U.S. DEPARTMENT OF ENERGY

SMARTMOBILITY

Systems and Modeling for Accelerated Research in Transportation

Coupling Land Use Models and Network Flow Models

Paul Waddell, LBNL, UC Berkeley
2018 VTO Annual Merit Review
June 19, 2018

Argonne NATIONAL LABORATORY

INL Idaho National Laboratory

BERKELEY LAB

OAK RIDGE National Laboratory

NREL NATIONAL RENEWABLE ENERGY LABORATORY

ENERGY EFFICIENT MOBILITY SYSTEMS PROGRAM
INVESTIGATES

MOBILITY ENERGY PRODUCTIVITY

THROUGH FIVE EEMS ACTIVITY AREAS

Advanced R&D Projects

Living Labs

Smart Mobility Lab Consortium

HPC4Mobility & Big Transportation Data Analytics

Core Evaluation & Simulation Tools

Advanced Fueling Infrastructure

Connected & Automated Vehicles

Urban Science

SMART MOBILITY LAB

CONSORTIUM

7 labs, 30+ projects, 65 researchers,
$34M* over 3 years.

Mobility Decision Science

Multi-Modal Transport

*Based on anticipated funding

Overview

Timeline

- Start date: October 1, 2017
- End date: September 30, 2019
- Percent complete: 25%
- New start in FY18 when project transferred to current PI

Barriers

- Regional transportation planning overlooks long-term impacts on urban development, induced travel demand
- Computationally expensive transport models undermine long-term analysis
- Impact of new mobility technologies on long term household choices uncertain

Budget

- Total project funding: $520k
- Funding for FY 2018: $260k
- Funding for FY 2019: $260k

Partners

- Collaborators:
  - UC Berkeley (project lead)
  - INL, LBNL, NERSC, HPC, BEAM
  - Bay Area Metro, CMAP, DRCOG
  - Purdue University
  - Google

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

Relevance

- **Relevance**

- Need to quantify the impact of urban development on mobility patterns and energy use
- Need to quantify the impacts of SMART technologies on long-term urban development
- Need to evaluate combined policy impacts of land use and transportation to avoid endogeneity bias
- Supports VTO/EEMS strategic goal to develop new tools, techniques, and core capabilities to understand and identify the most important levers to improve the energy productivity of future integrated mobility systems.

Relevance and Objectives

Overall Objectives

- Develop an integrated modeling pipeline that encompasses land use, travel demand, traffic assignment, and energy consumption
- Model combined and cumulative impacts of transportation infrastructure and land use regulations
- Improve model performance and time complexity to simulate regions over 30 years

Specific Objectives This Period

- Design initial pipeline architecture
- Develop preliminary modular prototype of pipeline
- Integrate initial alternative traffic assignment models into simulation
- Conduct preliminary benchmarking
- Develop conference papers and journal articles to publish progress

Milestones

DATE	MILESTONE	STATUS
December 2017	Technical report or working paper on initial architecture and prototype development of the extended UrbanSim models.	Completed (on time)
March 2018	Network flow model running at scale with UrbanSim interface.	Completed (on time)
June 2018	Peer reviewed publication or technical report summarizing: achievements (models and code), numerical computation and simulation work, findings and energy implications.	On track
September 2018	Repository for code run at scale (NERSC, HPC or AWS EC2 / GKE)	On track
December 2018	Technical report on performance (computation and validation)	On track
March 2019	Model calibration and validation results for 3 metro areas (potentially Chicago/Denver/San Diego in addition to SF)	On track
June 2019	Manuscript(s) to be submitted for peer-review	On track
September 2019	Code repository updated with validated models	On track

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

Approach (1)

- Integrate land use models, travel demand models, traffic assignment and energy consumption models to simulate metropolitan regions' development and energy use over 30-year horizons
- Land use model: UrbanSim – simulate real estate markets and development
- Travel demand model: ActivitySim – simulate metropolitan travel demand
- Traffic assignment models – simulate trip routing, congestion, and energy use:
  - Aggregate, Static user equilibrium (collaboration with LBNL HPC)
  - Dynamic, Mesoscopic (collaboration with LBNL (BEAM), HPC)
  - Microsimulation traffic and energy consumption (collaboration with Purdue, Google)

Approach (2)

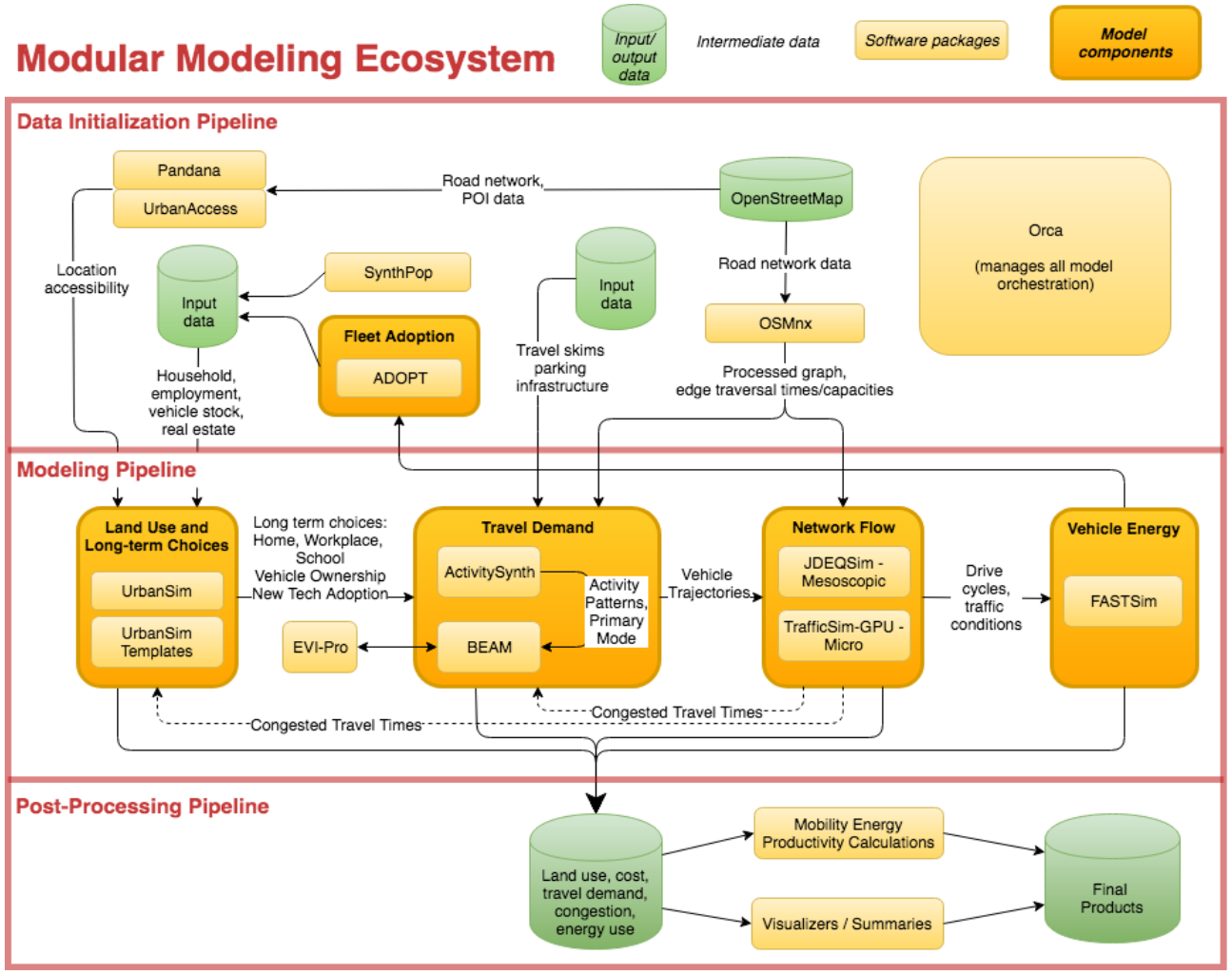
- Develop a Python-based pipeline built on model orchestration and templating to integrate a modeling workflow efficiently and flexibly
- Benchmark against empirical data for validity
- Benchmark against alternative methodologies for performance
- Provide policy analysis to urban planners (collaboration with MPOs)
  - Experiment with different land use/transportation policy combinations
  - Evaluate urbanization/energy impacts

Approach

The vision for this project is to create a foundation for broad integration and modularity across SMART models, enabling rapid innovation and advancement of research program.

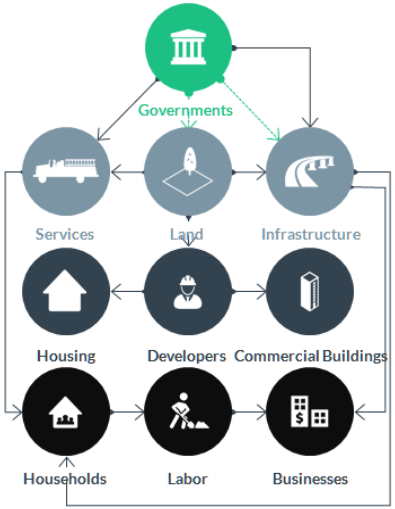
In the long-term proposed approach developed in collaboration with SMART Mobility Labs our project contributes many key components:

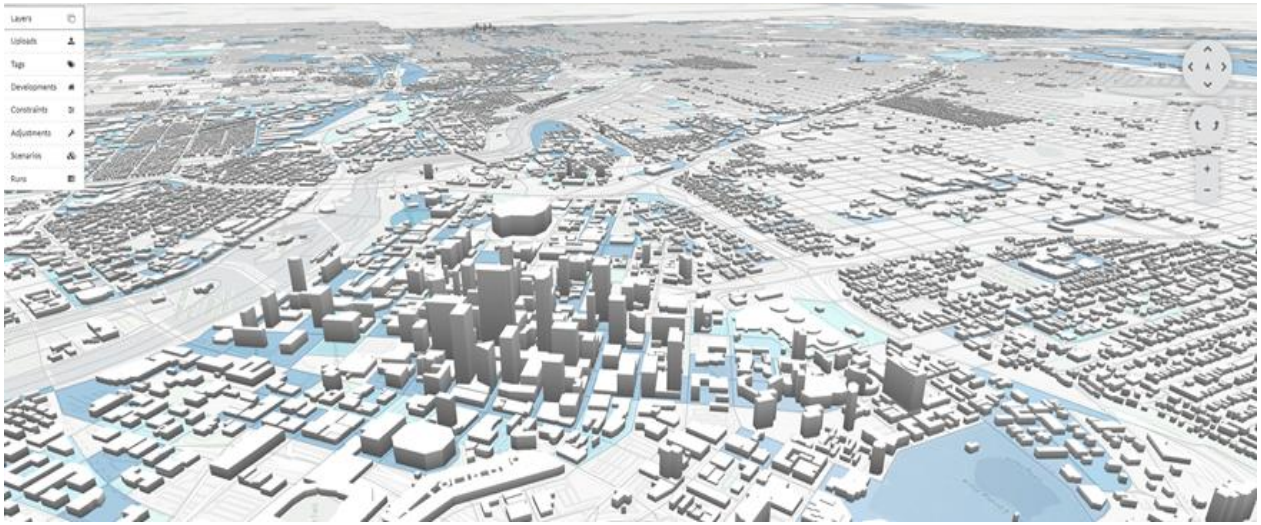
- **OSMnx** (network processing)
- **Pandana** (access computations)
- **UrbanAccess** (transit access)
- **SynthPop** (population synthesis)
- **Orca** (simulation orchestrator)
- **UrbanSim** (long-term models)
- **UrbanSim Templates** (modules)
- **ActivitySynth** (activity generation)
- **TrafficSim-GPU** (microsimulation)



Technical Accomplishments: UrbanSim Overview

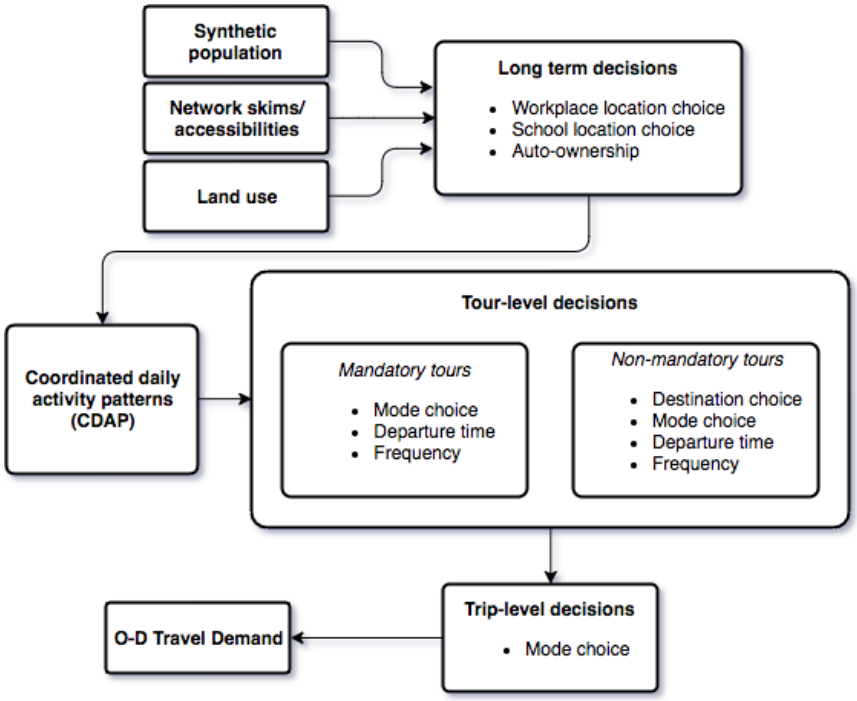
- Models urban development and transportation interaction
- Part of Urban Data Science Toolkit (UDST) on GitHub
- Used by MPOs for Regional Transportation Plans
- Microsimulation at MSA/Regional scale
- Development funded by six NSF grants, EPA, DOT, State and Local Agencies
- Bay Area simulation runs in ~10 minutes per simulated year with 2 million parcels, 7+ million population





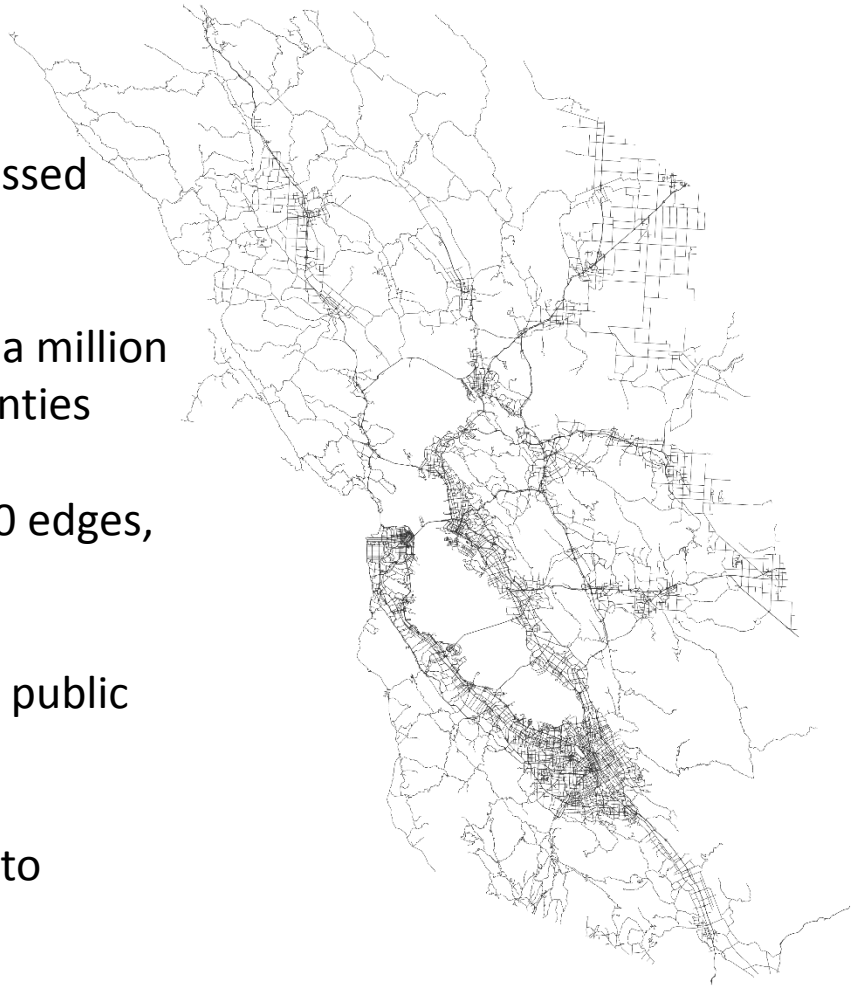
Technical Accomplishments: ActivitySynth Overview

- Inputs are shared with UrbanSim
- Computes daily travel plans for ~2.5M households and ~7M individuals in Bay Area model
- Outputs are easily ingested by Traffic Assignment algorithm



Technical Accomplishments: Network Models

- Road network models created and processed from OpenStreetMap data using OSMnx
- *Full network*: quarter million nodes, half a million edges, 53,000 km of streets across 9 counties
- *Simplified network*: 31,000 nodes, 66,000 edges, 20,000 km of streets across 9 counties
- Calculate BPR coefficients per edge from public data and imputation
- Convert zone-based travel demand data to network node-based



Technical Accomplishments: Traffic Assignment Models

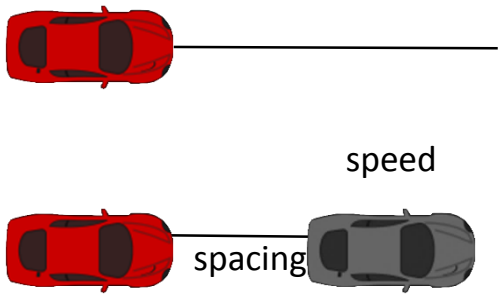
- Aggregate, Static (collaboration with LBL HPC)
  - Static user equilibrium using Frank-Wolfe algorithm
  - Routing: shortest path based given demand
  - Results: volumes, speeds on each link
- Dynamic, Mesoscopic (collaboration with LBL (BEAM), HPC)
  - BEAM/MATSIM for mesoscopic traffic assignment
  - Results: volumes, speeds on each link
- Microsimulation (TrafficSim-GPU, collaboration with Purdue University)
  - Routing individual vehicles using car following, lane changing
  - Acceleration, deceleration
  - Results: individual vehicle routes, volumes, speeds on each link, vehicle fuel consumption and pollution metrics

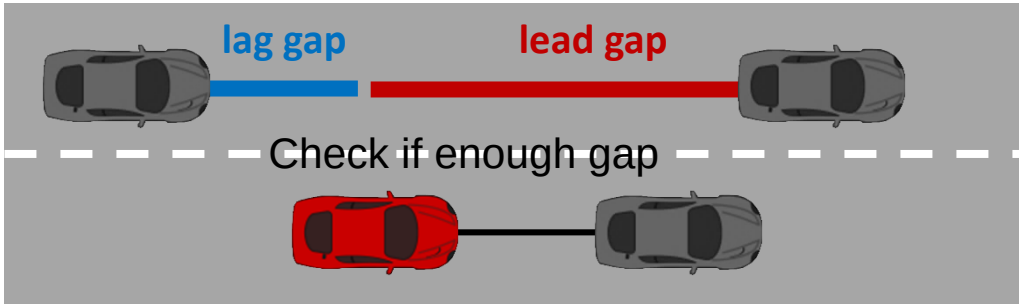
Technical Accomplishments: Traffic Microsimulation

- Why another travel model?
  - No existing model is fast enough
  - Must run 30 year simulations with a chained model set

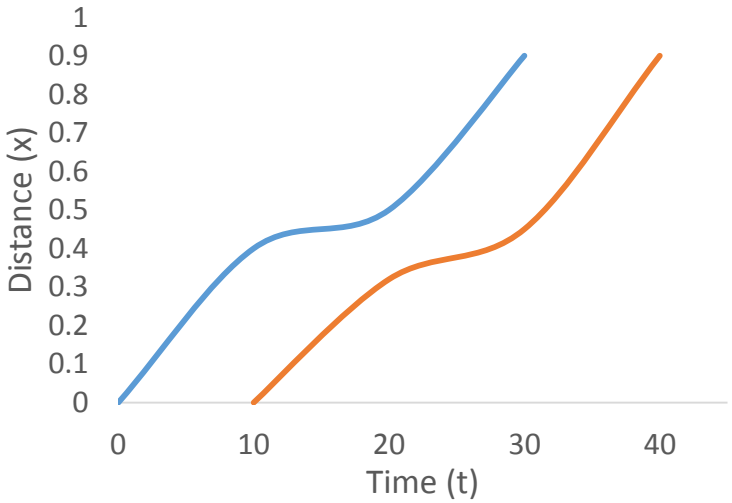
- Why microsimulation for decades-long planning time scales?
  - This is a different kind of microsimulation
    - Runs on GPU
    - Orders of magnitude faster
  - Coherent and consistent
    - Compatible with microsimulation of households/activities
  - Enables energy-use calculations
  - Avoids loss of detail necessary for accurate answers

Technical Accomplishments: Traffic Microsimulation





Car following model



Lane changing model

- Mandatory
  - Reach next exit
- Discretionary
  - Bypass car

Traffic Signalization

- Procedural generated (standard cycle)
- Defined by user

Technical Accomplishments: Traffic Microsimulation

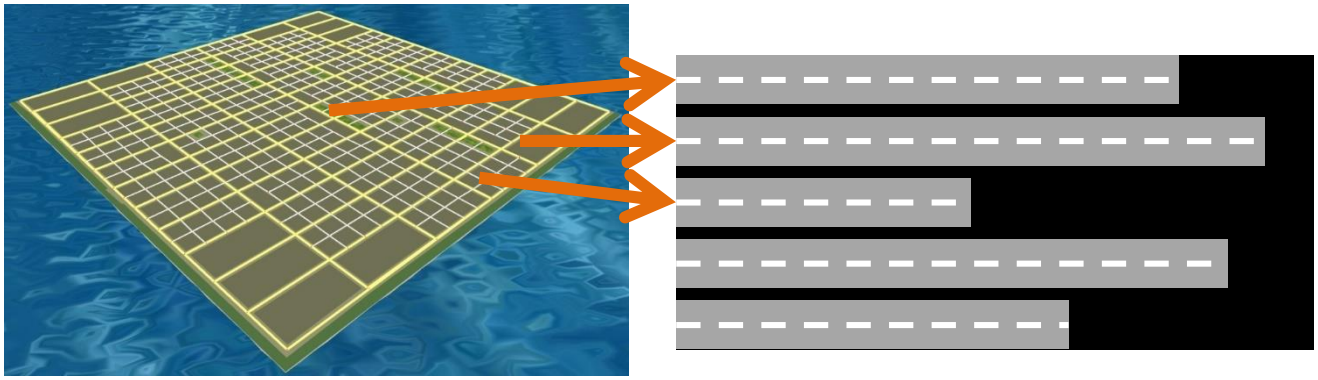
- For each car, for each simulation step:
  - Check whether it is time to leave
  - Find following car or traffic signal

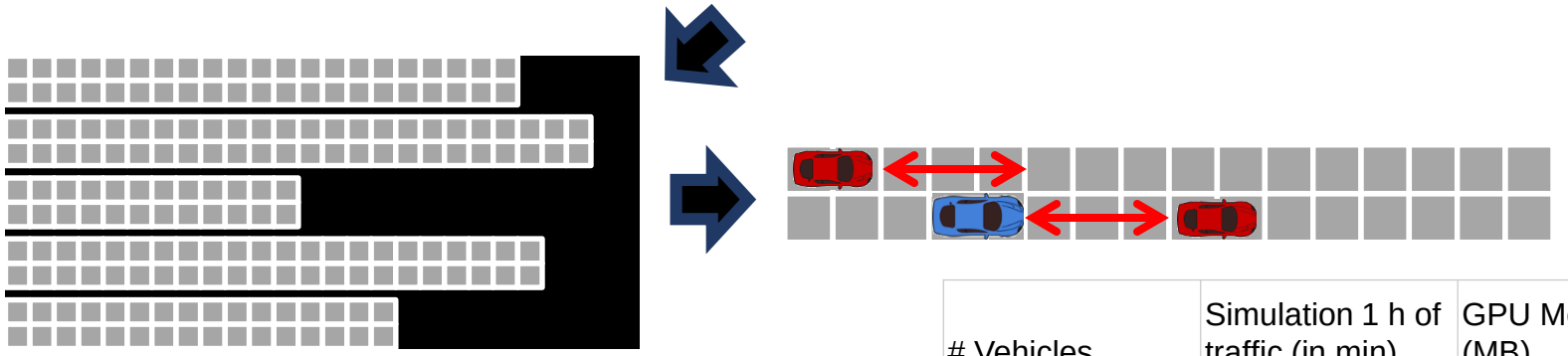
  - Calculate acceleration→ New velocity and position
  - Check lane changing

  - Reach intersection

Technical Accomplishments: Traffic Microsimulation

Traffic Atlas





Initial benchmarking on a laptop with GPU on a 66K link network

# Vehicles	Simulation 1 h of traffic (in min)	GPU Memory (MB)
160,000	3.7	501
320,000	9.0	720
640,000	15.8	1005
1,280,000	28.1	1676

Response to Previous Year Reviewers' Comments

Project was not reviewed last year

Collaborations with Other Institutions

- LBNL HPC/NERSC
- BEAM
- Purdue University
- Google
- San Francisco (Bay Area Metro)
- Chicago (CMAP)
- Denver (DRCOG)

Remaining Challenges and Barriers

- Performance improvements
- Network scaling-up
- Swapping multiple traffic assignment models to compare/benchmark, in collaboration with BEAM, Polaris, etc.

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

Proposed Future Research

- FY18:
  - performance and runtime improvements
  - testing on multiple street networks
  - testing multiple traffic assignment suites
  - code repository to run at scale
- FY19:
  - improve performance (computation and validation)
  - model calibration and validation results Bay Area
  - code repository updated with validated models
  - technical report on scenarios (land use and transportation)
  - simulations of alternative policy scenarios
  - explore extension to additional metro areas (e.g. Chicago, Denver, Columbus)

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

Summary

Relevance

- Quantify the impact of urban policy and growth on mobility/energy use
- Assess impacts of SMART tech on long-term urban growth patterns
- Evaluate combined policy impacts of land use and transportation at regional scale over several decades

Approach

- Integrate land use, travel demand, and traffic assignment models
- Pipeline built on model orchestration and templating to create a toolkit much faster than currently exists
- Provide foundation for modular integration across SMART models

Accomplishments

- Design initial pipeline architecture
- Develop preliminary modular prototype of pipeline
- Integrate initial alternative traffic assignment models into simulation
- Preliminary benchmarks

Proposed future research

- Performance and benchmarking
- Multiple road networks
- Multiple traffic assignment models
- Calibration and validation
- Simulate alternative policy scenarios

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

QUESTIONS?