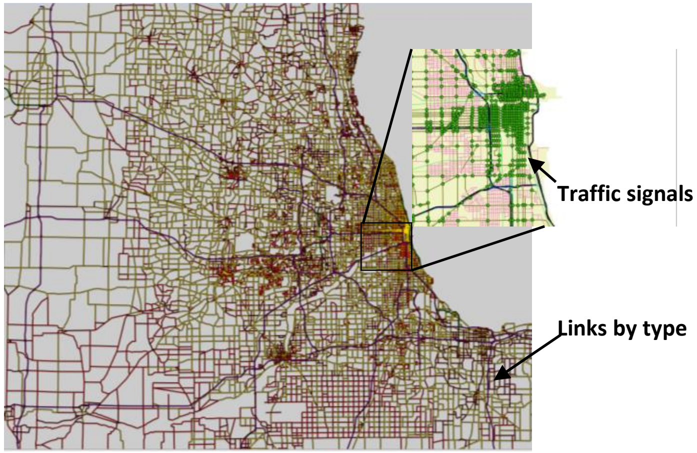
Street network

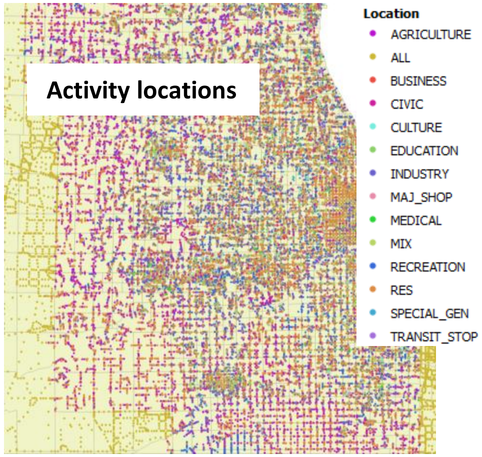
- 31,000 links
- 18,900 nodes
- 7,900 traffic signals
- 12,500 stop signs
- 32.8 million trips (27 million by auto)

Demand

- 470,000 individual activity locations
  - 22 land use types
  - Start/end point for trips
- 270,000 parking locations with cost and capacity
- 10.2M persons in 3.8M HH

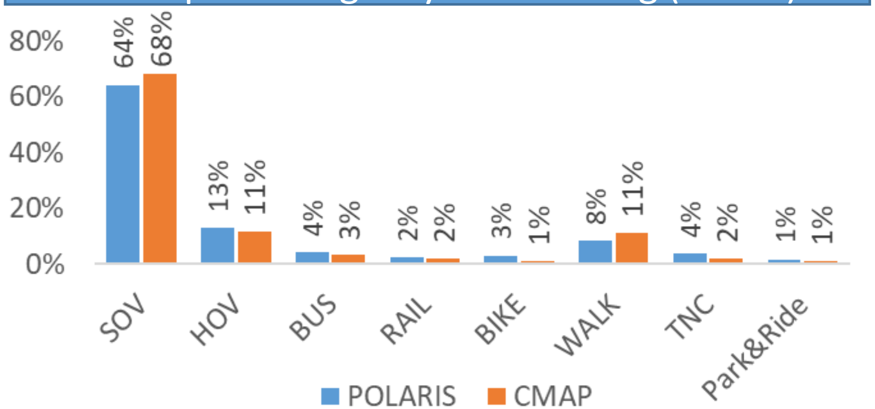




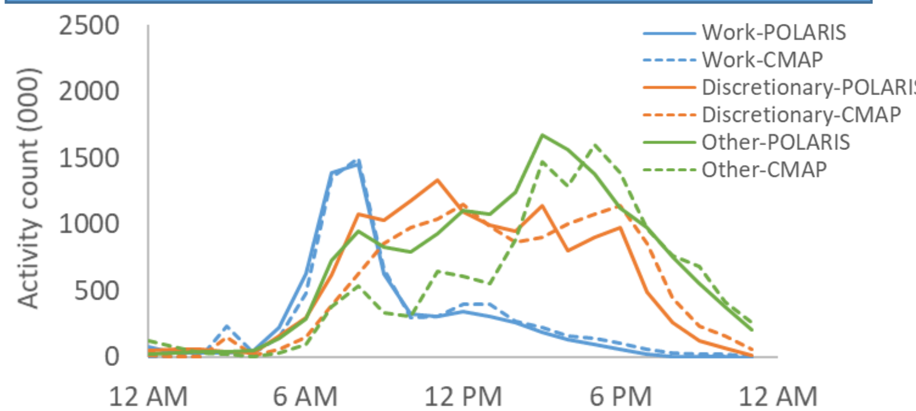


CHICAGO BASELINE MODEL HAS BEEN CONTINUOUSLY CALIBRATED/VALIDATED SINCE 2012

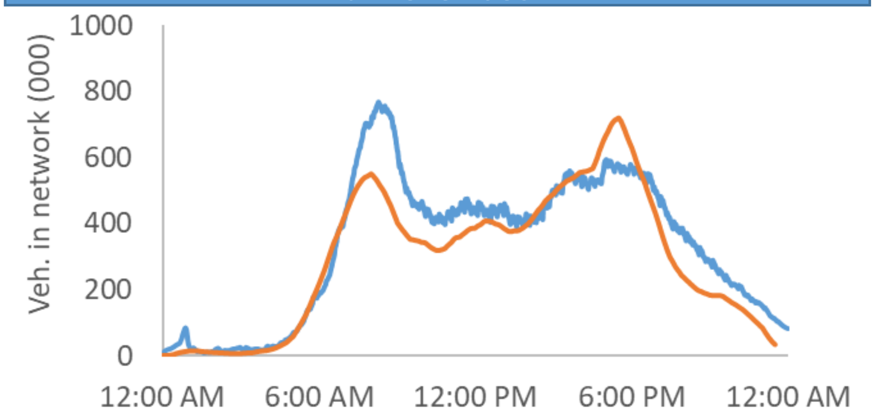
Mode shares closely matched to Chicago Metropolitan Agency for Planning (CMAP)



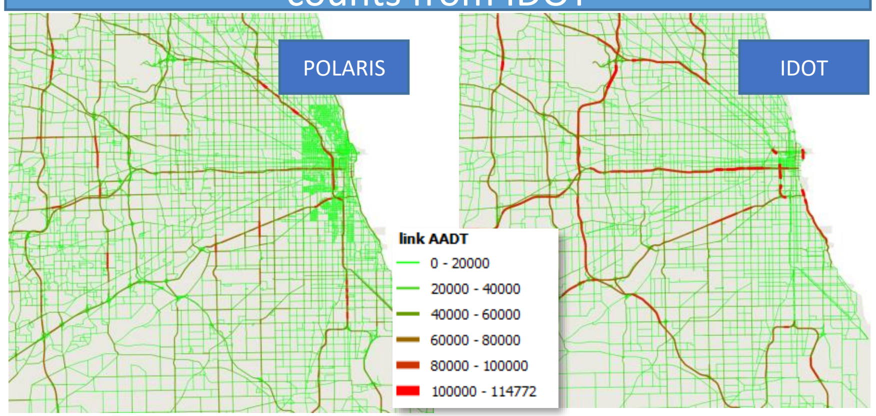
Activity counts & start times are similar to CMAP as well



In-network curves are very sensitive to model differences



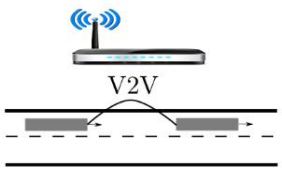
Simulated traffic counts compare closely to counts from IDOT

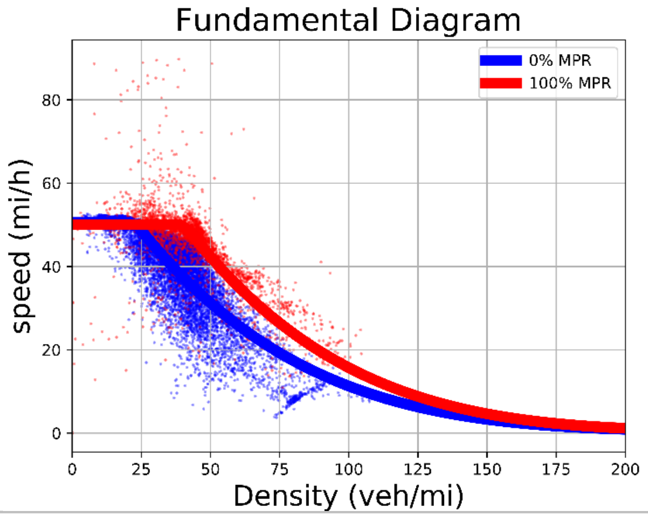


PARTIAL/FULL AV TRAFFIC FLOW IMPACTS MODELED AND INCORPORATED IN POLARIS

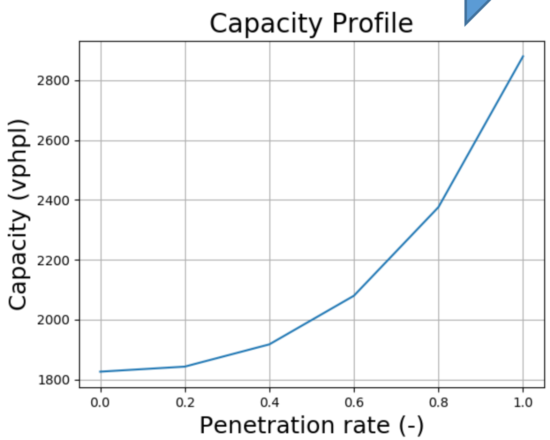
EEMS075

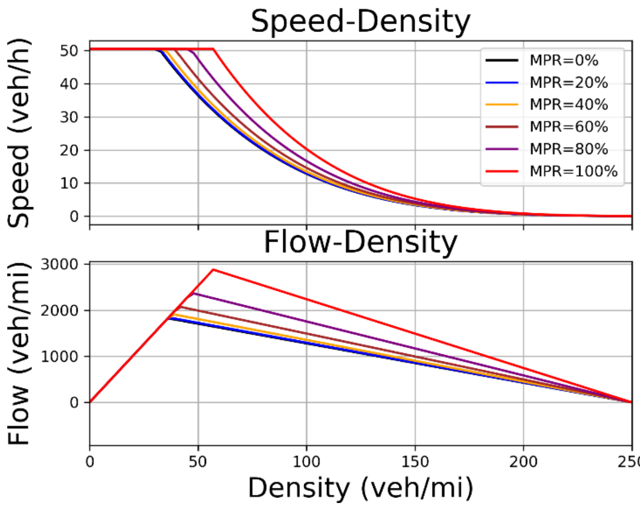
- Automated vehicles can adjust speed based on information from neighbor vehicles
  - Avoids unnecessary acceleration and deceleration
  - Expected to improve throughput (capacity) under high penetration
  - Critical for future scenarios as the technology becomes prevalent
- Microsimulation studies under different penetration rates
  - With AV it is possible to sustain at higher speeds at higher densities
  - Capacity increase of around 40%





Convert to POLARIS mesocopic model params.





DEVELOPED SHARED-AV (SAV) FLEET OPERATOR AND CONTROL ALGORITHMS

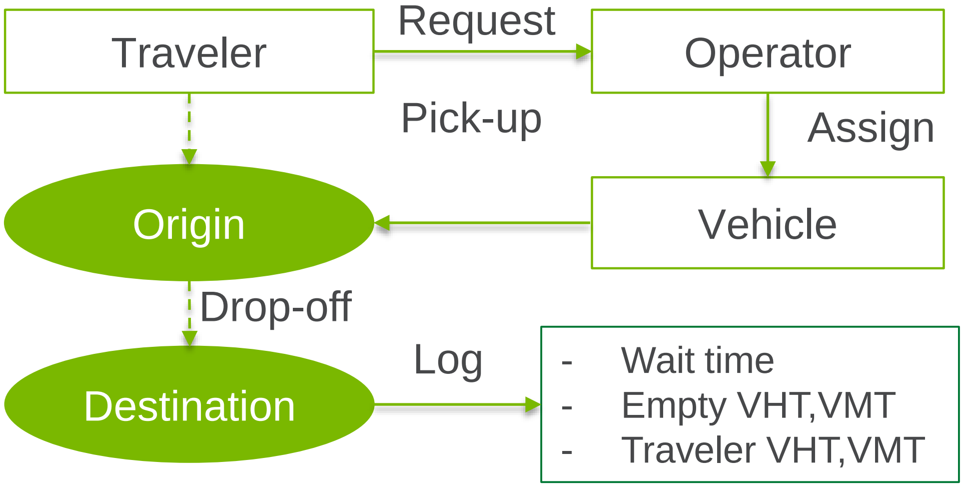
EEMS077

- Tasks:
  - Develop SAV operator and SAV vehicle agent code and algorithms
  - Integrate SAVs with advanced operational strategies into POLARIS
  - Perform impact analysis of better real-time ride-sharing, restricting SAV operation & station aggregation
- Features:
  - Handles millions of ride requests
  - Spatial-indexing for closest matching rider to vehicle
  - Repositioning algorithms based on zone-level wait times

Customizable operator model in POLARIS

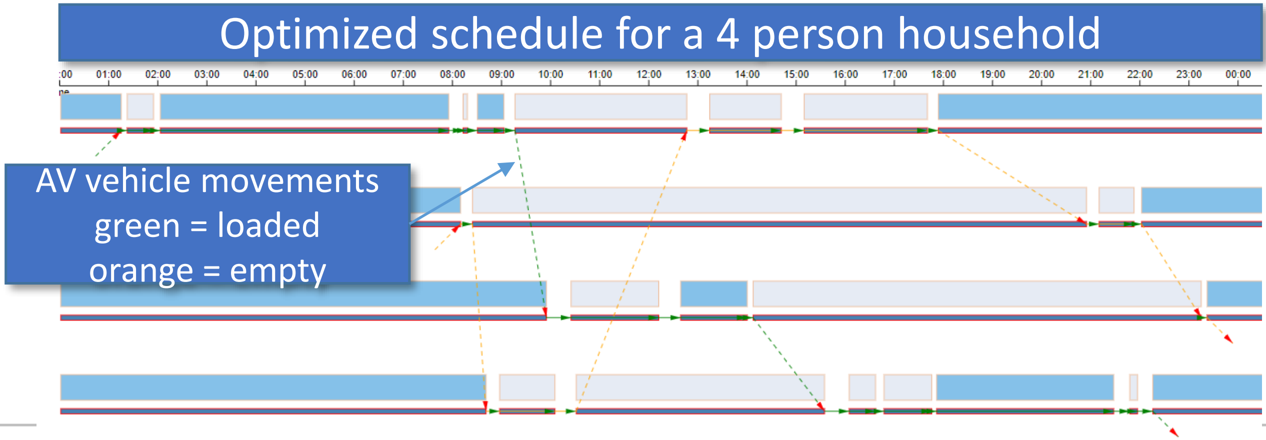

```
"SAV_Fleet_Model": {
  "NO_OF_OPERATORS": 1,
  "OP_1": "Operator_1",
  "SAV_DISCOUNT":  0.5
},
"Operator_1": {
  "Operator_1_SAV_FLEET_SIZE": 35000,
  "Operator_1_SAV_MAX_WAIT_TIME": 20,
  "Operator_1_SAV_MAX_SEATED_CAPACITY": 4,
  "Operator_1_SAV_MAX_SEARCH_RADIUS": 10.4,
  "Operator_1_SAV_LOGGING_INTERVAL": 120,
  "Operator_1_geofence_flag": false,
  "Operator_1_geofence_areatype_limit": 2
```


Traveler SAV request process



DEPLOYED HPC PROCESS REQUIRED FOR LARGE SCALE INTRA-HOUSEHOLD AV SHARING MODEL

- Private mobility scenario has highest impact on energy consumption
- Applied to find optimum number of AVs and schedule their movements
  - Costs: energy, parking, vehicle ownership, value of time
  - Input: synthesized population + their trips
  - Constraints: travel times, vehicle availability, activity flexibility, auto ownership
  - Solution: mixed-integer programming to minimize costs solved for each household
- Challenge: Computational time + Large population (2M+ households)
- Solution: Use HPC to solve complex optimization problems



TECHNICAL ACCOMPLISHMENTS AND PROGRESS

HIGH LEVEL SCENARIOS CONSIDERED (BASELINE + 3 FUTURES)

Scenario A	Scenario B	Scenario C
Sharing is Caring	**Technology Takes Over**	**All About Me**

Scenario A

Sharing is Caring

New technology (I.e., integrated Apps) enables people to significantly increase the use of transit, **car sharing** and multi-modal travel. **Partial automation** is being introduced mostly on the highway system

Scenario B

Technology Takes Over

Technology has taken over our lives, enabling a **high usage of automated ride sharing and multi-modal trips** as they are convenient and affordable. As a result, private ownership has decreased, **e-commerce** is common as is **telecommuting**

Scenario C

All About Me

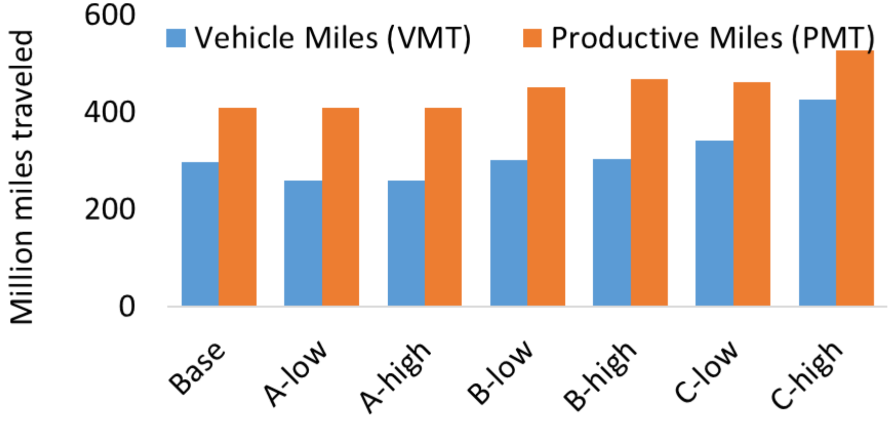
Fully automated vehicles within households are common with personal ownership resulting in **low ride sharing market**. The ability to own AVs leads to **lower e-commerce** and alternative work schedules, and feeds into urban sprawl.

Two vehicle technology levels for each scenario

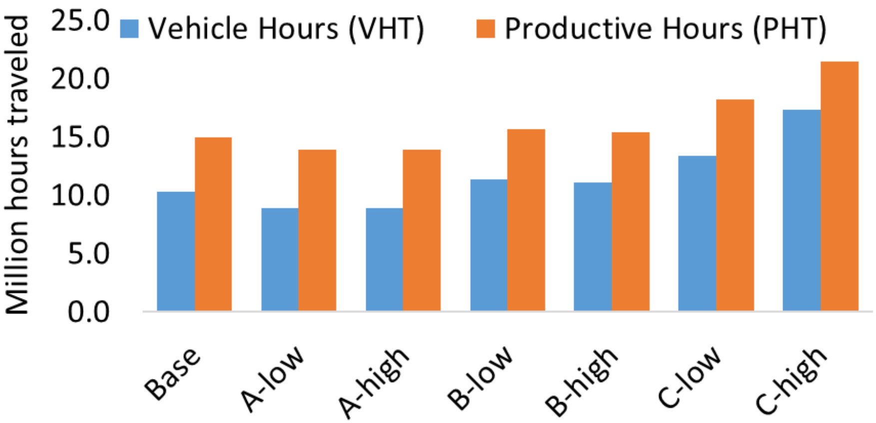
Low – Vehicle technology business as usual
High – VTO's vehicle technology targets

POLARIS MODEL RESULTS: PRIVATE AV LESS EFFICIENT THAN SHARED FLEETS FOR REGIONAL ENERGY AND MOBILITY

Vehicle and Productive[1] Miles Traveled

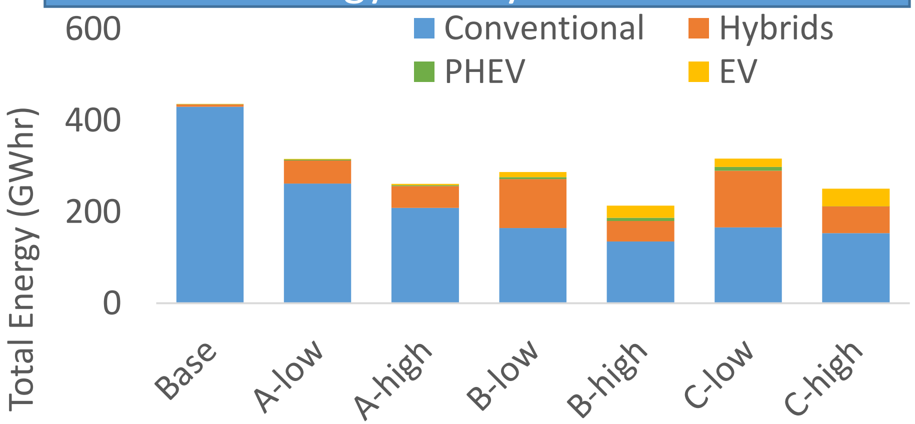


Vehicle and Productive Hours Traveled

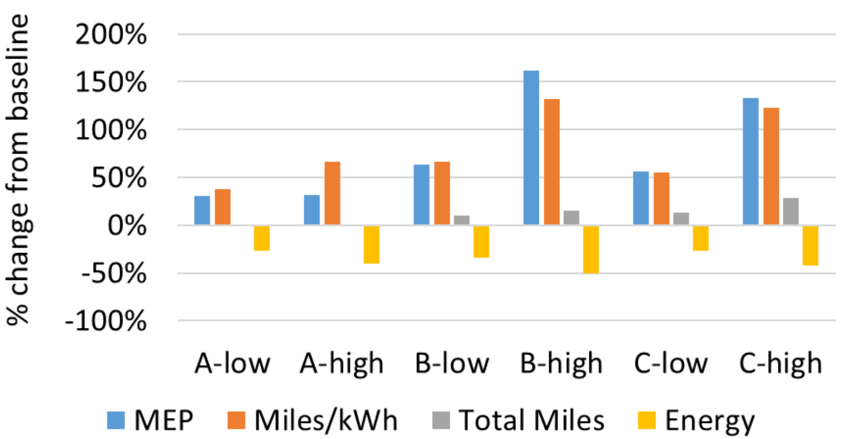


1. Productive miles includes all vehicle miles used to move people or goods (excludes unloaded travel miles)

Energy use by scenario



Mobility Energy Productivity metrics



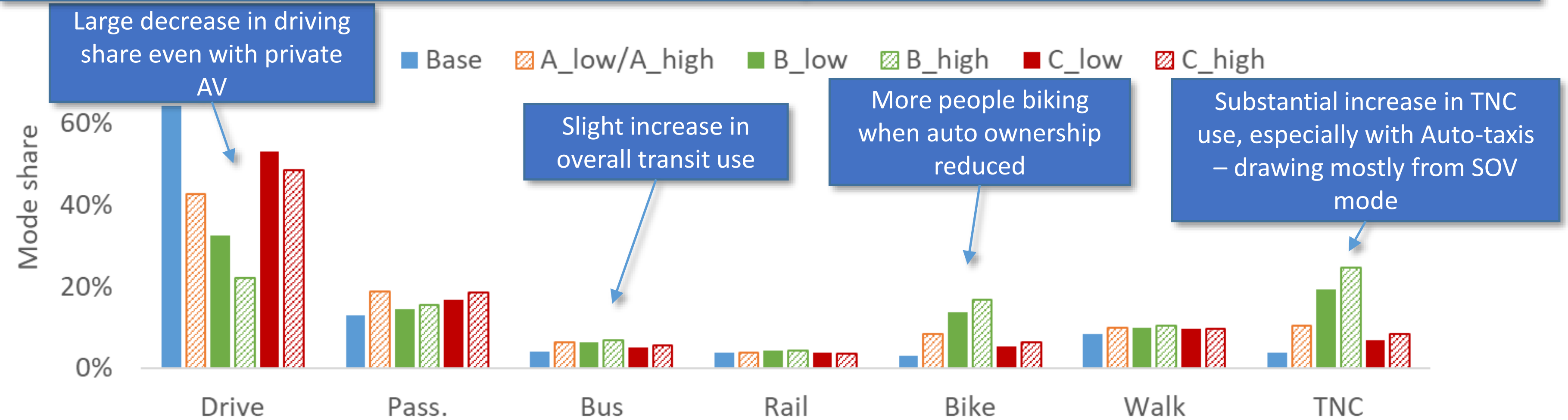
A – Sharing is caring
B – Technology takes over
C – All about me

Low – Vehicle business as usual
High – VTO Targets

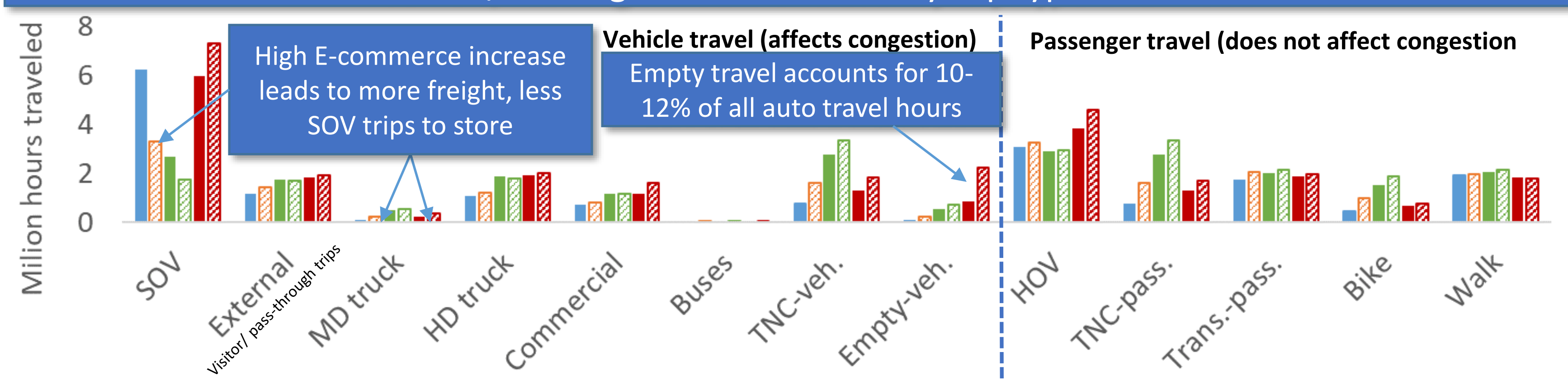
CHANGES TO MOBILITY AND ENERGY ARE LARGELY DRIVE BY MODE SHIFTS AND SHIFT TO E-COMMERCE

EEMS060 EEMS078

Mode share by Scenario



Vehicle/Passenger hours of travel by trip type and mode



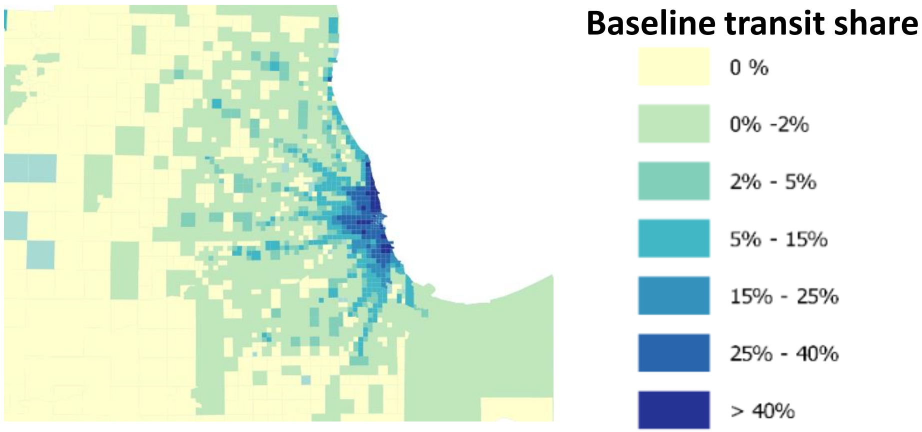
A – Sharing is caring
B – Technology takes over
C – All about me

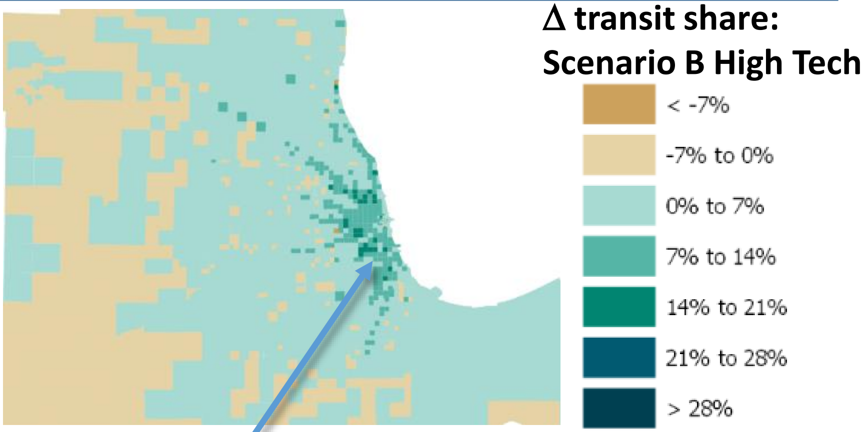
Low – Vehicle business as usual
High – VTO Targets

SHIFTS TO TNC AND TRANSIT OCCUR IN COMPLEMENTARY AREAS OF THE REGION

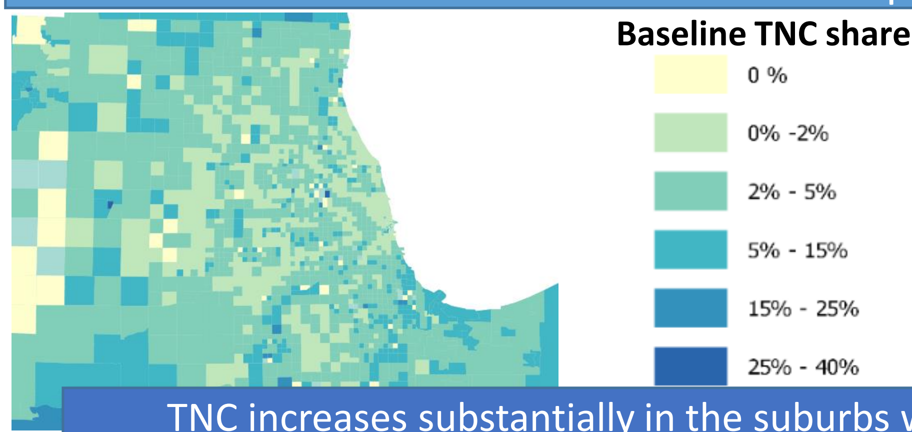
EEMS078

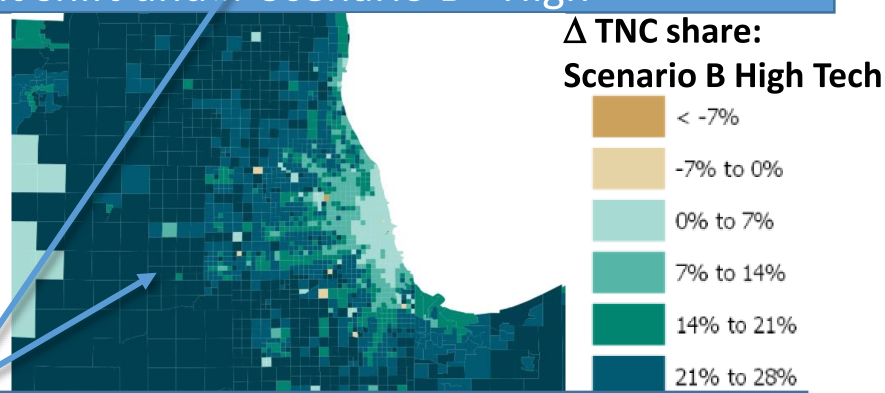
Baseline transit mode share and % point shift under Scenario B - High





Baseline TNC mode share and % point shift under Scenario B - High



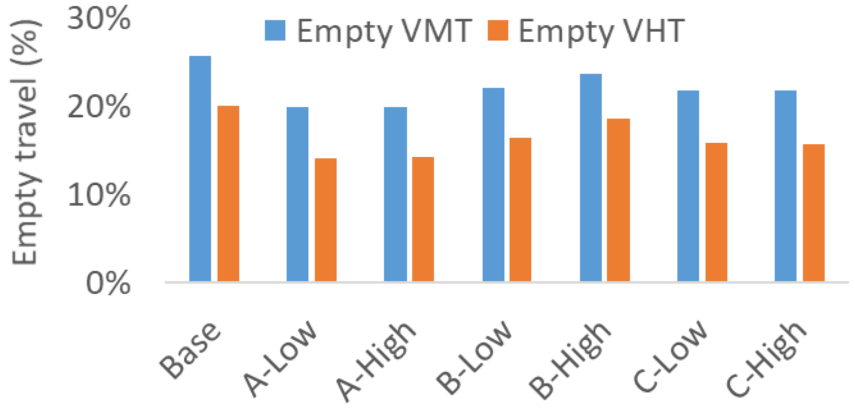


TNC increases substantially in the suburbs while transit increases in the city – driven by households giving up cars in the high-tech shared scenario

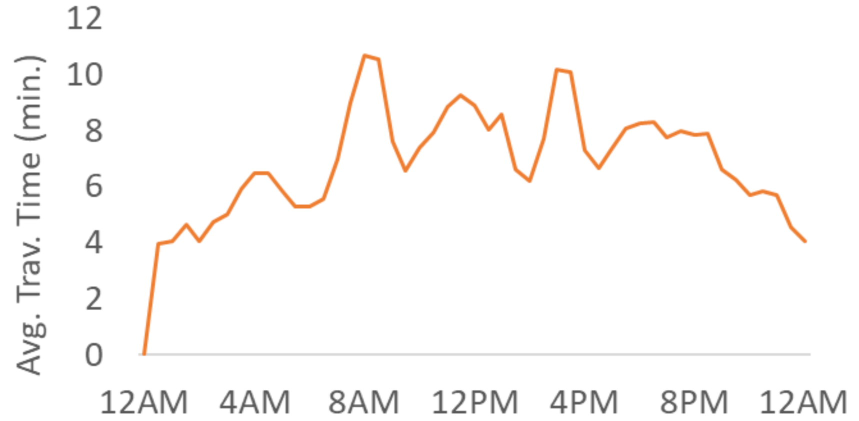
TNC/SAV USE INCREASES SUBSTANTIALLY FOR THE HIGH SHARING SCENARIOS (A AND B)

EEMS077

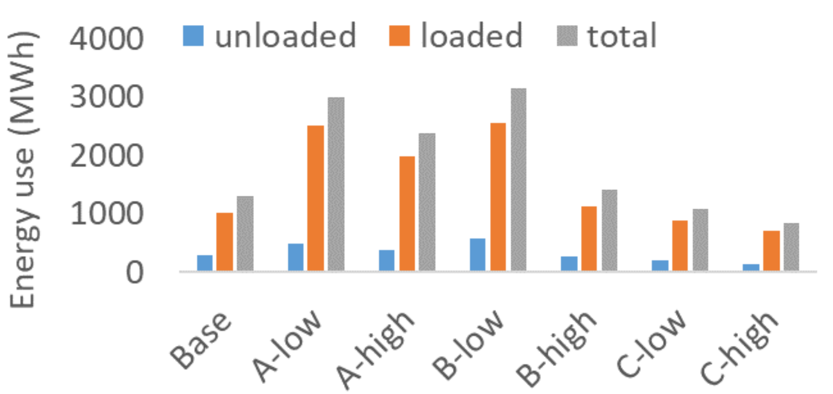
Pickup / repositioning are large part of total TNC miles



Avg. pickup wait times vary greatly during day



Energy use impacts of SAV



% change in operational characteristics from baseline

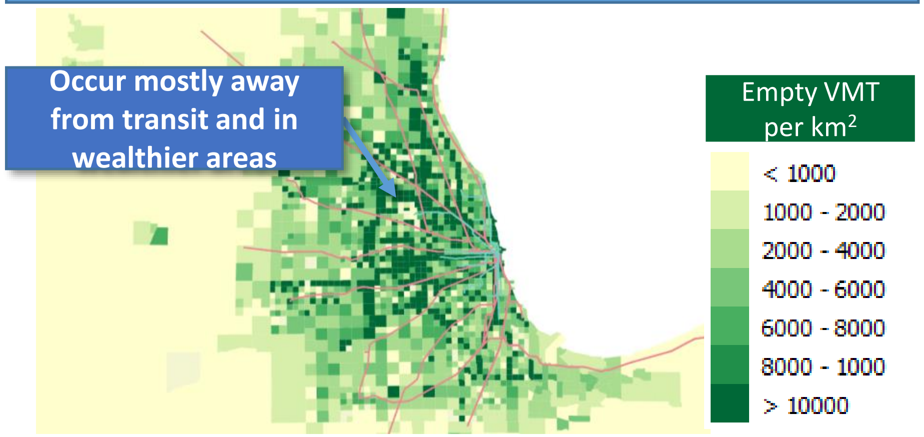
A – Sharing is caring
B – Technology takes over
C – All about me

Low – Vehicle business as usual
High – VTO Targets

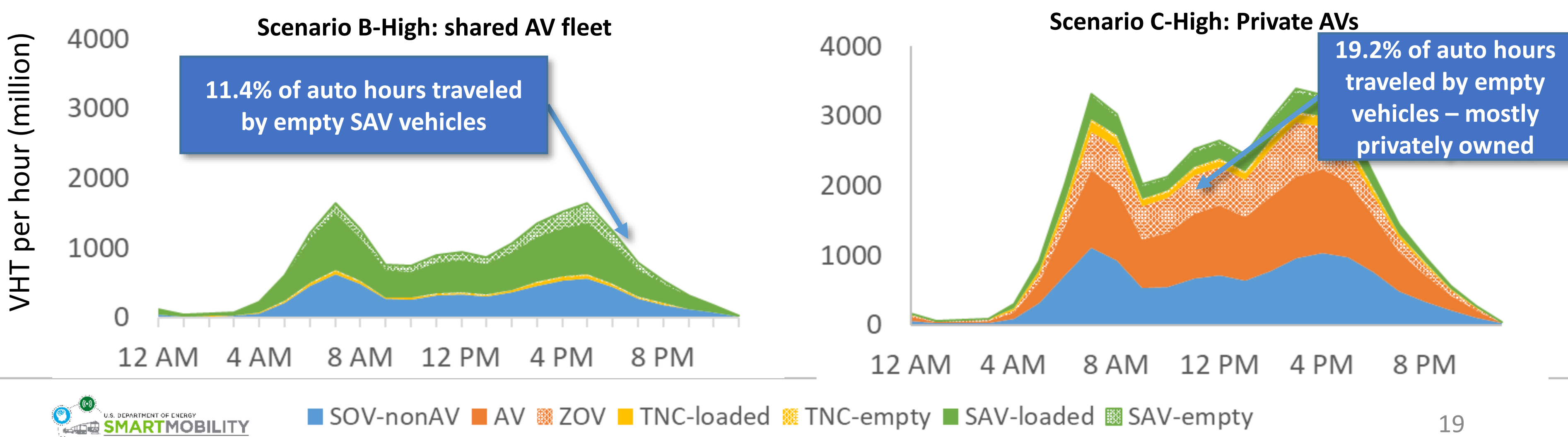
PRIVATE OWNERSHIP OF AV (SCENARIO C) LEADS TO UP TO 41% INCREASE IN TRAVEL WITH 19% OF MILES BY EMPTY VEHICLES

- Shared household AVs travel more due to decrease VOT vs. shared fleet scenario
- Shared-fleet still make substantial share of trips
- Private AV have much higher repositioning miles due to less opportunity for optimization

Unloaded vehicle travel by zone



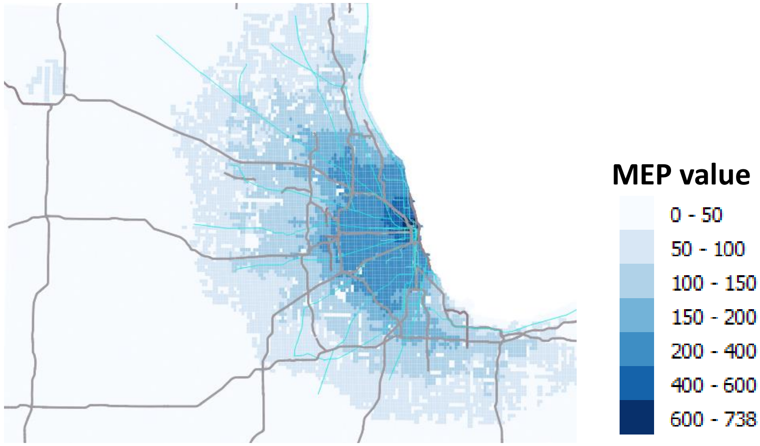
Overall travel, as well us unloaded vehicle travel, increases substantially for Private AV vs. Shared AV



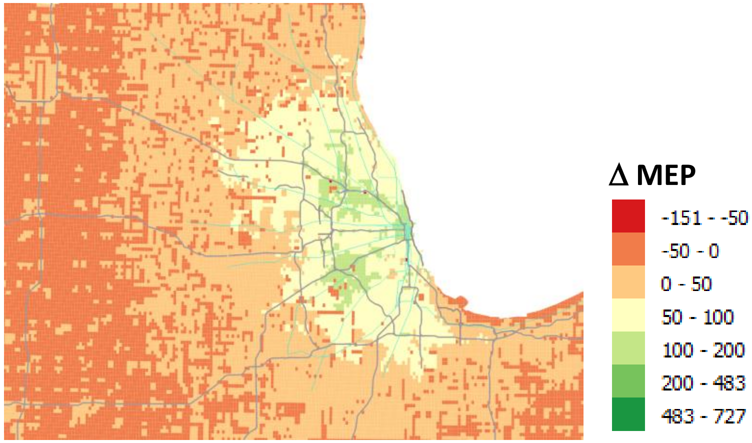
MOBILITY ENERGY PRODUCTIVITY (MEP) INCREASES IN WELL CONNECTED AND URBAN AREAS

EEMS057

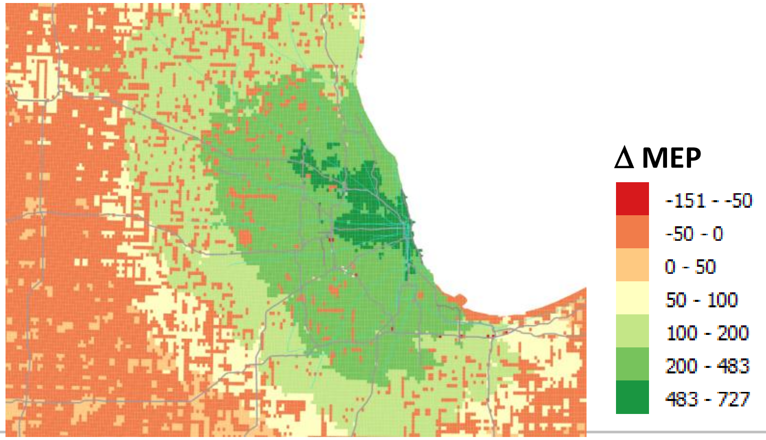
Baseline MEP distribution



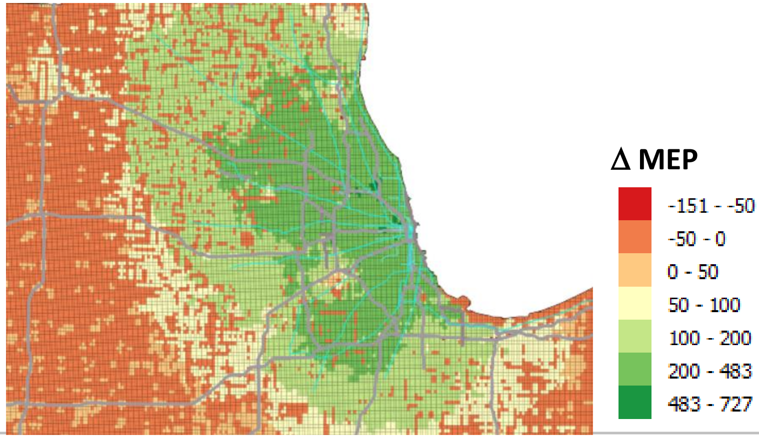
Δ MEP: Scenario A-High vs. Baseline



Δ MEP: Scenario B-High vs. Baseline



Δ MEP: Scenario C-High vs. Baseline



A – Sharing is caring
B – Technology takes over
C – All about me

Low – Vehicle business as usual
High – VTO Targets

RESPONSE TO PREVIOUS YEAR REVIEWERS' COMMENTS

Comments from 2018 AMR	Response
…without **baseline validation** of the new tool being employed, it is very concerning whether this tool will ever be accepted or useful by transportation system development agencies	Model validation is important and is performed for the base model using many data sources, including surveys traffic counts, transit boarding/alighting data, detector data, and many others.
The reviewer stated that the project fails to address the primary EEMS metric of **Mobile Energy Productivity**, and therefore the work has improper focus.	The Mobility Energy Productivity (MEP) metric was under development last year. MEP results have now been included in this presentation for this year.
…to consider adding a stochastic-based element to the analysis. Each variable could be given a range and then results would have error bars to demonstrate the **sensitivity to inputs**…	POLARIS is inherently stochastic. All agent choices are drawn from probability distributions using random numbers that change each run. Studies were run last year showing variation due to key parameters (See backup).
….give consideration for how this model of a limited geographic region might be **scaled to address state- or national-level** questions	This question is the focus of EEMS026 task. Progress has been made under this task to combine and transfer regional estimates to national forecasts.

PARTNERSHIPS AND COLLABORATIONS

U.S. DEPARTMENT OF ENERGY SMARTMOBILITY Systems and Modeling for Accelerated Research in Transportation	EEMS013, EEMS016, EEMS017, EEMS023, EEMS024, EEMS026, EEMS035, EEMS057, EEMS058, EEMS060, EEMS068, EEMS075, EEMS077, EEMS078
TEXAS A&M UNIVERSITY	Improvement of CAV traffic flow model using CAV-specific fundamental diagrams
THE UNIVERSITY OF TEXAS AT AUSTIN	SAV fleet modeling
BERKELEY LAB	CAV traffic flow impacts, platooning, on-road data, Land use
THE UNIVERSITY OF ILLINOIS AT CHICAGO UIC	Activity scheduling and resource allocation
TARDEC, AU	Vehicle platooning
UNIVERSITY OF MICHIGAN	Real-world vehicle energy use, route choice, eco-approach/departure

REMAINING CHALLENGES AND BARRIERS

- Improving assumption underlying simultaneously private and non-private CAV modeling is challenging:
  - Improve representation of: business models, human behavior, optimization, etc.
  - Collect additional data regarding TNC operations (especially on fleet level and driver-side)
  - Refine mixed fleet traffic flow impacts
  - Refine vehicle technology/ownership/mobility choice models
- Improve computational efficiency of optimization models through improved metaheuristics and HPC
- Incorporate vehicle platoons across modes with focus on system impact i.e. cost of waiting, merging, and leaving platoons
- Identify key driving parameters affecting regional mobility and perform large-scale sensitivity analysis on the existing seven scenarios

PROPOSED FUTURE RESEARCH

- Explore opportunities for system level optimization using connectivity-enabled technologies:
  - Vehicle-to-infrastructure
  - Route guidance, traffic control, coordinated signal optimization
- Refine market penetration inputs
  - Choice of shared mobility vs. private
  - Vehicle holdings and transactions
  - Private vehicle sharing
- Productive use of CAV e.g. delivery with private/shared AVs, UberRent
- Improve traffic flow models
  - CAV lateral control impacts on flow
  - TNC, SAV, delivery impacts of traffic flow through pickup/drop-off/stop
- Continue to engage with stakeholders in the mobility-energy space

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

SUMMARY OF SCENARIO RESULTS

Metric	Unit	Baseline	Sharing is Caring *∆ A-high to base*	Tech. Takes Over *∆ B-high to base*	All About Me *∆ C-high to base*
Total trips (all types)	million trips	42.0	*-7%*	*2%*	*7%*
Productive[1]-miles of travel	million miles	408.1	*0%*	*15%*	*29%*
Vehicle miles traveled	million miles	296.6	*-13%*	*2%*	*44%*
% empty miles	%	1.8%	*165%*	*522%*	*837%*
% non-drive travel	%	46.5%	*27%*	*40%*	*-6%*
Avg. travel speed	MPH	28.8	*1%*	*-5%*	*-15%*
Total energy	GWh	435.3	*-40%*	*-51%*	*-42%*
MEP metric		194.0	*32%*	*161%*	*133%*

1. Productive travel includes all passenger miles, driver miles and freight miles (excludes repositioning, empty travel, transit driver miles…)

QUESTIONS?

TECHNICAL BACK-UP SLIDES

RESULTS SUMMARY

Metric	Unit	Baseline	Sharing is Caring			Tech. Takes Over			All About Me		
			A-low	A-high	*Δ A-high to base*	B-low	B-high	*Δ B-high to base*	C-low	C-high	*Δ C-high to base*
Total trips (all types)	million trips	42.0	39.2	39.2	*-7%*	42.0	42.7	*2%*	44.8	45.0	*7%*
Total trips (freight)	million trips	3.8	5.2	5.2	*39%*	6.1	6.1	*62%*	5.0	5.0	*33%*
Total trips (auto-based)	million trips	22.6	16.7	16.7	*-26%*	18.4	17.9	*-21%*	22.0	22.3	*-2%*
Productive[1]-miles of travel	million miles	408.1	408.5	408.1	*0%*	449.6	468.3	*15%*	460.2	525.5	*29%*
Productive[1]-hours of travel	million hours	15.0	13.9	13.9	*-7%*	15.7	15.4	*3%*	18.2	21.5	*44%*
Vehicle miles traveled	million miles	296.6	258.0	257.9	*-13%*	300.5	302.2	*2%*	339.8	425.9	*44%*
Vehicle hours traveled	million hours	10.3	8.9	8.9	*-14%*	11.4	11.1	*8%*	13.3	17.4	*69%*
Empty miles traveled	million miles	5.2	12.0	12.0	*131%*	24.2	33.0	*534%*	29.9	70.0	*1245%*
% auto empty miles	%	1.8%	4.7%	4.7%	*165%*	8.1%	10.9%	*522%*	8.8%	16.4%	*837%*
% non-drive travel	%	46.5%	59.2%	59.2%	*27%*	60.1%	65.0%	*40%*	46.0%	43.8%	*-6%*
Avg. travel speed	MPH	28.8	29.0	29.0	*1%*	26.5	27.3	*-5%*	25.5	24.5	*-15%*
Avg. trip speed	person-MPH	27.3	29.3	29.3	*7%*	28.7	30.5	*12%*	25.3	24.5	*-10%*
Total fuel use	Million gallons	11.9	8.6	7.0	*-41%*	7.4	5.0	*-58%*	7.9	5.8	*-51%*
Total electrical use	GWh	0.1	3.4	5.3	*5110%*	15.3	33.8	*32938%*	26.6	38.7	*37708%*
Total energy	GWh	435.3	316.5	261.8	*-40%*	287.8	215.2	*-51%*	316.4	251.1	*-42%*
MEP metric		194.0	254.0	256.0	*32%*	317.0	507.0	*161%*	302.0	452.0	*133%*
travel efficiency	pers.mi/KWh	0.94	1.29	1.56	*66%*	1.56	2.18	*132%*	1.45	2.09	*123%*

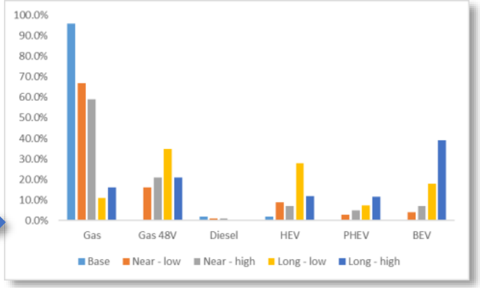
1. productive travel includes all passenger miles, driver miles and freight miles (excludes repositioning, empty travel, transit driver miles…)

SEVEN SCENARIOS DEVELOPED BY THE WORKFLOW TASK FORCE OF THE SMART MOBILITY CONSORTIUM

- Scenarios developed by subject matter experts across SMART Mobility Consortium
- Fixed factors or tables for most scenario inputs
- Low technology (business as usual) and high technology (program success) cases for each future
- Critical parameters:
  - Vehicle technology, private ownership, VOTT, E-commerce

Key scenario parameters

Variables	Baseline	(A) High sharing low automation	(B) High tech - mobility	(C)Low sharing high Automation
Market Penetration	Current	Near term	Long term	Long term
Automation Level	0%	0 to 11% L3/4 (CACC)	14 to 47% L5	14 to 47% L5
Private Ownership	Current	Low	Low	High
Shared Use	1.3	1	1	1.3 (vehicle with driver) - 1.6 (vehicle without driver
VOTT (Car mode only)	1	High (see table below)	Low (See table below)	Low (See table below)
Propensity non-car modes	1	0.5	1	1
E-Commerce	0.08 deliveries per person-day	0.5 deliveries per person-day	0.5 deliveries per person-day	0.2 deliveries per person-day
Long Haul Commodity Flow	1% CAGR	1% CAGR	1.3% CAGR	1.3% CAGR
Vehicle Technology	xEV penetration ~3%	xEV penetration from 16-25% for LDV	xEV penetration from 44-77% for LDV	xEV penetration from 44-77% for LDV
Non-Automated	98%	75% (low tech) / 74% (high tech)	41.5% (low tech) / 37.5% (high tech)	72.5% (low tech) / 35.5% (High tech)
L3/4	0%	5% (low tech) / 6% (high tech)	5% (Low Tech) / 8% (High tech)	5% (Low Tech) / 8% (High tech)
L5	0%	0%	0%	12.5% (Low tech) / 41.5% (High tech)
Non-Automated	2%	15%	36% (low tech) / 3% (high tech)	5%
L3/4	0%	5%	0%	0%
L5	0%	0%	17.5% (low tech) / 51.5% (high tech)	5% (low tech) / 10% (high tech)
L3/4	0%	10 (Low tech) /11 (high tech)	5 (Low tech) /8 (high tech)	5 (Low tech) /8 (high tech)
L5	0%	0	17.5 (Low tech) /51.5 (high tech)	17.5 (Low tech) /51.5 (high tech)



VOTT Factor Low

Congestion	Time Sensitivity	CAV's	Multiplier Highway/Arterial
Low	Low	Low	0.7/1.0
Low	Low	High	0.5/0.5
Low	High	Low	0.9/1.0
Low	High	High	0.7/0.7
High	Low	Low	0.5/1.0
High	Low	High	0.35/0.35
High	High	Low	0.7/1.0
High	High	High	0.5/0.5

VOTT Factor High

Congestion	Time Sensitivity	CAV's	Multiplier Highway/Arterial
Low	Low	Low	0.9/1.0
Low	Low	High	0.7/0.7
Low	High	Low	1.0/1.0
Low	High	High	0.9/0.9
High	Low	Low	0.7/1.0
High	Low	High	0.5/0.5
High	High	Low	1.0/1.0
High	High	High	0.7/0.7

INTRA-HOUSEHOLD VEHICLE SHARING: OPTIMIZATION MODEL DESCRIPTION

1. Developed using Gurobi Optimization
2. Used time dependent travel times
3. Solved for each household
4. Maximize the number of served trips
5. Least number of ZOV legs
6. Least modifications to the planned start and duration of activities

Minimize $M = A \sum_{per_i} \sum_{act_j} |start\ time\ shift| + |duration\ change| +$
$B \sum_{per_i} \sum_{act_{ij}} \sum_{per_k, i \neq k} \sum_{act_{kl}} t_{act_{ij\_out} - act_{kl\_in}} + C \sum_{per_i} \sum_{act_j} t_{act_{ij\_in}}$

Subject to

$t_{act_{kl\_out} - act_{ij\_in}} \in \{0,1\} \quad \forall k, i \in \{Persons\}$

$$t_{act_{kl\_in}} = \sum_{per_i} \sum_{act_j} t_{act_{ij\_out} - act_{kl\_in}}, \qquad t_{act_{kl\_in}} \in \{0,1\}$$

$$t_{act_{mn\_out}} = \sum_{per_i} \sum_{act_j} t_{act_{mn} - act_{ij}}, \qquad t_{act_{mn\_out}} \in \{0,1\}$$

$$t_{act_{ij\_out} - act_{ij+1\_in}} = t_{act_{kl\_in}} \qquad first\ trip: \sum_{per_i} t_{act_{i0} - act_{i0}} = 1 \qquad last\ trip: \sum_{per_i} t_{act_{il} - act_{il}} = 1$$

$$t_{act_{kl} - act_{ij}} \left(Start_{act_{ij+1}} - Start_{act_{kl}} - Travel\ Time_{act_{kl} - act_{ij}}(t_{Start_{act_{kl}}}) - Travel\ Time_{act_{ij} - act_{ij+1}}(t_{End_{act_{ij}}})\right) \geq 0 \ \forall k, i \in \{Persons\}, k \neq i$$

$$t_{act_{kl} - act_{ij}} \left(End_{act_{ij}} - Start_{act_{kl}} + Start_{act_{kl}} - Travel\ Time_{act_{kl} - act_{ij}}\right) \geq 0$$

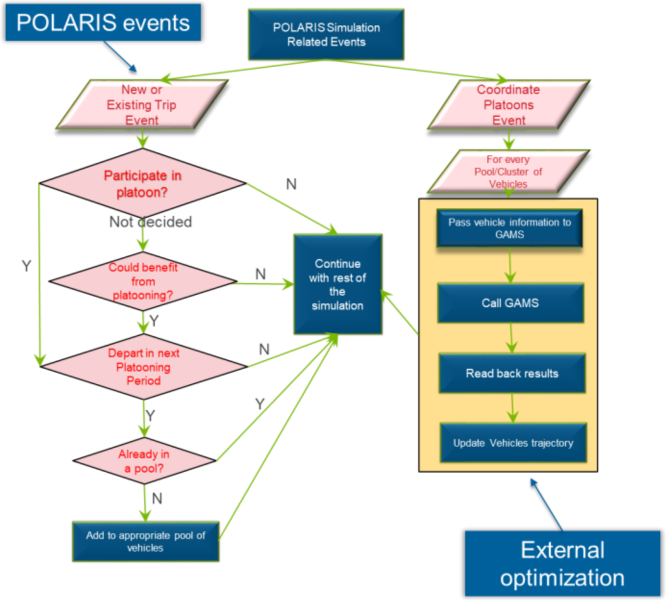
$$End_{act_{ij}} + t_{act_{ij} - act_{ij+1}} \leq Start_{act_{ij+1}}$$

$$start\ time\ shift = |scheduled\ start - start| < start\ time\ threshold \quad \forall\ all\ activities$$

$$duration\ change = |planned\ duration - duration| < duration\ time\ threshold \quad \forall\ all\ activities$$

AUTOMATED PROCESS FOR COORDINATED PLATOONING

- Platooning a key feature enabled by connectivity and automation
  - Potential impacts depends on how platoons are formed
- Effect on vehicle energy consumption
  - Aero drag reduction
  - Smoother drive cycles
  - Acceleration/deceleration to join/leave platoons
  - Increased idling
- Developed a platoon formation optimization algorithm
  - Objective function: Minimizing Energy Consumption
  - Applied to highway travel for CACC vehicles
  - Implemented in POLARIS with external solver



- Trip clustering used to improve optimizer performance:
  - Cluster based on O-D pairs are route similarity: Agglomerative Hierarchical Clustering

PLATOONING STUDY: PRELIMINARY RESULTS

- Increase in wait-time threshold increases opportunity to participate in platoons: increase platooning to 2.3% of total VMT
- Energy consumption estimation is highly dependent on how vehicles join/leave platoons
- Larger network with lower simulation variance could provide additional insights.
- To improve the performance, vehicles could be clustered in multiple groups where vehicles in each cluster have high potential for platooning with each other

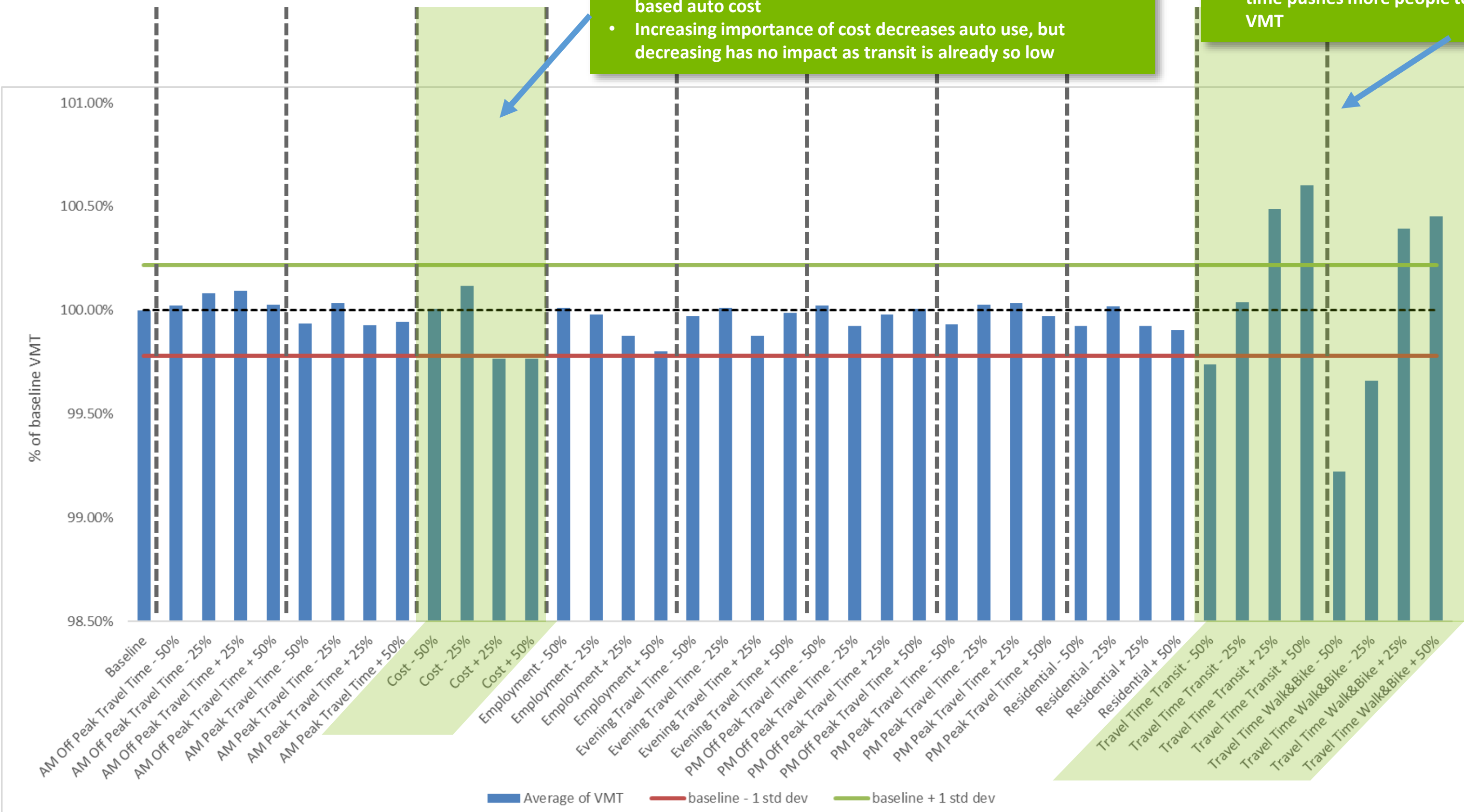
Penetration Rate	LOW (Cost = $2,500)		
Wait Time (second)	**No Platoon**	**300**	**600**
Total Trips	423,710	455,322	423,389
% of platooning capable trips	-	36.0%	35.0%
% of Platooning trips	-	2.1%	2.5%
Total VMT	1,996,495	2,141,793	1,989,705
%VMT in Platoon	-	1.8%	2.3%
Fuel Consumption(kg)	139,364	149,485	139,294

Note: The platoon heads, have not been counted in number of platooning trips or platooning VMT estimation

VEHICLE MILES TRAVELED (VMT) SENSITIVITY ANALYSIS

- Cost has a complicated impact (transit fixed fare, vs. distance based auto cost
- Increasing importance of cost decreases auto use, but decreasing has no impact as transit is already so low

- Increasing the importance of transit, walk or bike time pushes more people to auto mode, increasing VMT



These studies were conducted for Bloomington, IL model – which has low few alternatives to auto-drive mode. Rerunning the study starting in FY19 for Chicago model to get more detail on parameter sensitivity