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BEAM CORE

Behavior, Energy, Autonomy, Mobility - Comprehensive Regional Evaluator

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2021 Vehicle Technologies Office Annual Merit Review

ACKNOWLEDGEMENTS

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OVERVIEW

Timeline

Project start date: 9/1/2020
Project end date: 9/30/2023
Percent complete: 17%

Budget

Total project funding: $12.405 Million
- DOE share: 100%

Funding for FY2020: 0
Funding for FY2021*: $4.255 Million

Partners

Project lead: LBNL
Partners: NREL, UrbanSim, Inc., Sim Rise
Collaborators: PNNL, UC Berkeley

Barriers and Technical Targets

(from Vehicle-Mobility Systems Analysis Tech Team Roadmap Feb 2020)

- Analyses of priority research questions:
  - *"What does the future of mobility look like?*
  - *What are possible future scenarios for how people/goods will move?*
  - *How will these impact future R&D portfolios?*
  - *What would be the vehicle fleet composition?*
  - *What impact will these changes have on energy consumption?"*
- Application of integrated modeling workflow, as well as:
  - *"Taking a step back from the models themselves to consider how underlying relationships—such as land constraints and implications for where people live, work, and travel—and specific variable assumptions—such as modal travel preferences—are translated from conceptual narrative to model implementation.*
  - *Input from external experts with complementary perspectives (e.g. land use, city planning) …solicited..."*

*The project started just before the beginning of FY2021, so the $4.255 million is for FY2021 and about 1 month of FY2020.
Any proposed future work is subject to change based on funding levels.

RELEVANCE

Project Goals

BEAM CORE STRENGTHS AND SPECIALIZATION

- **BEAM CORE specializes in long-term scenario analyses with dynamic and nuanced realism in regional population and economic behavioral evolution** - modeling realistic evolution of households and firms over time, endogenizing multiple factors from mode choice, to technology adoption, to vehicle ownership, to residence and work location, to land-use, to firm and freight planning, and more.
- **BEAM CORE will be widely deployed (in 9 regions in the U.S. at least)** - broader access to these capabilities and the ability to study the role of regional differences in scenario outcomes.
- **BEAM CORE is open source and relies primarily on publicly available data** - a tool that is accessible to a wide range of users and not a “black box.”
- **BEAM improves upon other open source options (like BEAM’s foundation model MATSim)** - improving computational performance and enabling integration of multiple new transportation innovations and paradigms (electric vehicles, ridehailing, automation, micromobility, and more) into a single integrated scenario analysis, not previously possible with MATSim.

RELEVANCE

Project Goals

GOALS:

- Provide practitioners, planners, and stakeholders with insights on feasible actions they may take to improve **mobility**, **energy**, **environmental**, and **equity** outcomes in their regions
- Consider effectiveness of these solutions across multiple regions in the U.S.

Develop next generation of BEAM CORE integrated modeling framework

- Increased integration of sub-models
- Improved simulation capabilities
- Enhanced computational performance

Deployment of BEAM CORE

- 6 new regions

Stakeholder engagement to establish priorities

- Modeling capabilities
- Analyses and desired insights
- BEAM CORE ACT functionality
- Regional interest to inform deployment plan

A comprehensive set of investigations designed to generate actionable insights

- Global sensitivity analyses
- Targeted deep-dive research efforts

BEAM CORE Application and Collaboration Tool (BEAM CORE ACT)

- For stakeholders to efficiently interact with summary outputs from a multitude of BEAM CORE scenarios run using high-performance computing resources

RELEVANCE

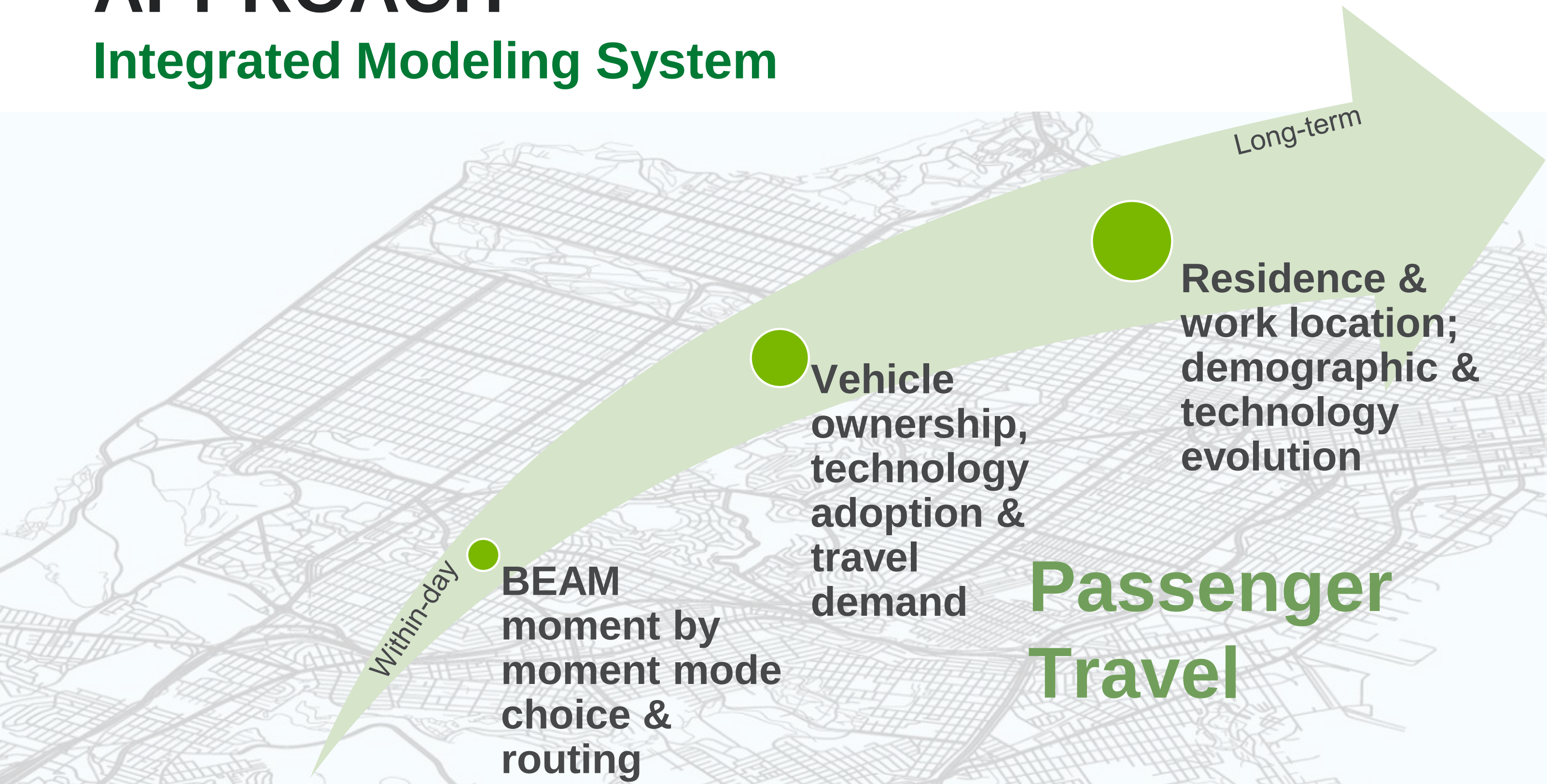
Objectives for Q1 and Q2 of FY2021

- Assessment and benchmarking for increased computational performance
- Progress on development of new capabilities
- First rounds of feedback from stakeholders to inform priorities
- Design of priority scenarios, analyses, and application plan

APPROACH

APPROACH

Integrated Modeling System

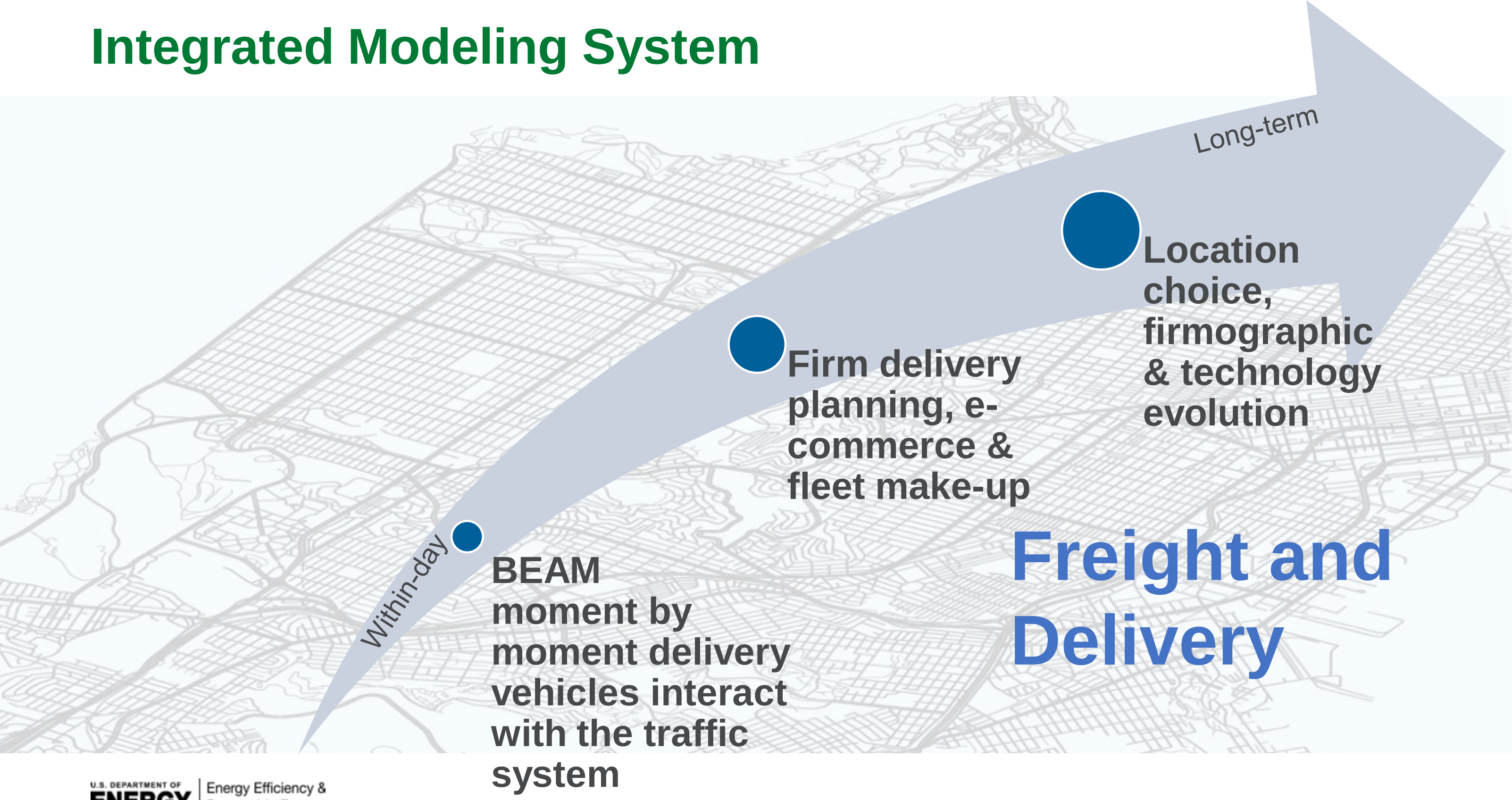


Output and Metrics

- Land use change
- Land value
- Fleet evolution
- VMT, PMT, travel time
- Energy
- Equity and distributional outcomes

APPROACH

Integrated Modeling System

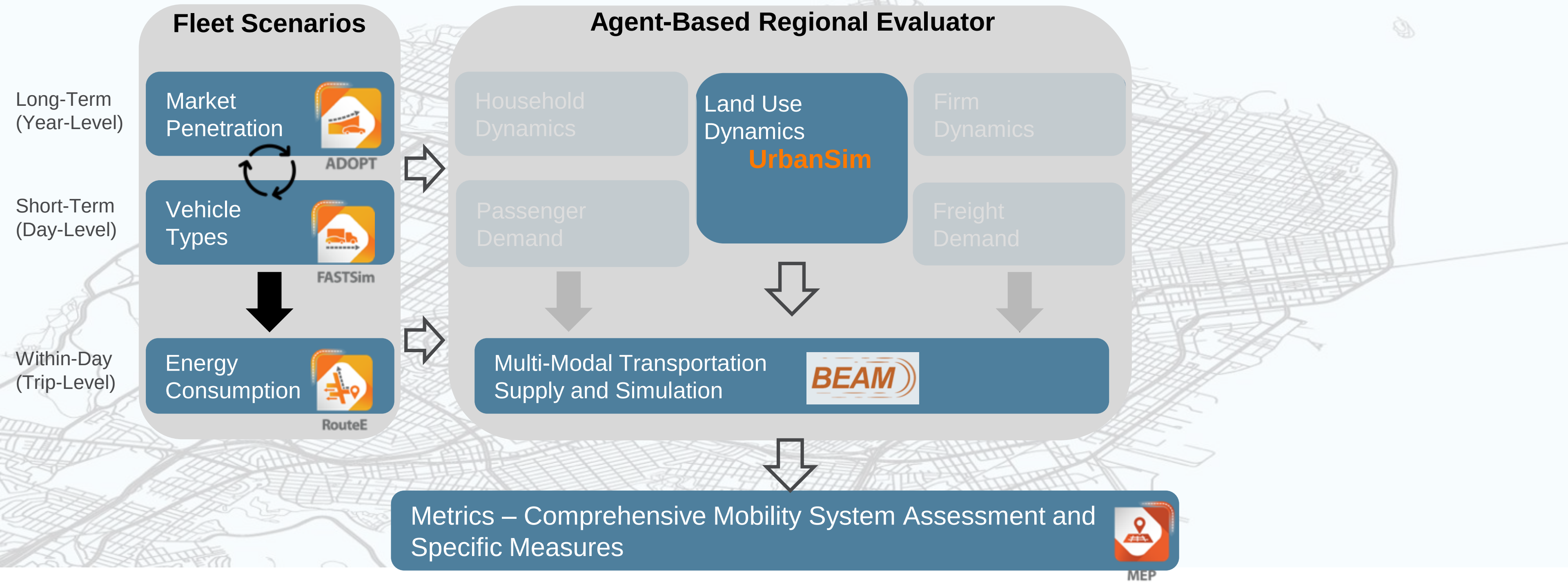


Output and Metrics

- Land use change
- Land value
- Fleet evolution
- VMT, PMT, travel time
- Energy
- Equity and distributional outcomes

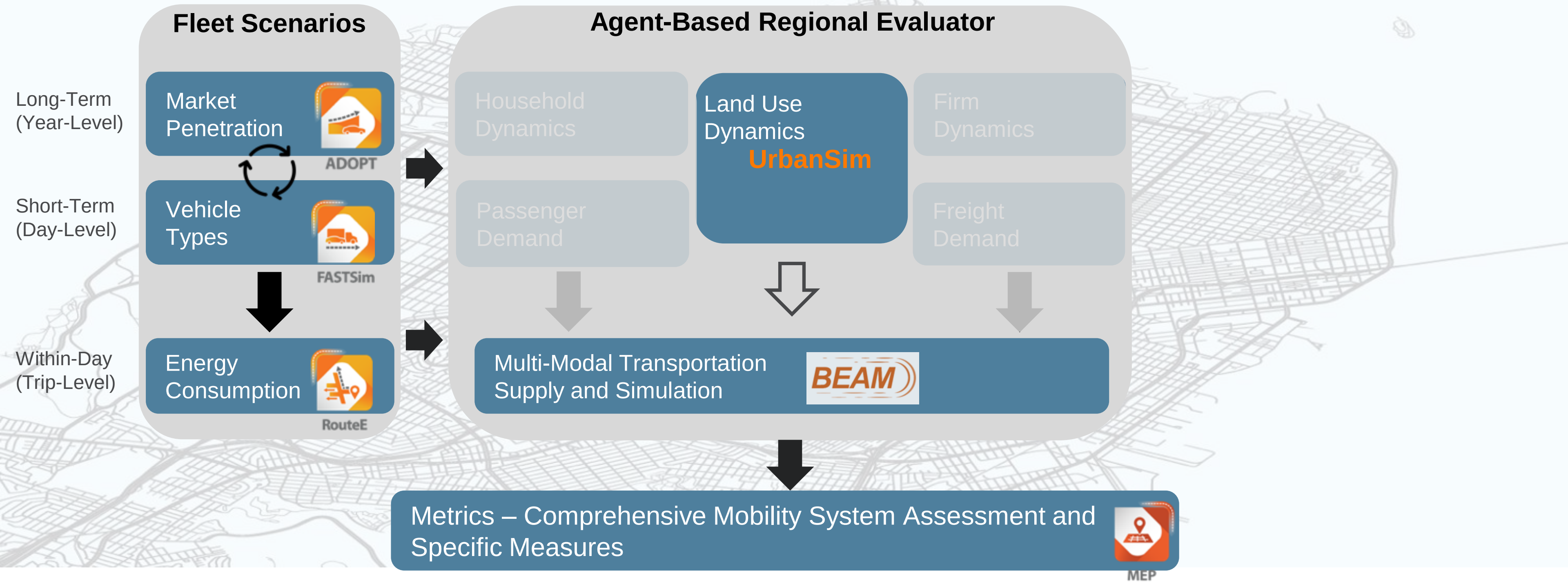
APPROACH

Starting point – end of SMART 1.0



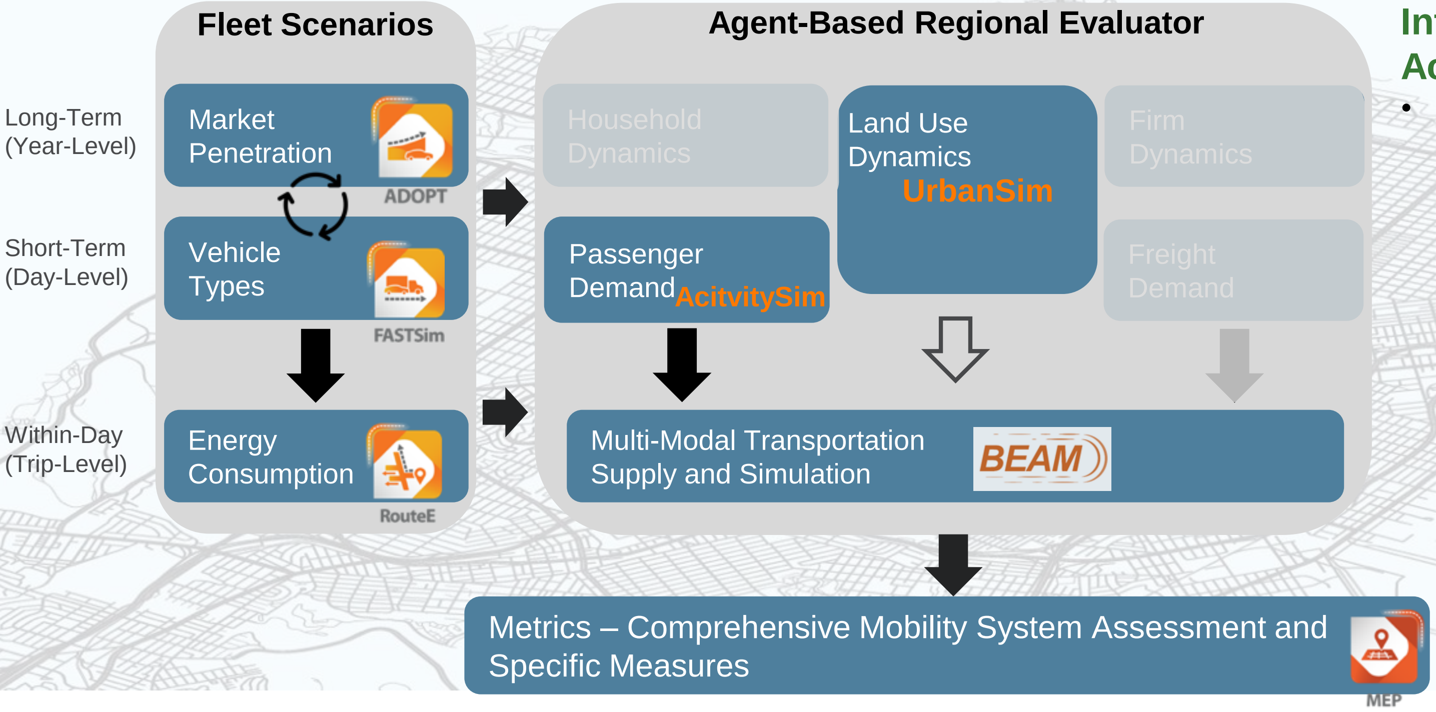
APPROACH

Tighter Coupling Between Modules



APPROACH

New Integration

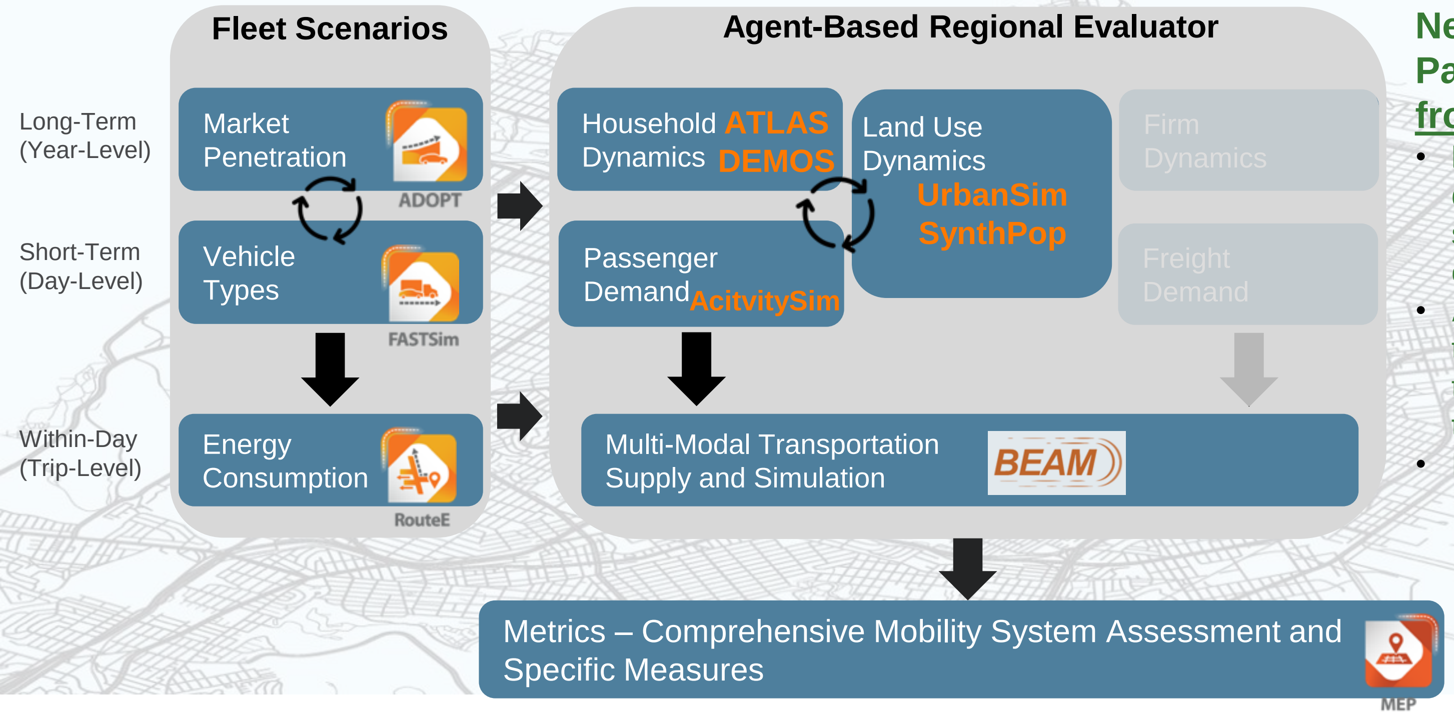


Integration with ActivitySim:

- an open source travel demand model used by many Metropolitan Planning Organizations (MPOs) in the United States. Enables BEAM CORE to capture:
  - Non-discretionary and discretionary activities
  - Joint trips, tours, and coordination within a household
  - Improved joint tour destination, timing, and mode choice models

APPROACH

New Model Development

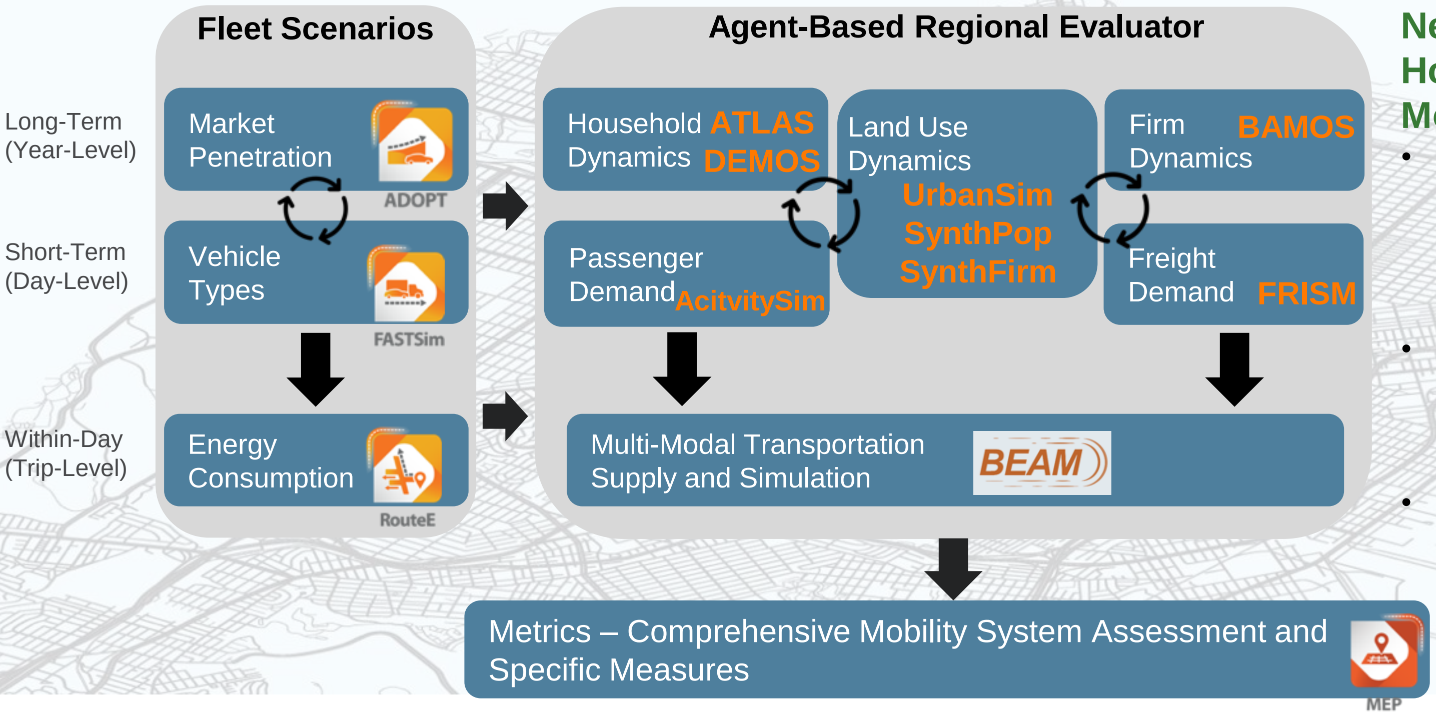


New Long Time Horizon Passenger Modules <u>built from scratch</u>:

- **DEMOS** - Dynamic demographic evolution simulator in which agents evolve over their lifecycle
- **ATLAS** – Dynamic vehicle transaction, vehicle choice, and technology adoption simulator that co-evolves with DEMOS
- Both co-evolve with UrbanSim

APPROACH

New Model Development

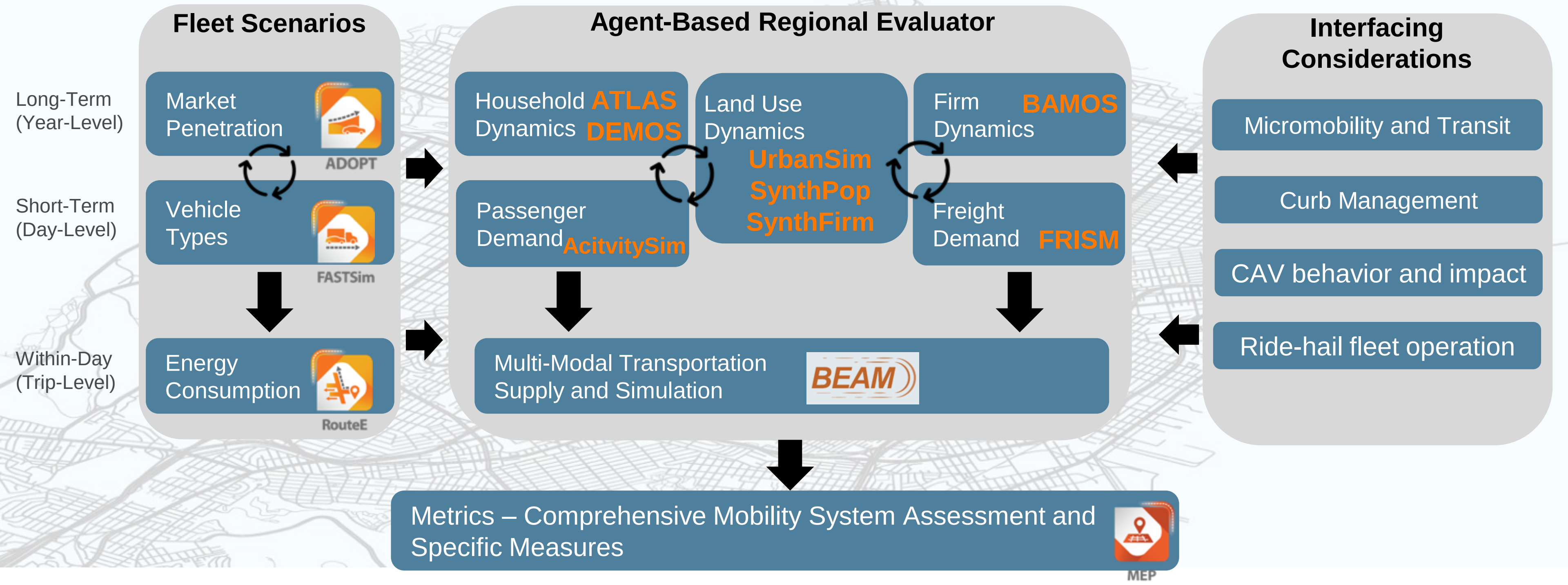


New Short and Long Time Horizon Freight/Delivery Modules built from scratch:

- **BAMOS -** Synthesis of freight agents, supply-chain logistics, and distribution channel with long-term firmographic evolution that co-evolves with UrbanSim
- **FRISM -** Consumer shopping behavior, fleet operation & vehicle-tour plans, and stop locations
- **BEAM-Freight -** Vehicle routing and en-route operations, infrastructure use, and traffic assignment

APPROACH

BEAM Comprehensive Regional Evaluator



TECHNICAL ACCOMPLISHMENTS AND PROGRESS

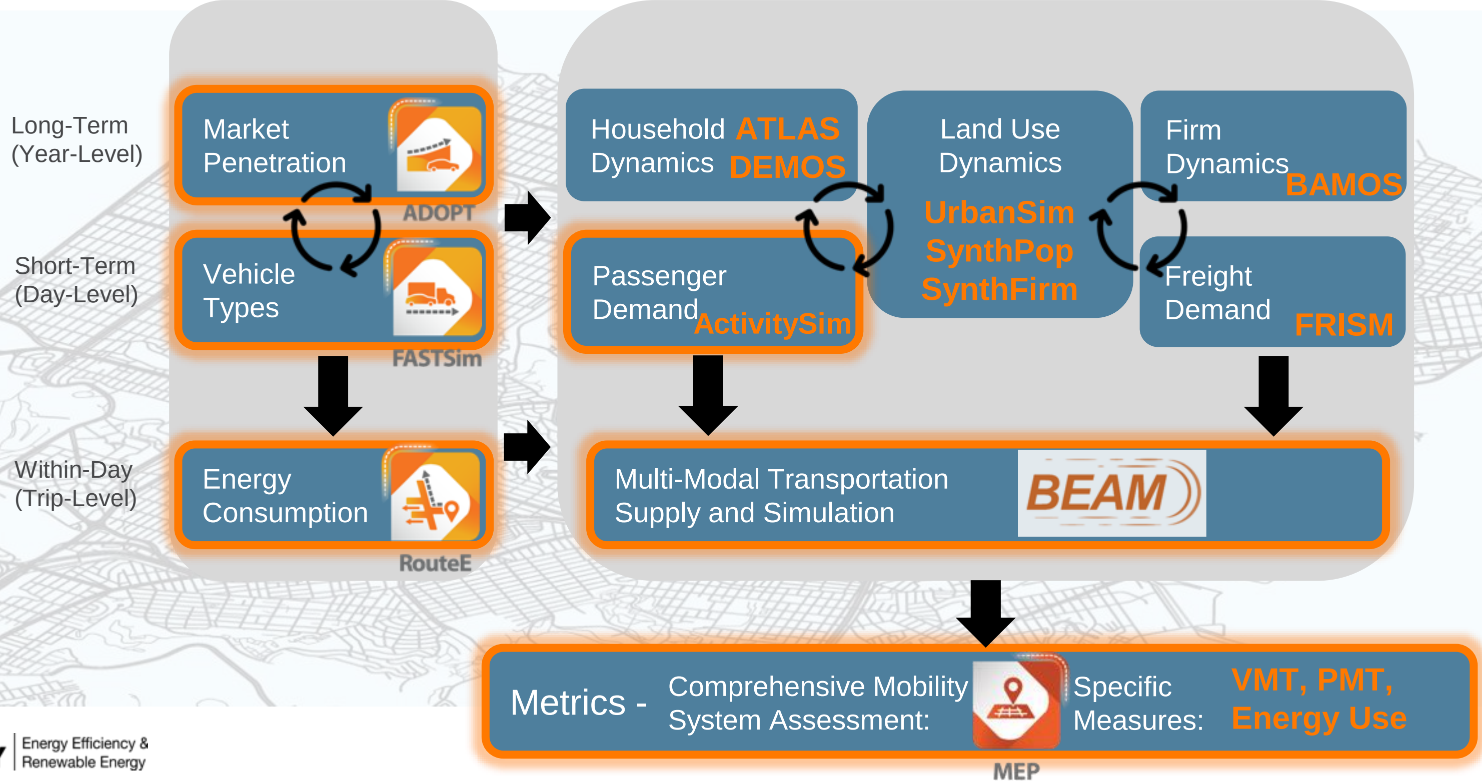
BEAM CORE Output Metrics

	System Level	By subpopulations of interest (e.g., income, race, geography)
Energy	X	X
Greenhouse Gases (GHG)	X	X
Vehicle miles traveled (VMT)	X	X
Vehicle hours traveled (VHT)	X	X
Occupancy for public and private modes	X	X
Redistribution efficiency quantification (e.g., Energy consumed from travel via micromobility divided by Total Energy Consumed for micromobility service including redistribution)	X	
Average trip/travel speed (Ratio of PMT/PHT)	X	X
Average vehicle travel/network speed (Ratio of VMT/VHT)	X	
Travel consumption (Average energy required to move a person or a good 1 mile)	X	X
Passenger-mile-travelled (PMT)	X	X
Normalized metrics (e.g., $/mile/kg for freight movement and $/mile/person for people movement)	X	
Mobility Energy Productivity (MEP) metric	X	X
INEXUS suite of metrics	X	X
INEXUS GINI Coefficient	X	

For more detail on MEP and INEXUS see EEMS099 Presentation

APPROACH

Task 1: Enhanced Performance and Deployment



APPROACH

Task 1: Enhanced Performance and Deployment

FASTER TO RUN

- **Make code more computationally efficient →** Faster algorithms, continued refactoring and profiling
- **Require fewer iterations →** Get to user equilibrium faster
- **More parallel →** Take full advantage of asynchronous agent communications in BEAM, deploy on multi-node HPC

EASIER TO RUN

- **SMART 1.0 model runs required manually passing inputs/outputs between many modules**
- **Get the human out of the loop →** Automate construction and sharing of inputs/outputs between models

MORE ACCURATE

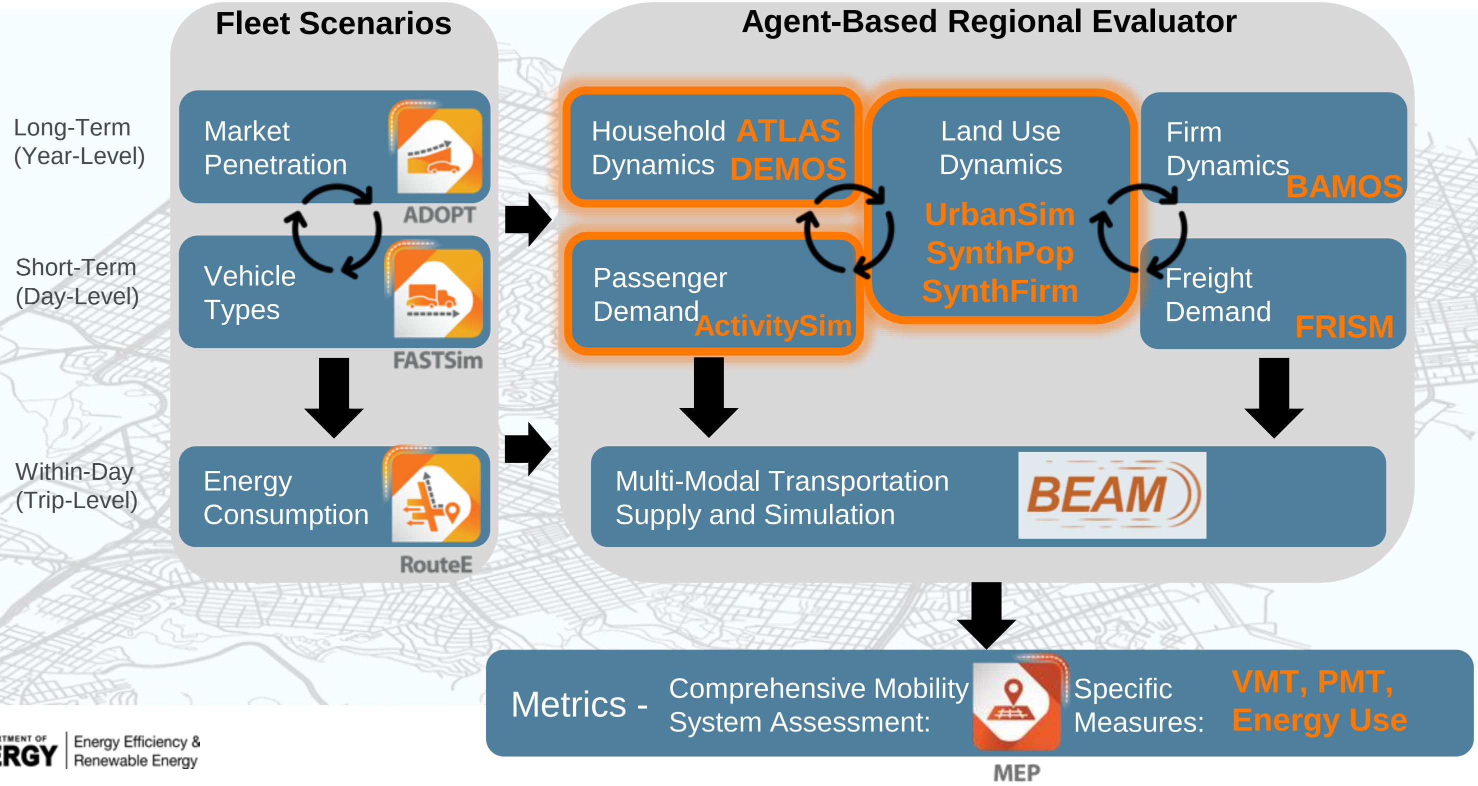
- **More consistency between agent decisions at different time scales**
  - Land use ▪ Activity planning ▪ Mode/route choice ▪ Fleet operations/Controls ▪ Freight
- **Make full use of all ActivitySim features**
  - ActivitySim already widely used in many cities ▪ Allows easy coordination with UrbanSim

MORE WIDELY DEPLOYED

- **Currently BEAM is deployed in 4 regions, with BEAM CORE deployment in 3**
- **Deploy BEAM CORE in 6 new regions**

APPROACH

Task 2: Household Evolution & Vehicle Ownership Dynamics



APPROACH

Task 2: Household Evolution & Vehicle Ownership Dynamics

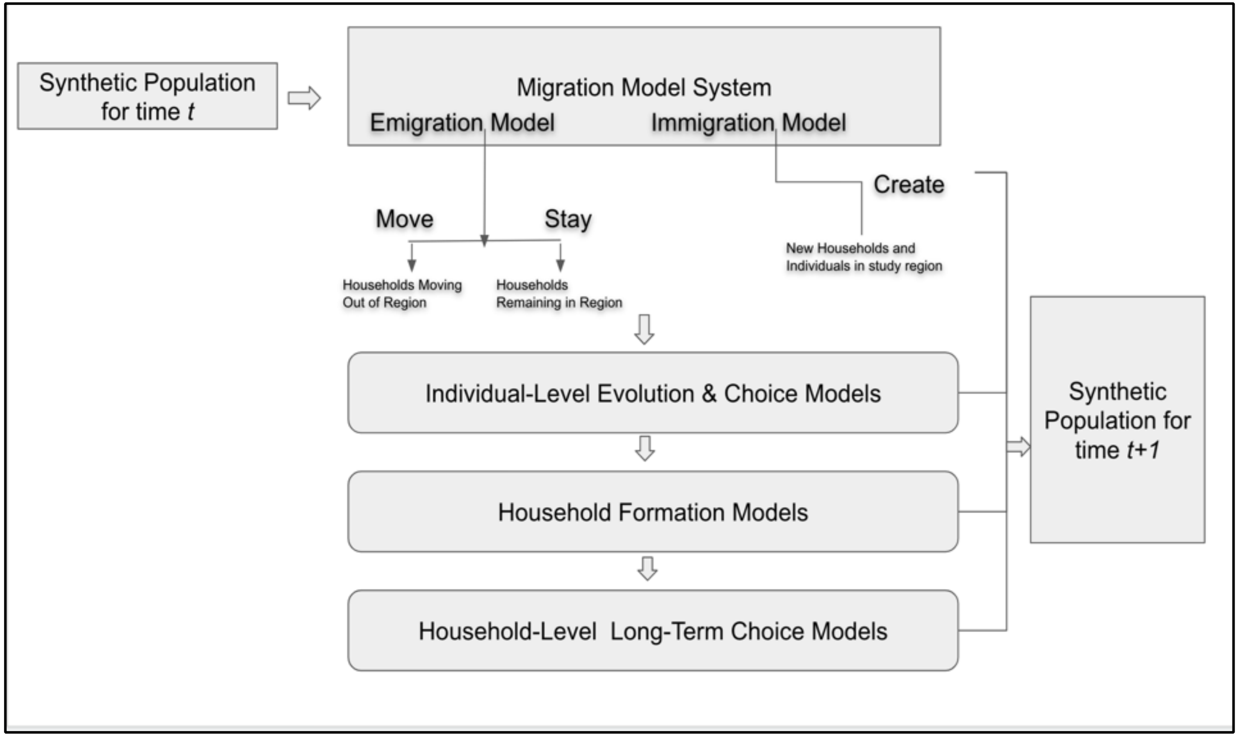
Building new models from the ground up

- **Lifecycle stage trajectory based approach**
  - Critical to activity-based travel analysis
  - Accounting for dynamic patterns and changes in employment status, home ownership, and family size has major implications on mobility and travel choices
  - Enables more powerful equity analyses
- **Vehicle ownership dynamics**
  - Affected by life-course events
  - Affects fleet composition and evolution by vehicle holdings, vehicle type, allocation and use
  - Vehicle availability impacts choice of location, travel, and mode

APPROACH

Task 2 - Demographic Microsimulation (DEMOS) Model

- **Migration Model** - Emigration and immigration into the region
- **Individual Events** - Birth, death, schooling, and employment
- **Household Formation** - Living arrangement, marital status (marriage/divorce), move-in and move-outs from family
- **Household Long-Term** - Residential mobility, housing tenure (rental/ownership), and housing type (single-/multi-family)

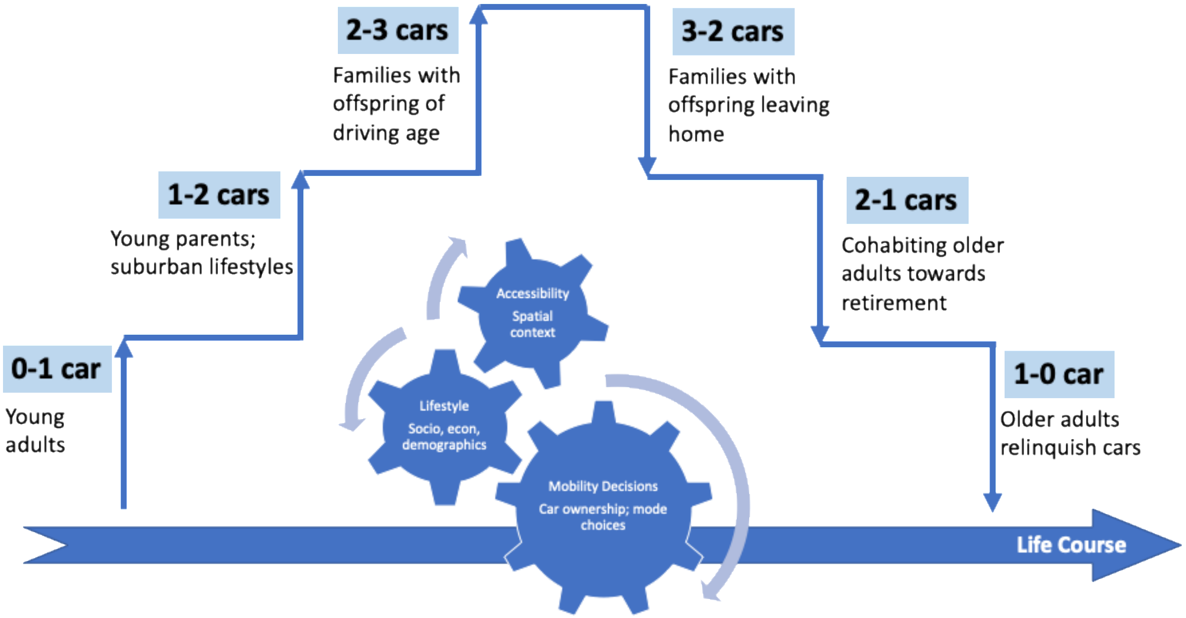


APPROACH

Task 2 – Vehicle Transition and Technology Adoption (ATLAS) Model

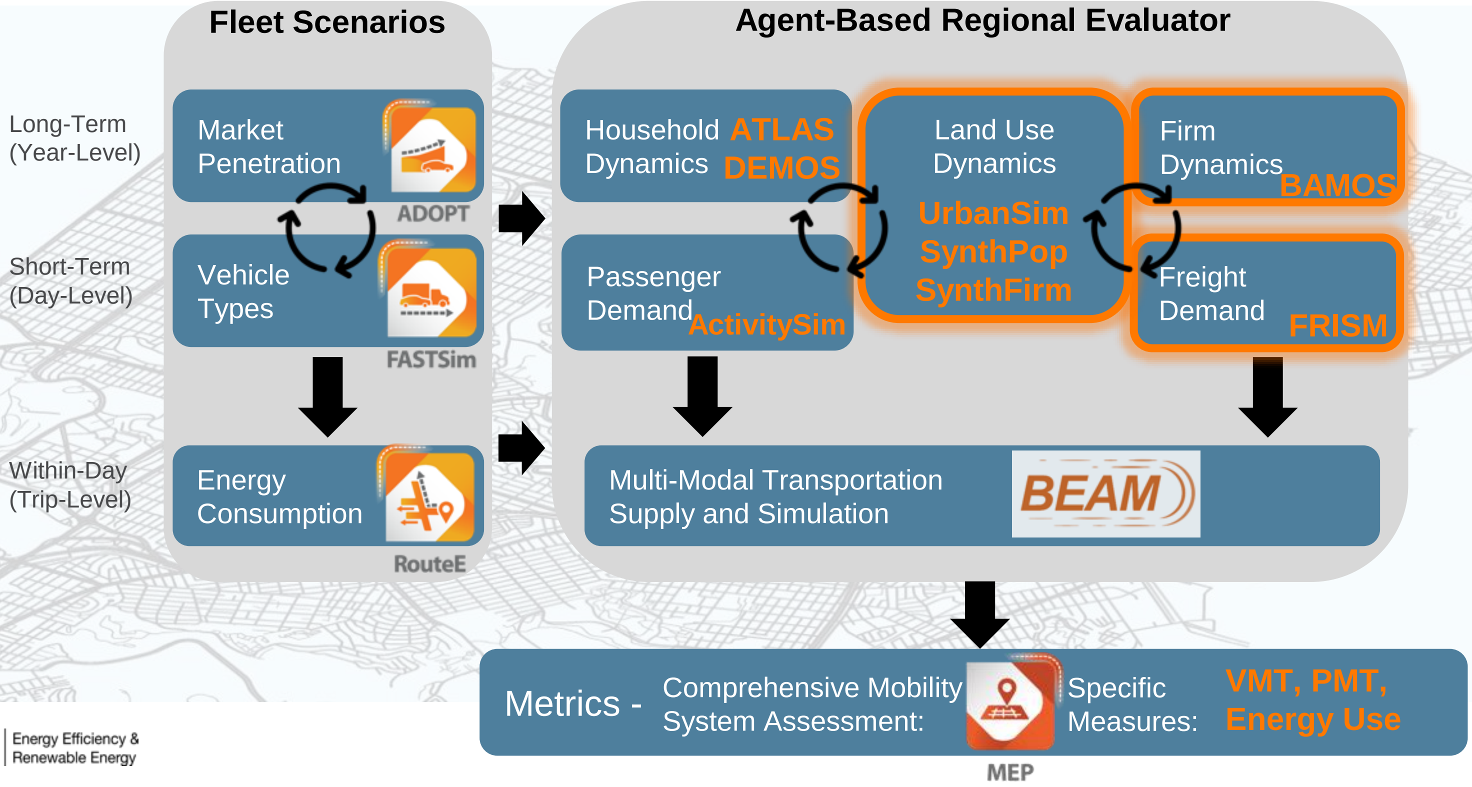
- **Previous existing models**
  - Static, snapshot
- **ATLAS**
  - Captures vehicle transaction decision processes
  - Dynamically co-evolves with socio-demo and spatial context
  - Enables identification of levers/opportunities at critical times and locations

Behavioral Insights from Vehicle Ownership Dynamics



APPROACH

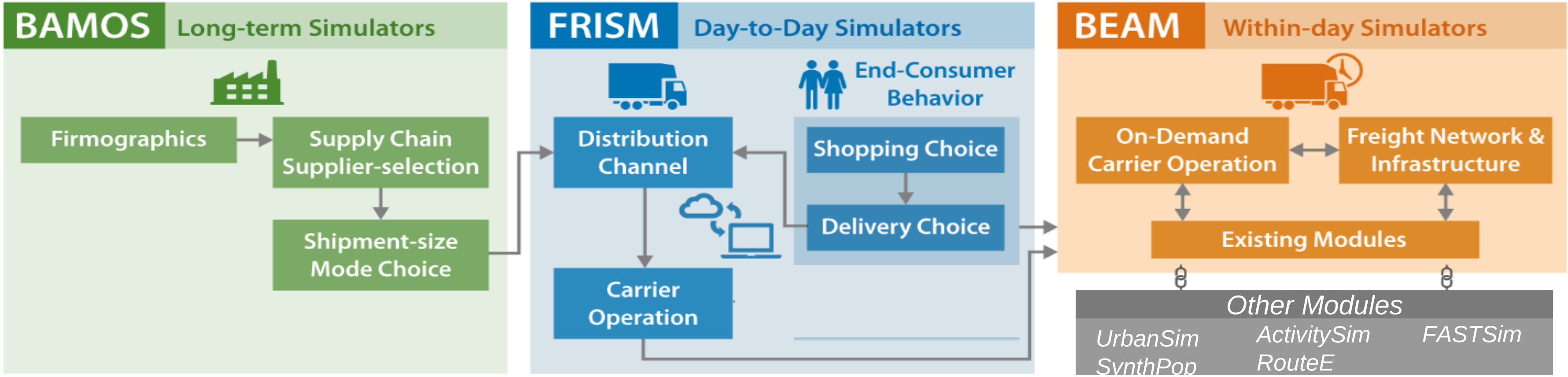
Task 3: New Freight Capabilities



APPROACH

Task 3: New Freight Capabilities

- **Building new models from the ground up:** interconnected agent/activity-based models to simulate freight behavior, operations and logistics over different time scales (short-term to long-term)
- Implementation and deployment integrated with BEAM CORE in the San Francisco Bay Area



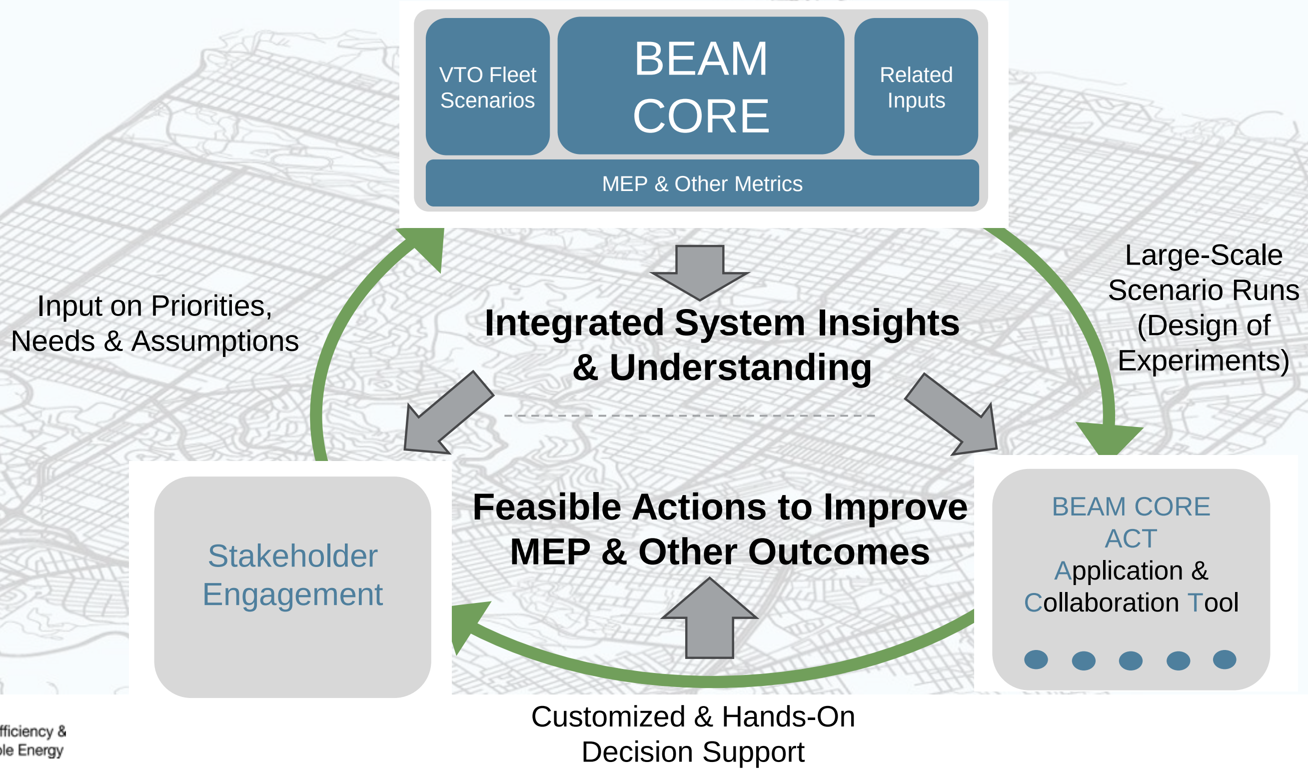
Business **A**ctivity and **M**obility **S**imulator (**BAMOS**): Synthesis of freight agents, supply-chain logistics, and distribution channel

Freight **I**ntegrated **S**imulation **M**odel (**FRISM**): Consumer shopping behavior, fleet operation & vehicle-tour plans, and stop locations

BEAM-Freight: Vehicle routing and en-route operations, infrastructure use, and traffic assignment

APPROACH

Task 4: Application and Outreach



APPROACH

Task 4: Application and Outreach

VTO Fleet Scenarios

BEAM CORE

Related Inputs

MEP & Other Metrics

Large-Scale Scenario Runs (Design of Experiments)

BEAM CORE ACT
Application & Collaboration Tool

Customized & Hands-On Decision Support

Stakeholder Engagement

Input on Priorities, Needs & Assumptions

Task 4.1: Stakeholder Engagement

- Outward-facing materials
- Model documentation
- Stakeholder Listening Sessions
- Ongoing stakeholder engagement

Task 4.2: Scenario and Sensitivity Analysis Design

- Developed based on stakeholder priorities
- Designed to expand beyond few scenarios and single-point forecasting

Task 4.3: BEAM CORE ACT

- Interactive meta-model tool synthesizing results from a global sensitivity analysis of critical levers in the BEAM CORE system
- For use by academia and stakeholders

Task 4.4 & 4.5: Deep-dive analysis to derive actionable insights

- 4.4: System dynamics and distributional impacts
  - Feedback loops
  - Spillover effect and externalities
- 4.5: Transit system scenarios
  - Long-term planning
  - Micro-mobility integration
  - COVID-19 adaptation

APPROACH

Milestones – Q1 FY2021

Status	Description
Complete	Task 1 - Complete prototyping and testing of faster routing algorithms (described in more detail in Task 1 description) for roadway assignment.
milestone pushed forward with new timeline to be determined	Task 1 (GPRA Comparison) - Complete comparison of BEAM and POLARIS for baseline models of Austin and Detroit. Work with the POLARIS team to explain the discrepant trends with BEAM. Agree on inputs and configuration for future SMART scenarios to be run on both BEAM and POLARIS.
Complete	Task 2 – Primary data assembled and processed for DEMOS/ATLAS.
Complete	Task 3 - Complete the model framework design and data needs and assembly for short-term freight models in SF Bay Area.
Complete	Task 4 - Catalog top interests of stakeholders in currently deployed cities and summarize plans to address them.
Complete	Task 4 - Documentation of data sources, current or anticipated calibration process, current or anticipated validation process for BEAM, ActivitySim, DEMOS, ATLAS, BAMOS, FRISM, ADOPT, FASTSim, and RouteE.

APPROACH

Milestones – Q2 FY2021

Status	Description
Complete	Task 1 – For initial performance improvements and parallelization of BEAM CORE runs, report benchmarking results containing percentage of sample runs with overall run-times on various cores.
Complete	Task 2- Complete framework design of simplified integration of DEMOS/ATLAS.
Complete	Task 3 - Develop and implement SynthFirm to generate synthetic firms and supply-chain formations (B2B flows) and mode choice by shipment-size for SF Bay Area.
Complete	Task 4 - Completed high-level prioritized analysis plan, based on stakeholder input.

APPROACH

Milestones – Q3 FY2021

Status	Description
On Track	Task 1 - First round of increased automation and enhancements (described in more detail in Task 1 description) of MEP and ADOPT/FASTSim/RouteE coupling for performance improvements implemented.
On Track	Task 2 - Complete development and integration of DEMOS transition models into UrbanSim and of the ATLAS model into BEAM CORE for the SF Bay Area.
On Track	Task 3 - Develop and implement freight truck-focused tour generation (B2B flows) along with end-consumer demand (B2C flows) and document model outputs and results.
On Track	Task 3 - Implement freight-focused traffic assignment in BEAM and document results.
On Track	Task 4 - Completed map of near-term and long-term design of experiments (DoX), based on stakeholder input.
On Track	Task 4 - Define transit scenarios based on SF stakeholder interest (was moved from a Q2 milestone to a Q3 milestone to allow for more opportunities for stakeholder involvement)

APPROACH

Milestones – Q4 FY2021

Status	Description
On Track	Task 1 – Demonstrate initial end-to-end automation of BEAM CORE (i.e., how initiating a full BEAM CORE run, including all component models, will result in final scenario output without researcher intervention).
On Track	Task 2 – Report on validation and calibration of DEMOS/ATLAS for SF Bay Area results, and capability to deploy to other cities.
On Track	Task 3 – Document validation and calibration metrics for short-term freight model modules in SF Bay Area, and report on model readiness for deployment to other cities.
On Track	Task 4 - Demonstrate test version BEAM CORE ACT platform using meaningful placeholder data.
	Go/No-Go: There is a risk that the computational time/cost constraints result in an inability to execute the ideal design of experiments (DoX) scenario plan, thereby affecting dependent BEAM CORE ACT planned capabilities and insight-generation scope. If this occurs, then the DoX and dependent task plans will need to be down-scoped to fit within the constraints.

TECHNICAL ACCOMPLISHMENTS AND PROGRESS

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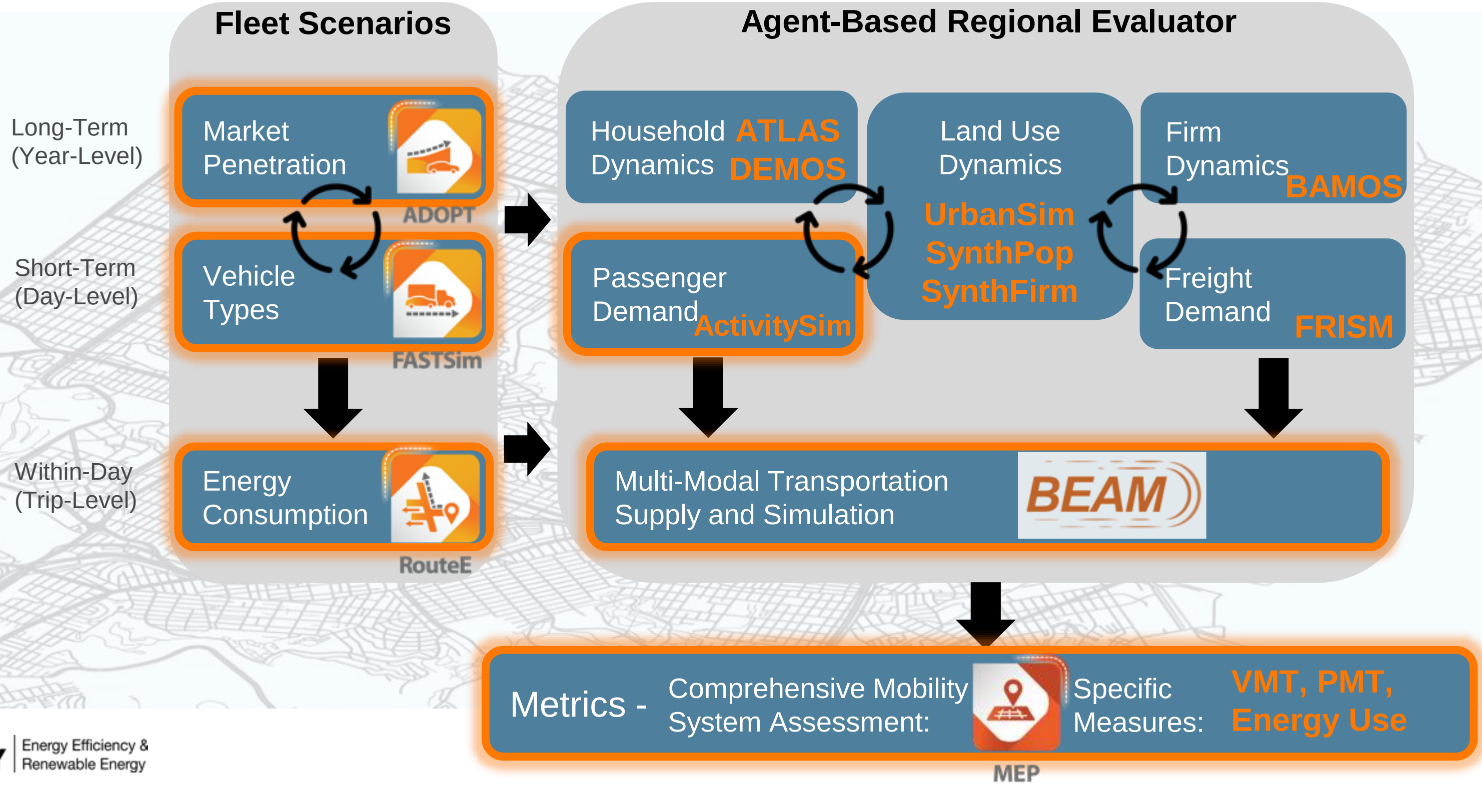
Task 1: Enhanced Performance and Deployment



TECHNICAL ACCOMPLISHMENTS AND PROGRESS

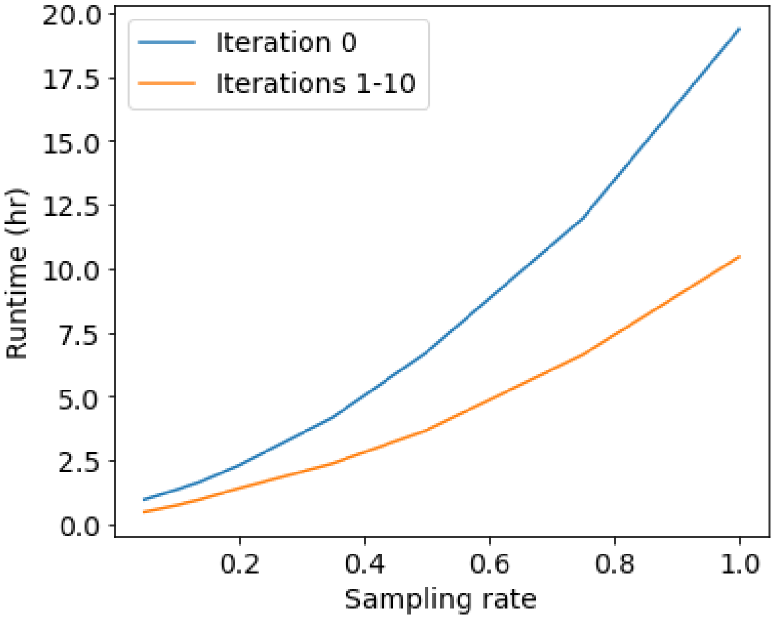
Task 1 – Enhanced performance and deployment

- **Benchmarking of BEAM improved performance**
  - Completed benchmarking runs to assess model performance and results impacts of runs based off of a 10%-100% sample size
  - Completed first runs on CORI supercomputer at LBNL

- **Modularized computationally intensive model components to optimize performance**
  - Implemented
    - customizable contraction hierarchies for street routing
    - distributed parking and ridehail managers

Improvements implemented so far resulted in a **14-17% faster** run time, even with concurrently added new features with additional complexity.

Baseline performance benchmarks in Austin Implementation



TECHNICAL ACCOMPLISHMENTS AND PROGRESS

Task 1 – Enhanced performance and deployment

Benchmarking of Model Performance with Population Subsampling in Austin

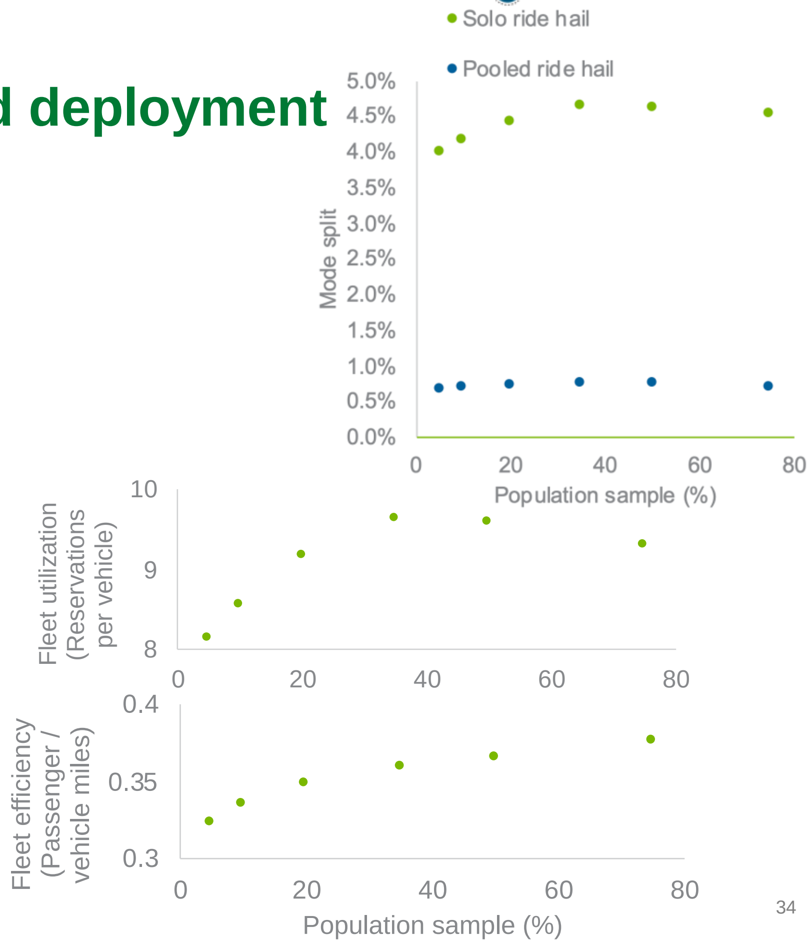
Running on a subsample can speed up the model… does it affect outcomes?

Assessment of population sample size impact on results for ridehail because:

- Ridehail is a network good
- Outcomes are likely to be sensitive to scale of demand relative to network size

Increasing population sample rate has some impact on results, but the impact diminishes beyond a ~40% sample

Running on a 40% sample captures majority of the accuracy at approximately 1/3 the run time of a full sample



TECHNICAL ACCOMPLISHMENTS AND PROGRESS

Task 1 – Enhanced performance and deployment

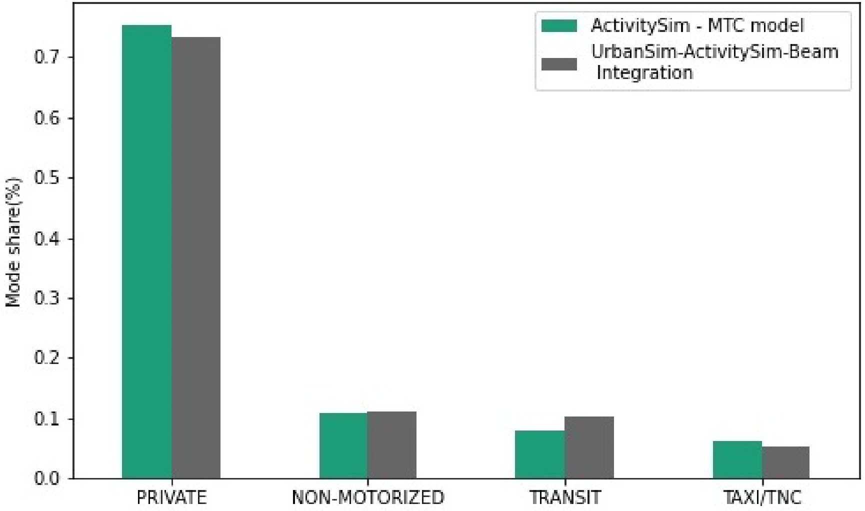
First complete joint ActivitySim/BEAM runs in the San Francisco Bay Area Implementation

- Data exchange between models:

BEAM → ActivitySim
- Origin/destination travel times, costs
- Wait times, access/egress times, transfers
- All access/egress mode combinations

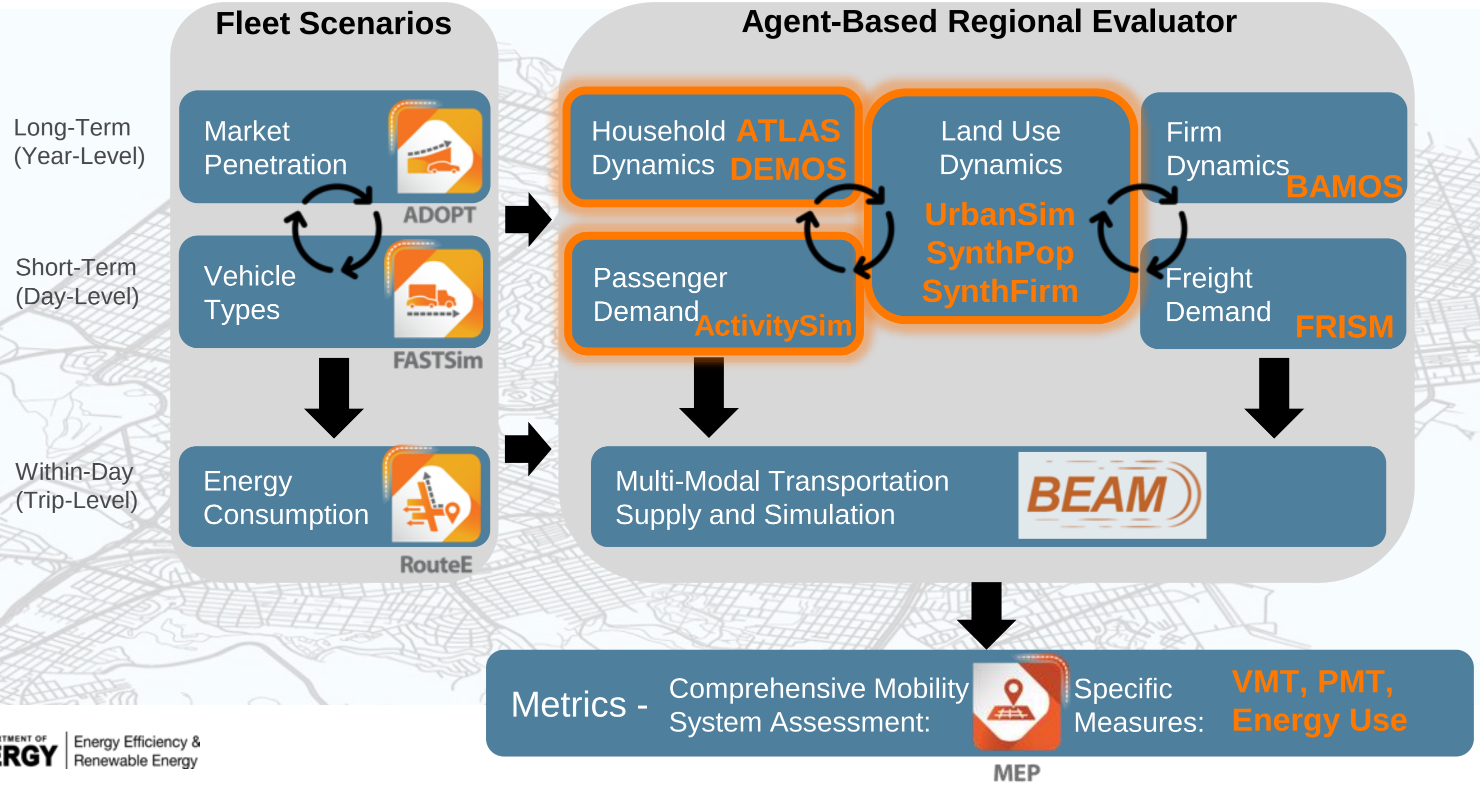
ActivitySim → BEAM
- Individual activity and trip plans
- Single and multi-occupant car trips
- Solo and joint discretionary activities

Mode Share Comparison in San Francisco Implementation



TECHNICAL ACCOMPLISHMENTS AND PROGRESS

Task 2: Household Evolution & Vehicle Ownership Dynamics



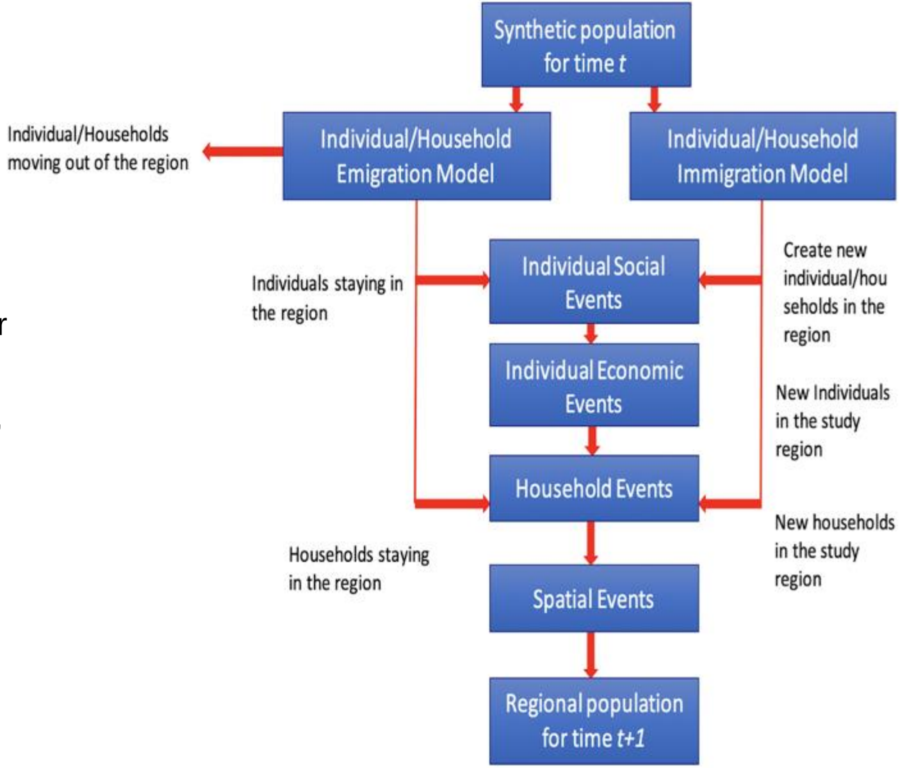
TECHNICAL ACCOMPLISHMENTS AND PROGRESS

Task 2 – DEMOS Model

Completed formulation of the full model structure, including 9 separate modules, identified and acquired data necessary to estimate all modules, and have begun model estimation

- Modules include:
  - ***Individual events:*** Aging, gender of the newborn, labor participation, employment status, employment type (full-/part-time), industry employed, occupation type, work duration/flexibility, personal income, employment spell (or tenure), and job change.
  - ***Household restructuring events:*** Marital status (single, cohabit, divorce, married, or widowed), child leaving parental home, and birth/death of household members.
  - ***Spatial events:*** Residential mobility (relocation and location choice), residential ownership (own/rent), workplace and school location choice.
  - ***Migration events:*** Individuals/households moving in and out of the study region

DEMOS Model Structure



TECHNICAL ACCOMPLISHMENTS AND PROGRESS

Task 2 – DEMOS Model

Detail on DEMOS Modules

DEMOS Module	Unit of Analysis	Model Type	Comments
Aging	Individual	Deterministic	Age increased by +1 for each simulator year
Mortality	Individual	Binary Logit	
Fertility	Individual	Binary Logit	Eligibility for Woman 15 - 50 years old
Marriage	Individual / Household	Multinomial Logit	Eligibility for single parent and one-person households
Divorce	Individual/Household	Multinomial Logit	Eligibility is for married female only
Cohabitation	Individual/Household	Multinomial Logit	Eligibility for single parent and one-person households
Break-up	Individual/Household	Multinomial Logit	Eligibility is for female in cohabitation
Child Leaving Home	Individual	Binary Logit	Child and HH head: Age diff > 18, same race
Educational Enrollment	Individual	Binary Logit	Determines enrollment in educational institution; Age > 16

TECHNICAL ACCOMPLISHMENTS AND PROGRESS

Task 2 – DEMOS Model

DEMOS Model Data Sources

All data necessary to estimate and validate the San Francisco Bay Area model acquired:

- Primarily built on publicly accessible datasets with state and/or national coverage
  - Less region-specific sample size and representation, but sufficient at a state level to apply to subregions
  - Enables extensibility to more regions across the state and U.S. more readily

Individual Events

- Panel Study of Income Dynamics (PSID)
- California Department of Finance (CDF)
- California Department of Education (CDE)
- National Household Travel Survey (NHTS)

Household Events

- Panel Study of Income Dynamics
- National Survey of Family Growth (NSFG)
- California Department of Finance

Spatial Events

- Panel Study of Income Dynamics
- California Department of Finance

TECHNICAL ACCOMPLISHMENTS AND PROGRESS

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

Task 2 – DEMOS Model

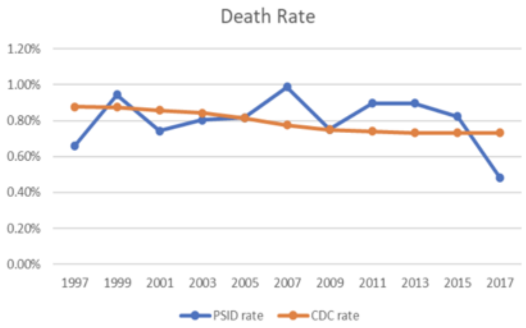
Significant reliance on PSID data for DEMOS estimation

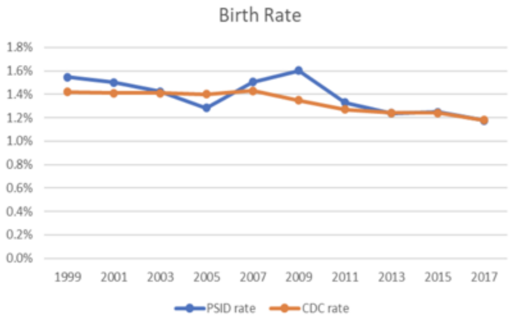
- PSID is a panel dataset, necessary for modeling dynamics of demographic trends and transitions over time

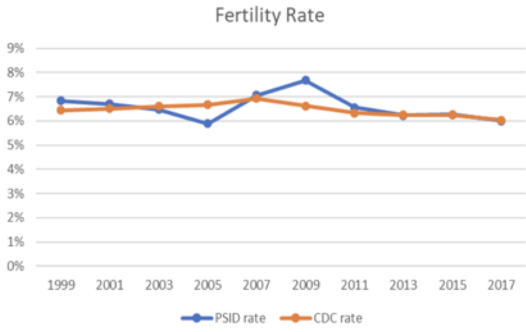
Validation of PSID data:

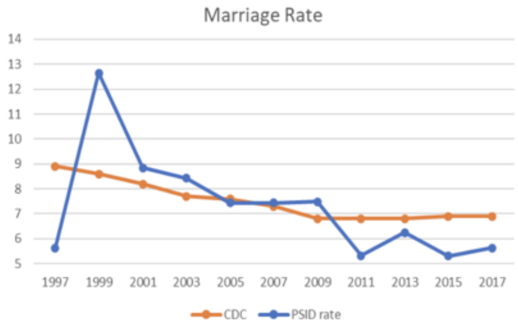
- PSID was compared against representative, but aggregate and cross-sectional, data from the Center for Disease Control and Pretension (CDC)

It was found that PSID data, while more noisy, trend sufficiently well with CDC data to justify reliance for DEMOS estimation purposes, especially from 2001-2017









TECHNICAL ACCOMPLISHMENTS AND PROGRESS

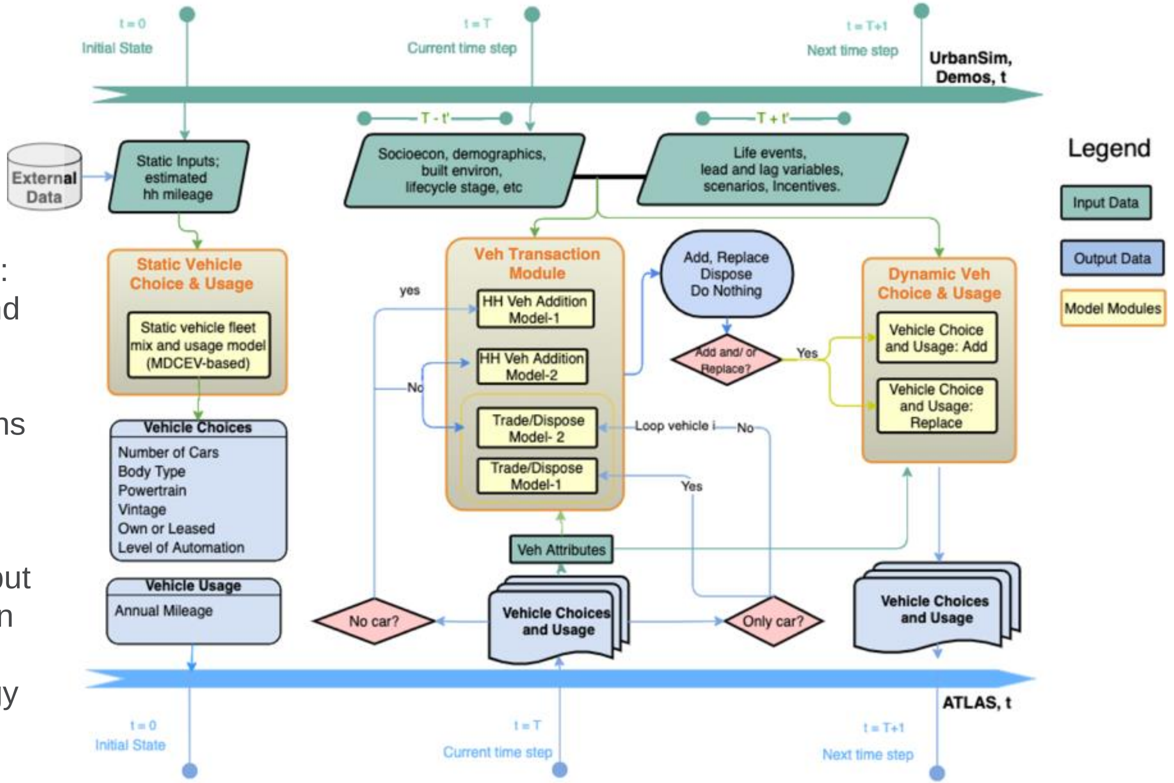
Task 2 – ATLAS Model

Completed formulation of the full model structure, including 3 separate modules, identified and acquired data necessary to estimate all modules, and have begun model estimation

Modules Include:

- **Static vehicle choice and use module**: Initializes household fleet composition and use
- **Vehicle transaction decision module**: Predicts probability of household decisions on vehicle addition, disposal, and/or replacement at an evolution timestep
- **Dynamic vehicle choice and use module**: Takes transaction decision output from dynamic vehicle transaction decision module and updates household fleet composition and use based on technology adoption decisions for next timestep

ATLAS Model Structure



TECHNICAL ACCOMPLISHMENTS AND PROGRESS

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

Task 2 – ATLAS Model

Model outputs

Transaction Decision
- *Acquisition*
- *Trade*
- Dispose
- Do Nothing

Vehicle Choices
- Number of Cars
- Body Type
- Powertrain
- Vintage
- Own or Leased
- Level of Automation

Vehicle Usage
- Annual Mileage

Utility Maximization Choice Modeling

Model predictors

Socioeconomical
- Household Income
- Number of adults
- Marriage status
- Presence of kids
- Education level
- Number of workers
- Race

Lifecycle Stage
- Presence of retired
- LIF_CYC_1
- LIF_CYC_2
- LIF_CYC_3
- ...

LIfe Events
- Marriage
- Child Entry
- Employment
- Education
- Residential Mobility
- Income Change
- (concurrent, lead, and lag)

Existing Fleet Attributes
- Body Type
- Powertrain
- Vintage
- Own or Lease
- Number of Cars
- Level of Automation

Built Environment
- Job density
- Housing density
- Housing type and tenure
- Transit access
- Walkability

Incentives
- Parking
- Rebate
- Toll etc...

Choice Specific
- Price;
- O&M;
- Performance
- Infrastructure
- Willingness to pay

Strategies/ Levers

TECHNICAL ACCOMPLISHMENTS AND PROGRESS

Task 2 – ATLAS Model

ATLAS Model Data Sources

All data necessary to estimate and validate the San Francisco Bay Area model acquired:

- Primarily built on publicly accessible datasets with state and/or national coverage
  - Less region-specific sample size and representation, but sufficient at a state level to apply to subregions
  - Enables extensibility to more regions across the state and U.S. more readily

Static Model	Transaction Model	Dynamic Model
▪ Panel Study of Income Dynamics ▪ National Household Travel Survey	▪ Panel Study of Income Dynamics ▪ California Vehicle Survey	▪ Panel Study of Income Dynamics ▪ California Vehicle Survey

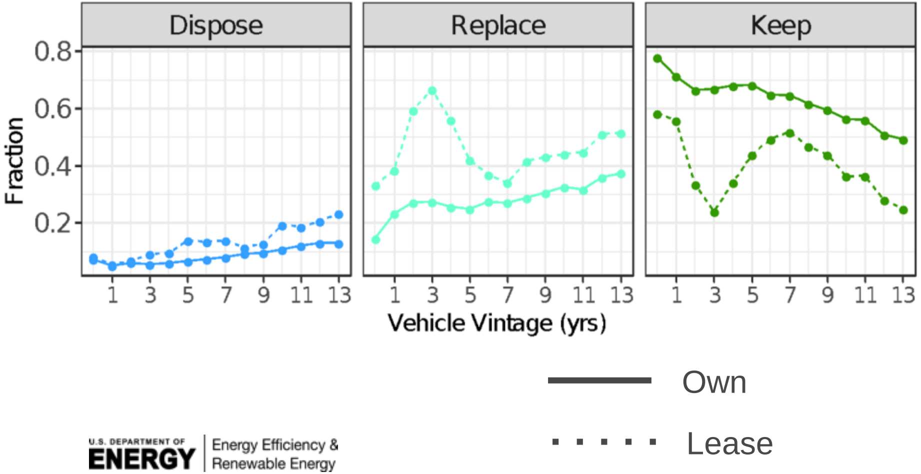
- **Panel Study of Income Dynamics (PSID):** Revealed household ownership, vehicle life trajectories for building transaction model.
- **National Household Travel Survey (NHTS):** Revealed household fleet composition and use information for building static model.
- **California Energy Commission (CEC) Vehicle Survey:** contains both a cross-sectional survey of revealed household vehicle choices and use and a stated intention/preference survey through discrete choice experiments for calibrating sensitivities to policy levers.

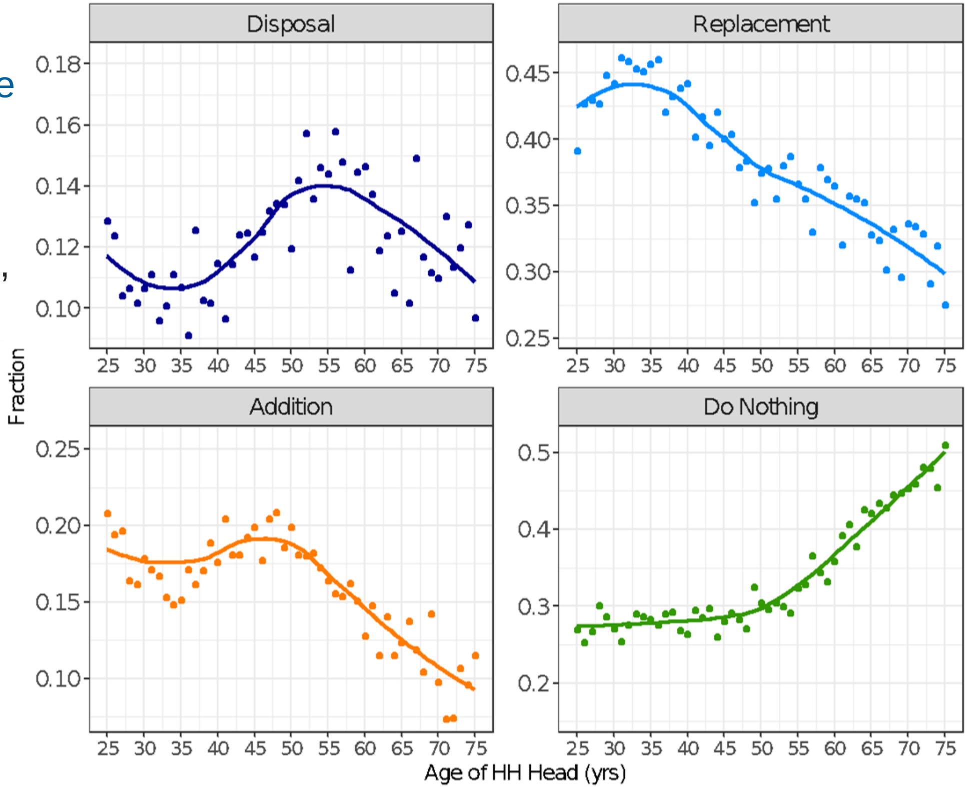
TECHNICAL ACCOMPLISHMENTS AND PROGRESS

Task 2 – ATLAS Model

Assessment of PSID data → does it contain the type of variation required to support ATLAS estimation?
✓ Yes

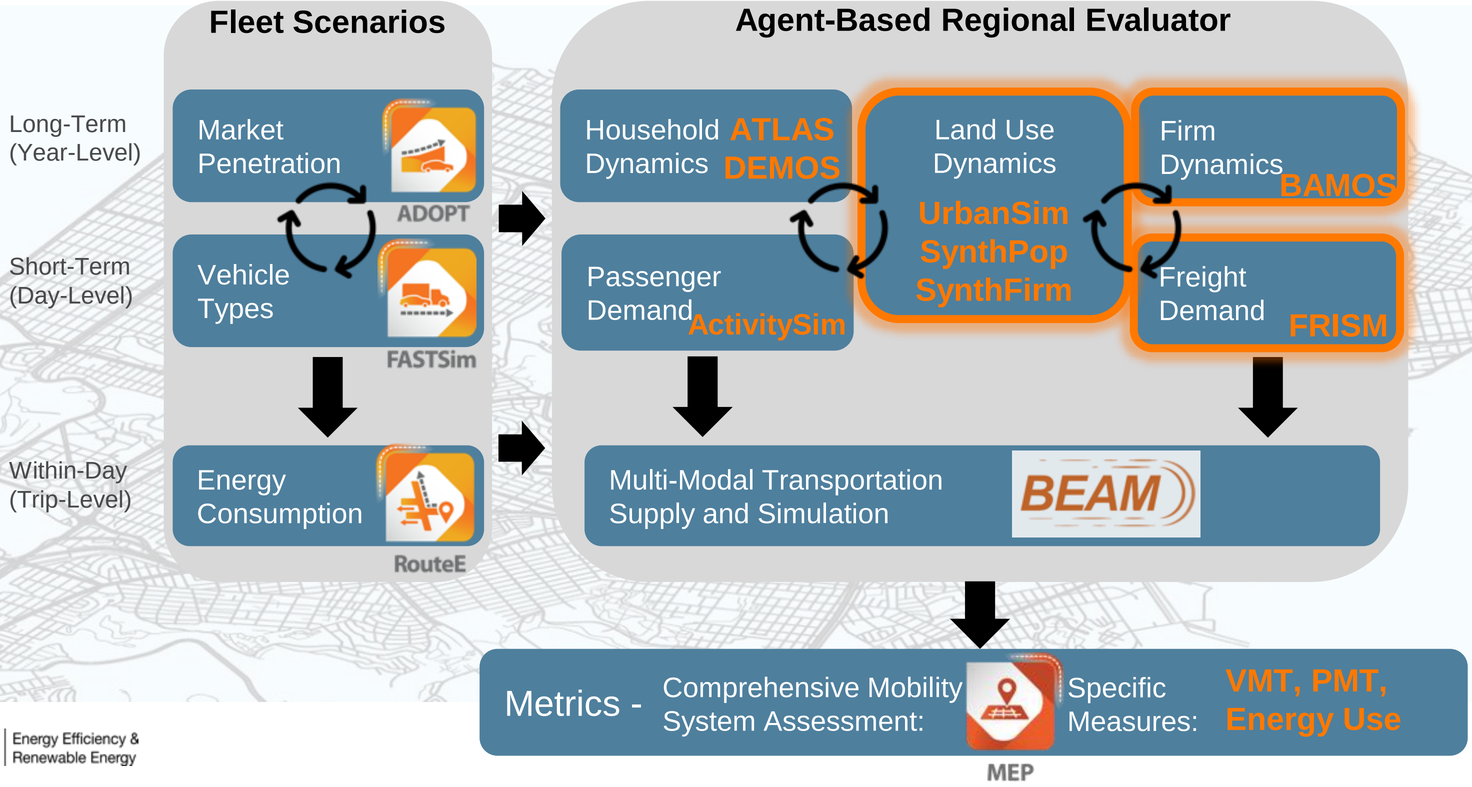
- Patterns in PSID data align with expectations:
  - Transaction outcomes vary by vehicle vintage, ownership types, and household lifecycle





TECHNICAL ACCOMPLISHMENTS AND PROGRESS

Task 3: New Freight Capabilities



TECHNICAL ACCOMPLISHMENTS AND PROGRESS

Task 3 - Freight Modeling Capabilities

We have designed an end-to-end simulation framework to develop a complete suite of long to short run freight models from scratch

- FY 2021 focus: Simulate near-term freight activities: firms, vehicles, deliver and operations
- Firmographic and other long-run dynamic capabilities in BAMOS → focus of FY 2022

SynthFirm

Firm Synthesis and Supply Chain Formation

- Population of individual firms
- Ownership of commercial vehicles by the firms
- Buyer-supplier matching and associated freight demand
- Shipment size and mode (i.e. truck, rail, air)

FRISM

Daily Demand Generation and Tour-Formation

- End-consumer e-commerce
- Daily B2B/B2C shipments
- Distribution channel formation
- Shipment assignment to carrier/vehicle
- Carrier operation plan

BEAM-Freight

Network-based Freight Assignment

- Mesoscopic traffic simulation
- Carrier operation plan execution
- Vehicle routing
- Access to the road network, parking, and charging infrastructure

TECHNICAL ACCOMPLISHMENTS AND PROGRESS

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

Task 3 - Freight Modeling Capabilities

Freight Model Data Sources

All data necessary to estimate and validate the San Francisco Bay Area model acquired:

- Primarily built on publicly accessible datasets with state and/or national coverage
  - Less region-specific sample size and representation, but sufficient at a state level to apply to subregions
  - Enables extensibility to more regions across the state and U.S. more readily

SynthFirm

- National Establishment Time Series
- County Business Patterns
- Bureau of Economic Analysis
- Freight Analysis Framework
- Commodity Flow Survey
- IHS Polk vehicle registration
- National Transportation Atlas

FRISM

- National Household Travel Survey
- American Time Use Survey
- WholeTraveler Survey
- NREL Fleet DNA
- INRIX GPS
- National Vehicle Inventory and Use Survey

BEAM-Freight

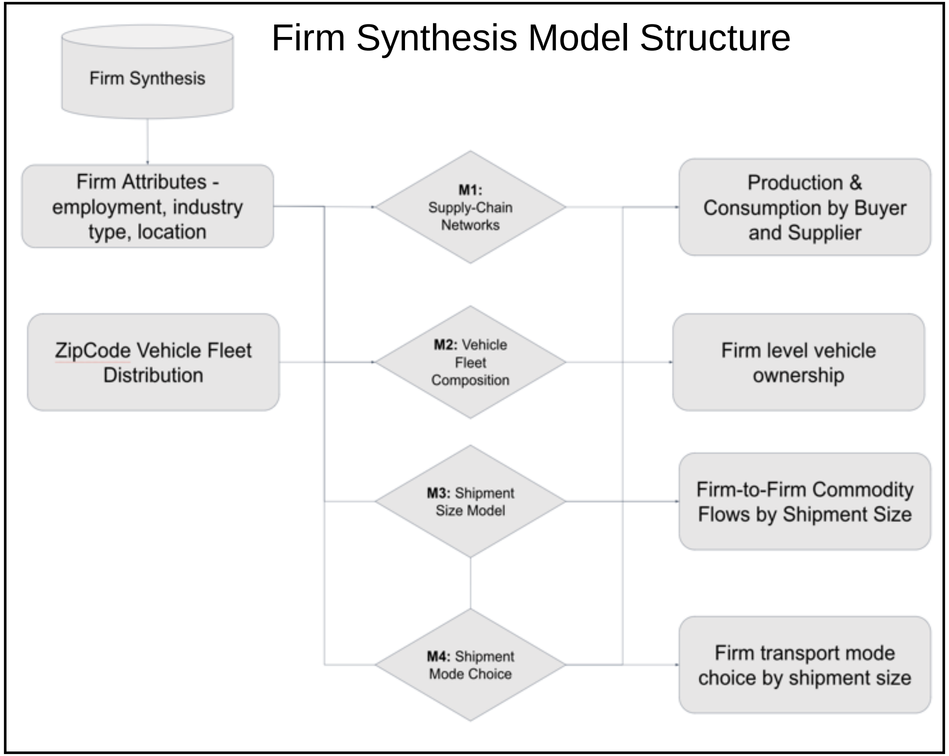
- OpenStreet Maps
- Loop counter data
- INRIX speeds
- Google Maps API

TECHNICAL ACCOMPLISHMENTS AND PROGRESS

Task 3 - Freight Modeling Capabilities

- ***Firm Synthesis (✓Estimated and generating data)*** - Synthesizes individual business establishments in the SF Bay Area to replicate their freight movement and travel behavior. Attributes include physical locations, number of employees, and detailed NAICS industry and commodity codes

- ***Vehicle Fleet Distribution*** - Allocates the ownership of commercial vehicles to the individual business establishments. Fleet mix includes medium/heavy duty vehicles by fuel type (gasoline, diesel and electric)
- ***Supply-Chain Networks***- Matches buyers to suppliers to emulate the business decision to select a supplier to allocate freight demand between buyers and suppliers
- ***Shipment Size & Mode Choice*** - Estimates the choice of shipment size and mode, thereby generating individual shipments to be transported by various modes



TECHNICAL ACCOMPLISHMENTS AND PROGRESS

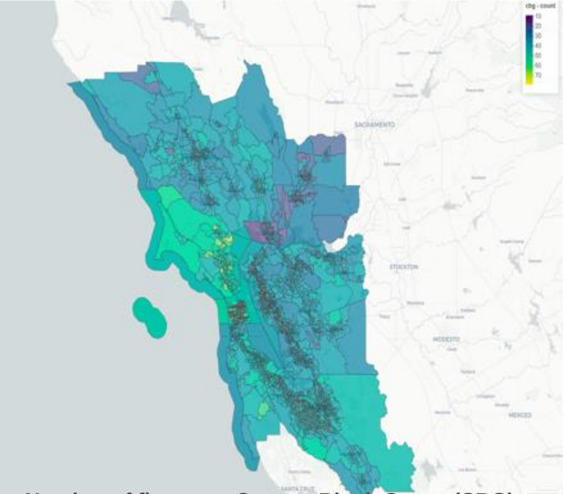
Task 3 - Freight Modeling Capabilities

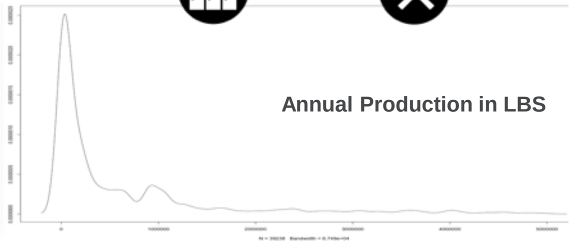
Firm Synthesis Module Preliminary Results

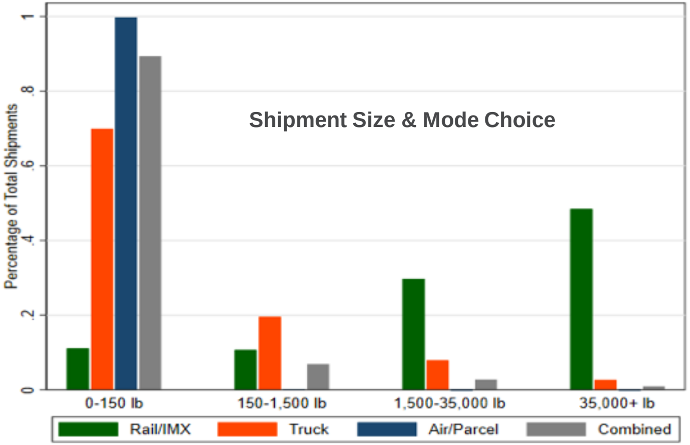
- ~584K business establishments
- ~20 industry types by NAICS 2-digit
- ~85K MD/HD vehicles

- ~55K suppliers and ~6M buyers
- 42 commodity types

- Multinomial Logit model for mode choice with shipment size
- 2012 CFS (estimation), 2017 CFS data (validation)

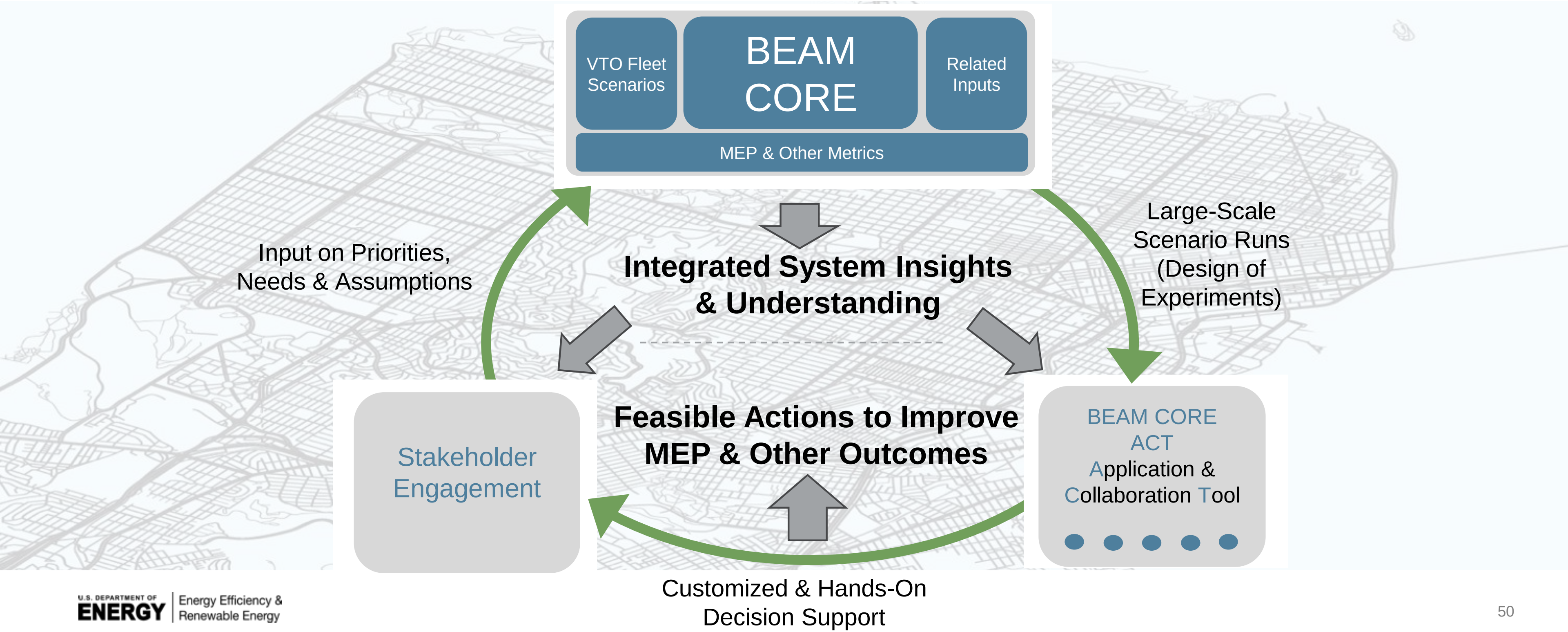

Number of firms per Census Block Group (CBG)


Annual Production in LBS



TECHNICAL ACCOMPLISHMENTS AND PROGRESS

Task 4: Application and Outreach



Technical accomplishments and progress

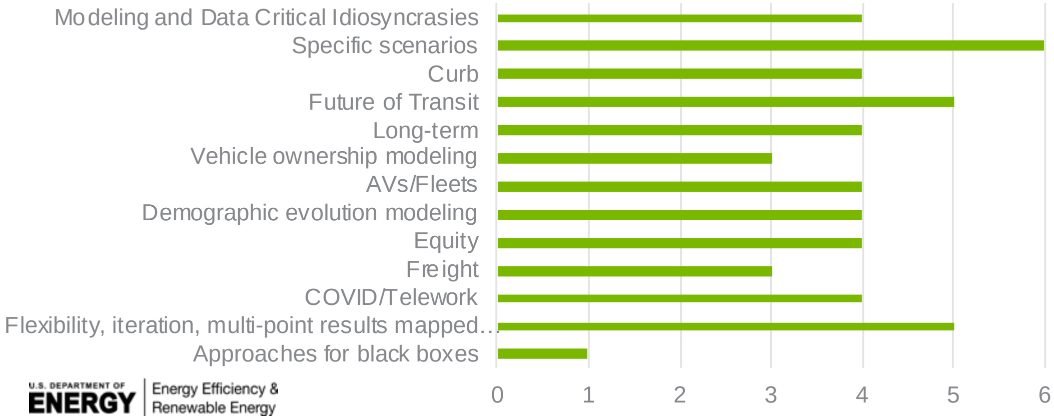
Task 4 – Stakeholder Engagement

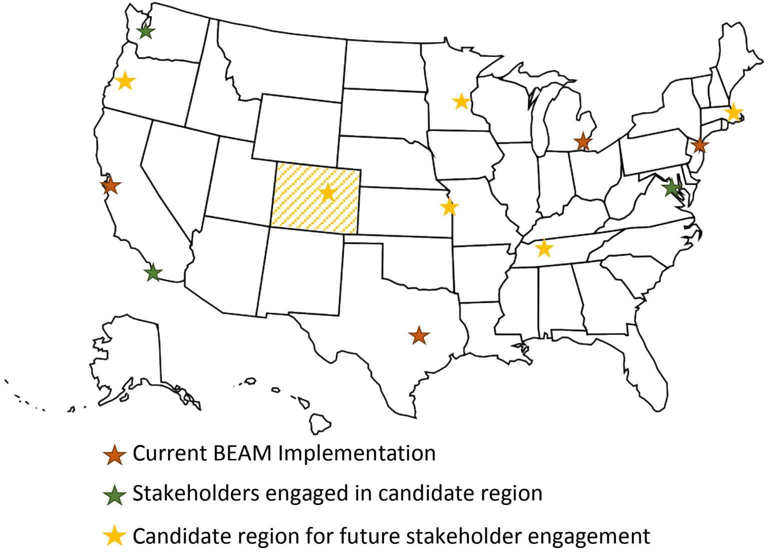
Listing to a Range of Perspectives in Diverse Geographies

- **Objective**: to prioritize research, inform capabilities, and frame relevance
  - Scenario design and analysis results that are useable and useful for real-world benefit & enhanced performance

16+ listening sessions: across multiple regions and perspectives (MPOs, transit agencies, cities, planning agencies, researchers, and more)

Stakeholder Interest in Specific Focus Areas (n=10)



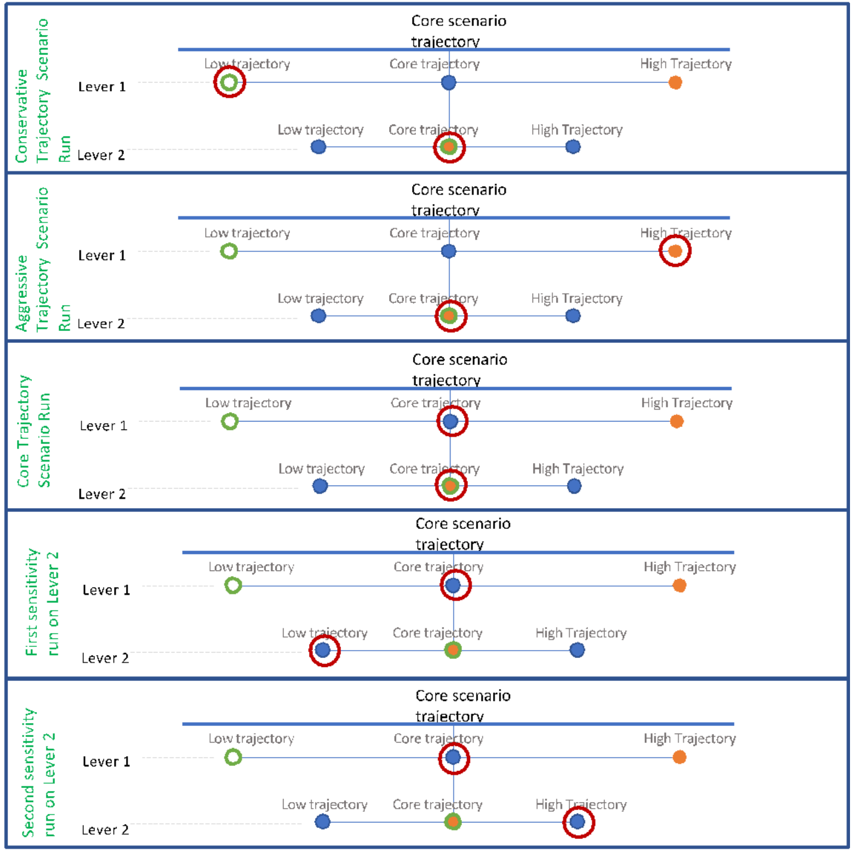


TECHNICAL ACCOMPLISHMENTS AND PROGRESS

Task 4 – Scenario Design

Completed plan for design of experiments approach with comprehensive sensitivity analyses

- Scenarios made up of multiple levers in a range of categories:
  - Light-, Medium-, and Heavy-Duty Vehicle Powertrain Technology
  - Connectivity and Automation
  - Ridehail
  - Micromobility
  - Freight/Delivery
  - Transit
  - Curb Management
  - Telecommuting
  - Behavioral Model Parameter Sensitives
- Scenarios defined as trajectories over a ≈30-year time horizon
  - Run "Conservative," "Aggressive," and "Core" trajectories
  - For each lever identify marginal impacts of variation in that single lever from the core trajectory

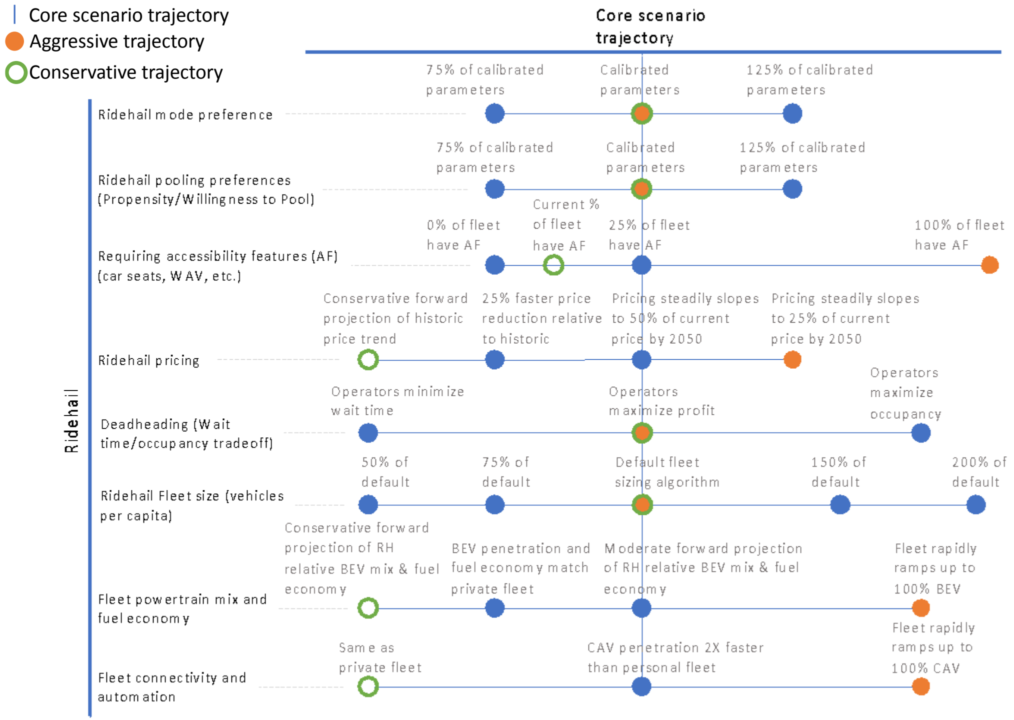


Core scenario trajectory
Aggressive trajectory
Conservative trajectory

TECHNICAL ACCOMPLISHMENTS AND PROGRESS

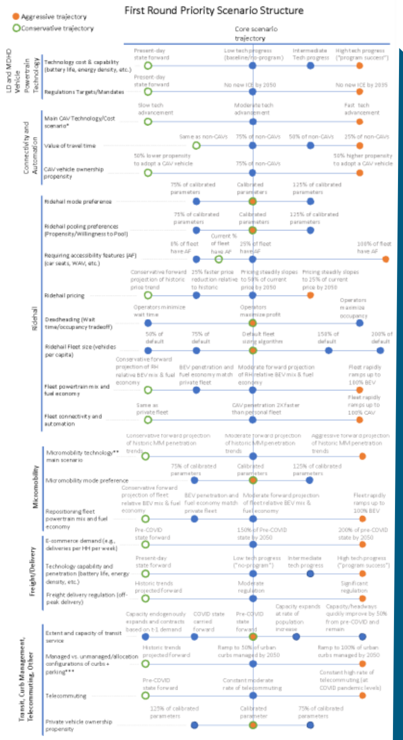
Task 4 – Scenario Design

Example: Ridehail Category Scenario Levers



TECHNICAL ACCOMPLISHMENTS AND PROGRESS

Task 4 – BEAM CORE ACT



BEAM CORE ACT

Application & Collaboration Tool

Have begun design of BEAM CORE ACT:

- Moving beyond single-point forecasting exercises
  - High-level insights
  - Marginal impacts of specific levers
  - Implications of uncertainty in behavioral and operational parameters
  - Compare across multiple regions
- Interact with results from ~60 simulation runs initially… then hundreds… etc.

TECHNICAL ACCOMPLISHMENTS AND PROGRESS

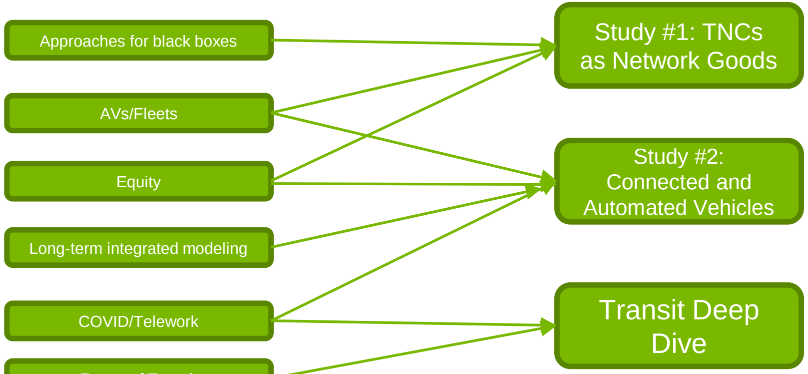
U.S. DEPARTMENT OF ENERGY SMARTMOBILITY
Systems and Modeling for Accelerated Research in Transportation

Task 4 – Deep-Dive Analyses

Studies analyzing output from specific sets of scenarios to derive insights regarding specific research questions

➡ Have completed the design of the high-level research plan for Study #1 and #2

Prioritized plan informed by stakeholder priorities



Study #1 Research Questions

- What TNC fleet penetration is needed to get **pooling savings (in terms of decreased VMT) to outstrip deadhead losses** under different pooling preference scenarios?
- What are the distributional and **equity implications** of different levels of ride-hail fleet size with respect to wait times, user experience, region-specific increased congestion, etc.?
- How does the fleet penetration of specialized TNC vehicle types (e.g., those equipped with car seats, or those that are wheelchair accessible) influence the **accessibility, user experience, ability to pool, for specific subpopulations?**

Study #2 Research Questions

- If people are willing to drive more in a CAV, do people **change home or work location** as a result? How does this change the labor market and land values? Do firms move out of city centers? **Does this mitigate the increased congestion impacts?**
- How are these results sensitive to changes in telecommuting scenarios and the **interplay between CAV adoption and telecommuting propensity**?
- What are the **distributional/equity impacts** of these patterns? Who is choosing to move and who is being displaced? (equity and gentrification over time). How do firm and residential demographics change for different locations over time?

RESPONSE TO PREVIOUS YEAR REVIEWER COMMENTS

Project was not reviewed last year

Collaboration and Coordination with Other Institutions

Highly Collaborative Integrated Multi-Task Effort

LBNL (Prime):

Leading ATLAS, DEMOS and BEAM Development
Co-Leading Freight model development
Leading stakeholder engagement, scenario design, and deep dive research applications

NREL:

Leading ADOPT, FASTSim, RouteE, MEP automation
Co-Leading Freight model development
Co-Leading scenario design
Contributing to stakeholder engagement
Leading BEAM CORE ACT development

UrbanSim:

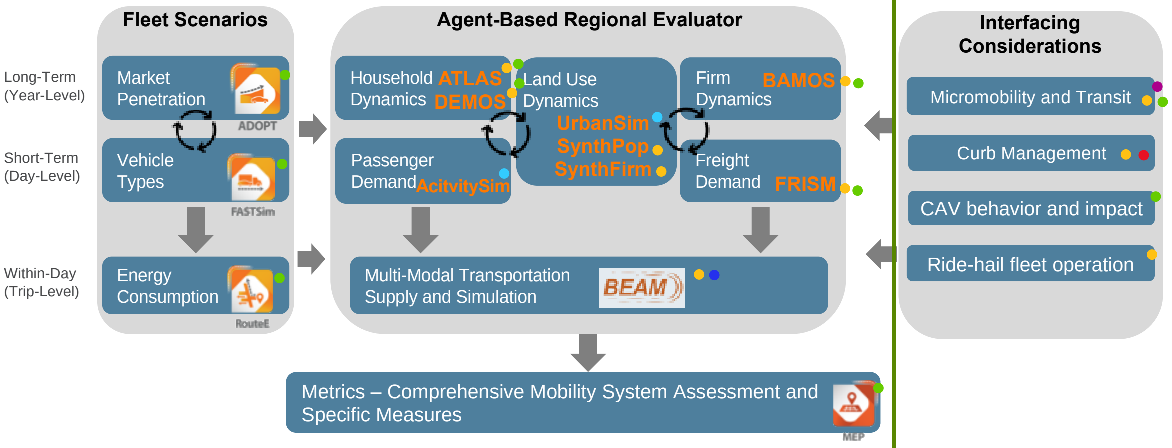
Operationalizing ActivitySim and UrbanSim integration with BEAM CORE, and enabling integration of ATLAS, DEMOS and Freight modules.
Contributing to stakeholder engagement

Sim Rise:

Contributing to BEAM development

UC Berkeley and PNNL

Interfacing other SMART Mobility projects with BEAM CORE to enable additional modeling capabilities (micro mobility, curb management)



- Stakeholder engagement
- Scenario Design
- Deep Dive Research Tasks
- BEAM CORE ACT

BEAM CORE

Non-BEAM CORE Projects with which we are actively coordinating and collaborating

REMAINING CHALLENGES AND BARRIERS

Moving the state of the art forward and making it more widely available

- **No other tool fills the niche of BEAM CORE** (open-source, transparent, accessible comprehensive integrated modeling framework, including long-term endogenous land-use and vehicle fleet impacts, and able to model multiple transportation innovation and paradigm transitions simultaneously)
- **Major challenges inherent to this type of tool include**:
  - Computational intensity and burden
  - Technical knowledge to implement
- From stakeholders: more is needed beyond single-point forecasting in order to understand the range of potential outcomes from a highly uncertain future. This requires running many many scenarios, which is challenging with a computationally expensive model such as BEAM CORE
- **We are addressing these challenges through current and future work with creative solutions taking advantage of the powerful resources available from DOE and the national laboratories:**
  - Improving computational performance, modularity, and automation of the model
  - Architecting to leverage High Performance Computing resources at the national laboratories, enabling dozens of scenarios to be run in parallel simultaneously
  - Developing the BEAM CORE ACT tool to enable stakeholders to explore the frontier made up of a range of scenarios resulting in a desired outcome or metric

PROPOSED FUTURE RESEARCH

Task 1 – Enhanced Performance and Deployment

FY 21	• Runtime cut by 30% from 2020 • Allow full population runs • Integrate ActivitySim
FY 22	• Run on multiple nodes in HPC environment to reduce runtime • Run full BEAM CORE at the push of a button • Dynamic ridehail pricing and smarter repositioning
FY 23	• Fully integrated transportation/land use model deployed in ≥6 new cities • Single-node runtime cut by 60% from 2020

Task 2 - Household Evolution & Vehicle Ownership

FY 21	• Integrate Version 1 of modules with UrbanSim/ActivitySim (SF Bay Area) • Calibrated/validated simulators in SF Bay Area and readiness for deployment to other regions
FY 22	• DEMOS and ATLAS (SF Bay Area): Refine model structure and integrate Version 2 of modules into BEAM CORE simulator • Begin process of assessing deployability across BEAM CORE regions
FY 23	• End-to-end integration of advanced (Version 3) models in SF Bay Area • Demonstrate validity and scalability when tightly coupled with BEAM CORE • Deployment of Version 2 modules to other BEAM CORE regions

Task 3 – New Freight Capabilities

FY 21	• Day-to-day freight operational models (FRISM) & freight vehicle assignment (BEAM) in SF Bay Area • Calibrated/validated simulators and ready to deploy to other regions
FY 22	• Long-term firm behavior dynamics & mid/short-term freight/passenger interactions enabled • Deployment of FY21 simulator in other BEAM CORE regions
FY 23	• End-to-end integration of advanced freight models (SF Bay Area) • Demonstrate validity and scalability when tightly coupled with BEAM CORE

Task 4 – Application and Outreach

FY 21	• Design of Experiments mapped out and scenario runs in process • Test version of BEAM CORE ACT shared with stakeholders for feedback • Deep dive analyses framed out and initial analyses underway in SF
FY 22	• Ongoing and active stakeholder engagement • BEAM CORE ACT populated with first round sensitivity analyses output • Complete first round of results from deep-dive analyses in the SF Bay Area
FY 23	• Ongoing and active stakeholder engagement • BEAM CORE ACT completed and stakeholders trained on the use of the tool • Cross-region deep dive analyses results presented to stakeholders

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

Summary

Three-year enhancement, expansion and application of integrated transportation modeling capabilities

- **BEAM CORE strengths:** open source, transparent, widely deployed, powerful integrated simulation tool. Specialization in long-term scenario analysis: dynamic lifecycle event based demographic evolution driving household vehicle fleet and residence and work location choices integrated with transportation system simulation including traditional and emerging modes, multiple vehicle technologies (electrification, CAVs), energy modeling, and powerful accessibility metrics, including MEP and INEXUS (see EEMS099), enabling unique equity analyses
- **Streamlined** and more closely coupled model integration will reduce runtime
- **New capabilities being built from scratch**: household demographic evolution, vehicle ownership modules, firm evolution and freight/goods delivery modules
- **Expansion** to a total of at least nine regions
- Series of engagements with **stakeholders** to inform priorities and scenarios
- Develop higher-level planning tool (**BEAM CORE ACT**) for use by local practitioners and other stakeholders
- **Design of large scenario and sensitivity analyses and deep dive studies to understand the impacts of new technologies and services on mobility and energy use over time in diverse areas of the U.S.**
- All efforts are on track

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MOBILITY FOR OPPORTUNITY

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

TECHNICAL BACKUP SLIDES

TECHNICAL ACCOMPLISHMENTS AND PROGRESS

Task 4 – Application and Outreach

13-Point Synthesis of Top Takeaways from First Round of Stakeholder Listening Sessions

The synthesis to follow, organized into 13 categorized groupings of the top takeaways, highlights key stakeholder interests, analytical or actionable information they care about, and the most impactful possible outcomes for them and their organizations in making use of BEAM CORE capabilities and/or BEAM CORE ACT features. Beside the summary description, the team has proposed how the BEAM CORE project will address the articulated interests. The strategies are subdivided between (teal-colored) capability plans for BEAM CORE and its subcomponents, and (orange-colored) development input for the deep dive analyses and/or scenario and sensitivity evaluations to be conducted with BEAM CORE and to be made accessible to stakeholders via BEAM CORE ACT.

TECHNICAL ACCOMPLISHMENTS AND PROGRESS

Task 4 – Application and Outreach

13-Point Synthesis of Top Takeaways from First Round of Stakeholder Listening Sessions

1. Approaches for "black boxes"	There are two key areas where planners and modelers generally are struggling with a huge amount of uncertainty due to lack of available data: (1) e-commerce/delivery fleet operations and demand-side information; and (2) TNC or mobility-as-a-service fleet operations and how they relate to rider preferences around sharing and automation. How does one grapple with modeling in cases where so much critical information is in a "black box"?	BEAM CORE plans to address: In the BEAM CORE scenario and sensitivity analysis design more detailed sensitivity analyses will be conducted in instances where less data or greater uncertainty prevail in order to understand the implications of the least certain elements. Fleet operations, for both delivery and TNCs, are cases where this will be important.
2. Flexibility, iteration, multi-point results	Systems are so complex that we no longer live in a world where single-point forecasting is useful or sufficient. There is a need to be able to quickly query and iteratively test large numbers of different conditions or combinations of scenarios. For entities that are trying to understand tradeoffs among broad sets of scenarios or strategies to best achieve their goals, they need a tool that can let them get a sense of the frontier of potential combinations that can achieve a certain level of a given metric (e.g., GHG emissions or climate goals). In addition, in a world where conditions on the ground are rapidly changing (as is the case for the context of delivery), there needs to be flexibility to quickly asses what the situation is going to look like when certain conditions change. In addition, there is a lot of uncertainty around certain key parameters or data inputs. For example, stated preference surveys are likely to paint too optimistic a picture for certain things. There is a need, because of this uncertainty, to be able to look at a range of outcomes from a range of values for given inputs.	BEAM CORE plans to address: BEAM CORE ACT is a valuable way to make multi-dimensional results digestible. The BEAM CORE team will take these comments to heart in the scenario design we are undertaking. The way we are balancing the need for tractability/focus with the need for high-resolution sensitivity analyses is to define specific core scenarios and conduct sensitivity analysis on key behavioral and operational parameters around those core scenario threads. We will focus, through this effort, on finding ways to characterize metrics of uncertainty in the model.

TECHNICAL ACCOMPLISHMENTS AND PROGRESS

Task 4 – Application and Outreach

13-Point Synthesis of Top Takeaways from First Round of Stakeholder Listening Sessions

3.Equity	Multiple entities reported having approaches, requirements, or tools for assessing racial and socio-demographic equity considerations in their planning. For example, an Equity Climate Action Plan, or a tool or framework for reviewing equity and racial impacts of policy activities to ensure they are serving everyone. A big priority in the Bay Area is housing affordability. There is significant interest in tools that can help planners and policymakers assess displacement, which would involve tracking the movement of individuals or households over time and linking that to scenarios. There is interest in capturing specific metrics with respect to equity, such as housing and transportation costs combined. There is a recognition that some of the equity impacts may result from the actions of other users of the system (i.e., externalities or spillover effects). For example, if CAVs generate conditions of decreased congestion or increased safety, is it the adopters of AVs that actually experience those benefits? What level of penetration is needed in order for those benefits to be tangible to the CAV adopters themselves?	BEAM CORE plans to address: The agent-based modeling framework of BEAM CORE coupled with the development of the individual-level metric, INEXUS (Individual-level Experienced Utility-based Synthesis), creates a powerful tool for mapping out distributional impacts on a wide range of outcomes in the system, including spillover effects and externalities, time-delays in realization of impacts (leveraging DEMOS/BAMOS) and coupling analyses of impacts on private wellbeing of different classes of agents with impacts on broader social costs (such as GHGs, air quality, etc.). Understanding which users are driving different of outcomes is also something that can be done with this model. This capability will be heavily leveraged in the deep dive analysis tasks in BEAM CORE. Building in metrics and default outcomes broken out by different groups will also be something of value to consider in the design of BEAM CORE ACT.

TECHNICAL ACCOMPLISHMENTS AND PROGRESS

Task 4 – Application and Outreach

13-Point Synthesis of Top Takeaways from First Round of Stakeholder Listening Sessions

4. Vehicle ownership modeling	Vehicle ownership and transaction modeling appears to be of significant value to a number of stakeholders for supporting current transportation modeling efforts, for helping to answer questions regarding AV adoption scenarios and how people may use subscription services to replace a second car, and for considering interactions with potential COVID-19-driven shifts to increased telecommuting.	BEAM CORE plans to address: This underscores the value of the ATLAS model to stakeholders. The ability to capture different ownership regimes in the model (such as a subscription paradigm) is something important to consider while developing the model. Private sector interest in this model will help maximize its value for all potential users.
5. Freight	There is interest in a variety of delivery service models and scenarios: heavy goods delivery, mobile services, food delivery, people delivery. On the heavy-duty side there is a desire to better understand where trucks are actually moving in the system so they can better plan for charging siting for heavy-duty fleet electrification. There is interest in understanding how to shift delivery and freight out of heavy and medium duty vehicles and into alternative delivery formats (bikes, lockers, etc.). Many agencies, even with relatively sophisticated modeling capabilities, haven't yet managed to incorporate freight into their modeling. There is significant interest in leveraging the BEAM CORE efforts for this added value.	BEAM CORE plans to address: This set of interests underscores the value of the freight modeling integration into BEAM CORE. Interest in the movement of freight vehicles, as a potential value to those interested in those inputs to inform electrification/charging infrastructure is something we can consider in designing the scenario / sensitivity analysis plan for BEAM CORE populating BEAM CORE ACT. Interest by some stakeholders in leveraging the freight model we are building for their own purposes speaks to the value of that capability, but also will motivate partnering on developing that model in mutually beneficial ways.

TECHNICAL ACCOMPLISHMENTS AND PROGRESS

Task 4 – Application and Outreach

13-Point Synthesis of Top Takeaways from First Round of Stakeholder Listening Sessions

6. Demographic evolution modeling	There is interest in capturing demographic and economic characteristics and understanding how demographics inform propensity for mode shift. In addition, there is a recognition that, in long-term scenario analysis, population growth is very uncertain and can have a big impact on outcomes. In addition, there is interest in being able to track individual agents or households over time to capture the evolution of their conditions over time (e.g., displacement).	BEAM CORE plans to address: Being able to dynamically track groups of agents over time through the system, impossible without DEMOS, can enable studying displacement in a way a snapshot in each modeled time period would not. This is a major value of BEAM CORE's integration of DEMOS. This speaks to the importance of testing the sensitivity of the model to assumptions in DEMOS and regarding population growth.
7. Long-term integrated modeling	Many stakeholders see the value of integrated modeling environments, including transportation modeling closely coupled with land use modeling. Land use can be difficult to model and there are a lot of uncertainties around these forces. One stakeholder described a modeling capability such as BEAM CORE having the "potential to transform practice." Smaller cities we spoke with tend to not have any in-house capacity to grapple with modeling for land use. There is an interest in being able to leverage such capabilities, but no resources for in-house dedicated personnel for these efforts. There was also an interest in using the long-term modeling capabilities for the private sector to better understand how they can contribute in a tangible way, such as by improving private sector complementarity with transit.	BEAM CORE plans to address: This underscores the need for and value of a sophisticated land use model (such as UrbanSim) and coupling this with transportation system modeling through an integrated modeling framework such as BEAM CORE. These interests also highlight the value of the DEMOS/BAMOS capabilities being built into BEAM CORE, as they are designed to maximize the value of long-term modeling. The value of BEAM CORE ACT to smaller cities is evident in this comment as well, as is potential DOE-supported partnerships with BEAM CORE for more refined scenarios.

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8. AVs/Fleets	There is significant interest in multiple aspects of fleet operations, particularly in the context of AVs. This is an area where a lack of data on current fleet operations intersects with a lack of information on future demand for AVs, on the extent to which AVs will operate in fleets or be privately owned, and on considerations for future AV fleet operations. There is a desire for core model functionality to tackle a suite of fleet scenario simulations with regionally calibrated demand to assess fleet sizing, consumer wait times, and business models that make shared AVs profitable. It is recognized that fleets and fleet operations will be impacted by and will impact many aspects of planning and policy, such as curb management, micromobility, multimodality, microtransit. While more data is certainly needed, the limited data that is available often demonstrates results at odds with what many posit about these fleets. For example, many assume TNCs are supporting transit, but there are data sources demonstrating the opposite. These questions are becoming increasingly critical to grapple with as the California Public Utilities Commission (CPUC), for example, is on the cusp of letting more AV TNCs out of pilot phase and into actual TNC application. The critical questions brought up by stakeholders around this topic include: (1) How do driver assistance technologies affect the flow on the network (safety, congestion benefits)? (2) How much adoption is needed before a region of users actually experiences benefits from CAVs? (3) Will vehicles be fleet-managed or will people want to own individually (what will be the business models for technology and service provision)? What will be the implications of this for operations? (4) What happens when there is a single service provider versus multiple for a travel option like ridehailing? (5) What TNC penetration is needed to get sharing savings to outstrip deadhead losses under different sharing scenarios? What would be needed to induce that level of sharing? (6) Where will AVs park? How will this impact land use structure? Will parking be zoned near poorer districts? (7) How do micro impacts, such as dynamics at the curb under different curb management scenarios, scale up to fleet level macro impacts? (8) There is the potential that AVs will not deliver on capacity benefits to the system, but rather will slow down the system in urban areas, as the reality on the ground with pedestrians, bicyclists, mixed traffic and motorcycles will make it extremely difficult for AVs to navigate smoothly and benefit the system overall. What level of penetration is needed and in what types of traffic mix would we see benefits versus costs in terms of traffic flow? (9) Is it really true that AVs can possibly live up to the rhetoric and solve the congestion problem? (10) Land use can be difficult to model and there is huge uncertainty around how it may evolve in response to different ways CAVs may be adopted. Time-use impacts on land use compounds this issue. (11) What is it going to take to run an AV system in a city in the medium to long term with respect to all kinds of factors: curb space, safety, integrated policy and regulatory environment?	BEAM CORE plans to address: This general suite of stakeholder questions informs multiple aspects of the BEAM CORE work. It highlights the value of careful modeling of fleet operations so the model is capable of testing a refined set of scenarios with respect to these factors. Many of the dynamics highlighted in the questions are well suited for the deep dive research tasks of BEAM CORE and will inform the design of those analyses.

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9. COVID/Telework	There is growing interest in near-term scenarios (e.g., 2-3 years out), driven by the current context of the COVID-19 pandemic to understand the implication of telecommuting, unemployment, and transit avoidance by industry sector on the transportation system. Transit agencies are facing a potentially completely transformed world, even after current shelter-in-place restrictions are relaxed. Will people return to work, or will there by widespread increased levels of telecommuting? Transit agencies are facing massive deficits (e.g., 13% of normal ridership while running 60% of normal service), but struggle with how to adapt as they aren't even sure if transit will play the same role as before the pandemic. There are no models that help them understand the extent to which transit ridership is sensitive to preferences around crowding. If they can relieve crowding, will this tap into latent demand or not? Will there be new firm structures around telework? If people end up going into work half as often, will they move twice as far away? Who and how many will be continuing to work from home?	BEAM CORE plans to address: This set of interests will inform the transit deep dive analyses being conducted with the BEAM CORE framework. In addition, it will be important to highlight telecommuting scenarios in our scenario analyses and in the inputs to BEAM CORE ACT. Assessing the extent to which making mode choice sensitive to transit crowding may be worth looking at in the long term.
10. Specific scenarios	Many stakeholders articulated interest in specific local/regional scenarios and planning efforts: mobility hub siting and design; car restriction policies in specific areas of the city and impacts on other areas; testing specific policies constraining operations of on-demand services that are not constrained by the road network; specific transit expansion scenarios; specific congestion pricing scenarios in specific areas of the network; specific road and highway network expansion scenarios.	BEAM CORE plans to address: Many of these specific scenarios of interest would require close collaboration with specific stakeholders in each modeled region to explore. However, having an understanding of what is of interest in these different areas is valuable and to the extent possible we can assess whether these topics can inform our more general scenarios to be run in the near term.

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11. Future of Transit	Comments from transit provider stakeholders suggest that transit is facing an existential moment. Agencies are planning the nuts and bolts of their 2030 horizon with no information about what role transit will be playing in the system at that point. How will their principal commute market be different? How will transit ridership interface with other regional or state policies, such as the EV mandate in California? Will the higher upfront cost of EVs drive people towards transit, or will the lower operating costs drive them away? There is interest in some cities to understand how best to design and conceptualize "mobility hubs" that bring together major transit systems with new/shared mobility platforms, supporting and thereby accelerating electrification, EV adoption and shared EV use. From a land-use perspective there was an observation that only 10% of the settlement pattern is of a density that could support transit…yet a lot of the discussion is on “transit first.” What are the right metrics to understand the value of transit in such a context? Is it important to actively support transit, such as with first-/last-mile strategies in less developed or smaller urban areas especially considering the near-term COVID response? How do we transition transportation and land use systems when land use has been geared towards single-occupancy vehicles for decades if not centuries? How will the private sector affect transit? How can partnerships enable the private sector to support transit in mutually beneficial ways?	BEAM CORE plans to address: With regard to the question about the impact of state policies (like the EV mandate) on transit ridership, BEAM CORE may be the only model that can do this as holistically as they are talking about. This speaks to the value of integrating car ownership with mode choice, which will happen with a close coupling of ATLAS, ActivitySim and BEAM. This is something we will take into account in our scenario design process. In general, these concerns can help inform the transit deep dive task, how we grapple with scenarios around telecommuting, mode shift, and sensitivity of technology adoption to mode features and vice versa.

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12. Curb use and management	There was a clear recognition by many regarding the value of tackling curb management. Many cities depend on parking revenue and need to understand how they will evolve that model as the use of the curb evolves. Curb management is critical for siting and coordination of EV charging. Everyone wants a piece of the curb: private vehicles for parking, EVs for charging, TNCs, freight and transit for pick-up/drop-off, etc. Transit operators are interested in how removing parking affects transit ridership and then how that impacts street parking around stations. What are the system-level impacts of removing a certain amount of parking on a given block? Does that have to be made up for elsewhere? If so where?	BEAM CORE plans to address: The interest by stakeholders in curb management modeling capabilities underscores the value of that work and its integration into BEAM CORE. These specific topics are valuable for the BEAM CORE team to weigh in designing the core scenarios and sensitivities to be captured in the BEAM CORE ACT tool. The topic of parking more broadly is clearly something of import to stakeholders, including revenue impacts of different curb management scenarios. This is something we can assess in our scenario design.

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13. Critical Modeling and Data Idiosyncrasies	Several observations about modeling and data idiosyncrasies and other factors came up and are worth documenting. These include: (1) There is a need to define metrics of resilience to sea level rise, wildfires, air quality impacts, power outages, earthquakes, pandemics, etc. (2) Right now, urban and regional areas are planned and managed from a parcel- or building-based perspective. There tends to be limited incentive to think at a system/dynamic perspective about the integrated nature of these systems, which is a lost opportunity. (3) There is a need for higher spatial/temporal resolution than current MPO transportation models can support in modeling mode choice and replacement dynamics to better answer specific context-relevant questions. (4) One stakeholder noted that they had assessed a lot of different simulation models and tools, and have found that for microtransit there is really nothing of quality available. (5) To the extent possible, models need to be grounded on data. In addition, baseline data across models and contexts need to be consistently used. (6) One of the biggest challenges with modeling urban and regional planning dynamics and space allocation is that everything is on a different elasticity cycle. For instance, a region's population can grow more quickly than can its inventory of housing, buildings and/or large-scale transportation infrastructure.	BEAM CORE plans to address: The time-dynamic capacity of BEAM CORE is a valuable way to get at the issue of mismatched elasticity cycles. Rather than modeling snapshots in time, BEAM CORE can capture the evolution of the system over time, which means the model can represent how adaptation happens to elements on different time horizons. This is a unique capability of BEAM CORE enabled by DEMOS and BAMOS. Digging into these dynamics in a case study or two is a good application focus for the deep dive analyses. With respect to the historic tendency to focus on the building based perspective, disaggregate methods and micro-level representation of urban systems, as is the case in BEAM CORE, is the key to evaluating complex policy questions that grapple with bridging this gap. With regard to consistent and rigorous use of data for grounding the model and consistently calibrating, we fully agree with the sentiment of grounding modeling in data. However, this comes with a caveat that data does not always exist for the behavior or the trend we would like to model, especially looking far into the future. Calibrating the baseline (extensively) to ground truth data is sometimes the best we can do. "All model forecasts are bad. Some are useful." Our approach to grappling with this systematically is to have our plan for scenario and sensitivity analyses designed with this in mind. In areas where there is more uncertainty underpinning the parameters or assumptions in the model, we will focus our sensitivity analyses heavily in those areas to quantify the extent to which that lack of data matters for modeled outcomes or not. With regard to microtransit capabilities, this is something being developed by users of BEAM currently, which represents a value of the open-source nature of the BEAM CORE modeling infrastructure.

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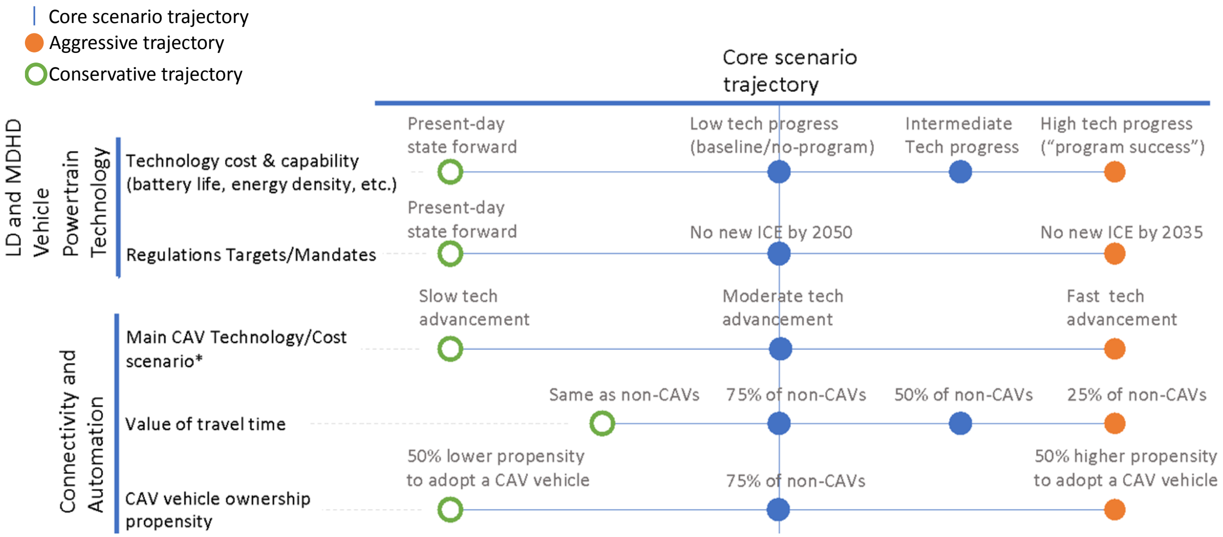
Task 4 – Scenario Design

Design of experiments approach with comprehensive sensitivity analyses



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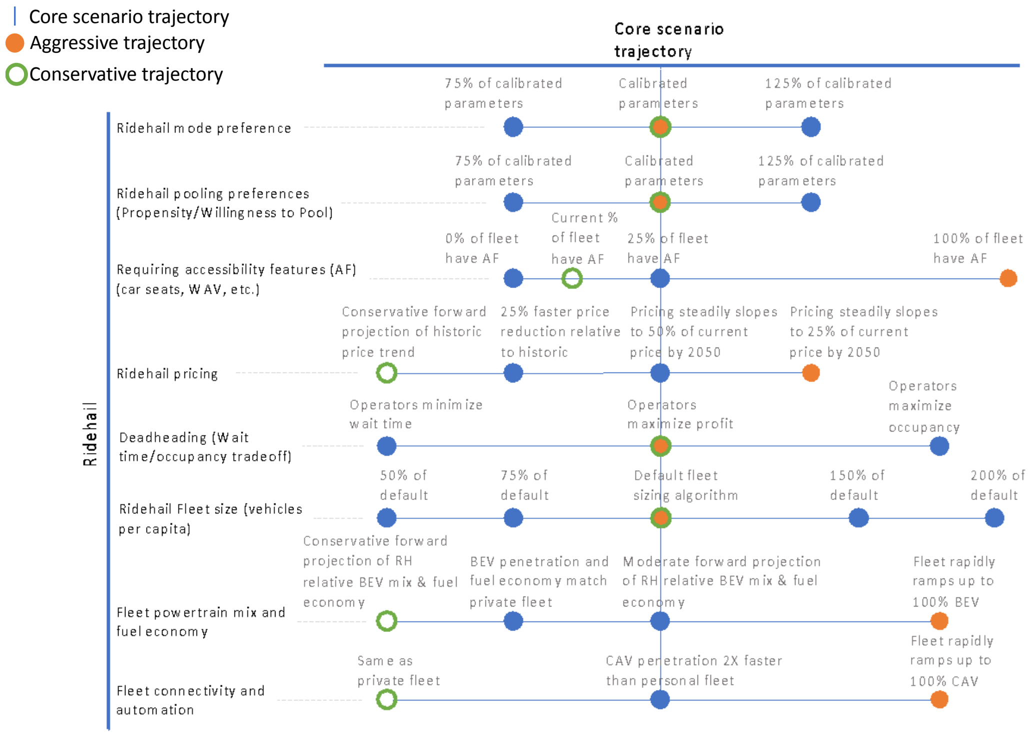

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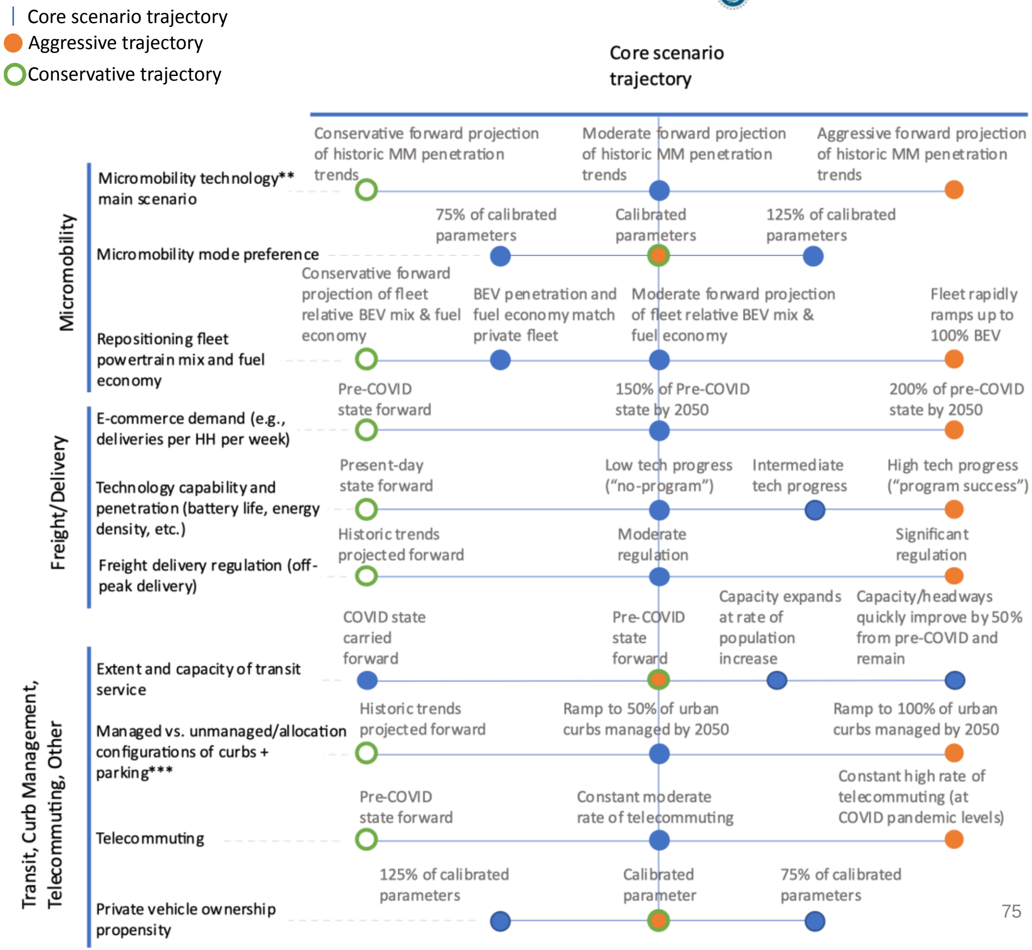

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- **Second Round Priority Levers**

Category	Lever/Parameter
LD and MDHD Vehicle Powertrain Technology	Regulations – CAFE; Low-income incentives; Fuel prices; Extreme fast charging; Electric grid mix
Connectivity and Automation	Operational design domain (ODD) for fully self-driving
Ridehail	Dedicated charging infrastructure; Number of fleets operating; Battery capacity of battery electric vehicle (BEV) ridehail fleet relative to privately owned fleet
Micromobility	Level of docked vs. dockless micromobility; Regional distribution; Prevalence of on-demand summon and automated redistribution management of shared micromobility; Privately owned e-bikes/e-scooters vs shared use
Transit	Sensitivity to transit crowding
Freight/Delivery	Novel freight paradigm: Lockers, Drones, Micro-freight; Delivery fleet operation cost (fleet size and vehicle types utilization); Delivery fleet willingness to participate in collaborative logistics (e.g., minimizing empty back-haul/deadheading); Urban freight distribution practices (omni-channel logistics, consolidation; land-use/infrastructure side); Freight fleet payload (load capacity, operation hours) (technology-driven operating factors)
Other	Population growth; Population aging; Residence location and work location; Income distribution; Distribution of age at first child; Private vehicle ownership propensity based on presence of children; Private vehicle ownership propensity based on income; Road infrastructure extent and capacity