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Agent-based modeling of potential mobility futures using BEAM

Zach Needell, LBNL

July 16, 2020
Overview

- Why bother modeling?
- Modeling transport systems in general
- Modeling transport systems in particular (with BEAM)
- Incorporating 3 revolutions into transport modeling
- What sorts of questions is this model best equipped to answer?
MODELING TRANSPORTATION SYSTEMS

(In general and in BEAM)
Why bother modeling?

What is the problem?

- Automation, electrification, and other changes will transform transportation systems in unknown ways
- Behavioral change will be just as important as technology change in shaping the future transportation landscape--how do they interact?
- Changes will occur in short term and long term (and interact with land use)

What is needed?

- We still need to make decisions, even if there is uncertainty (we just need to be realistic about accuracy)
- Modeling is especially important for systems where we don’t have empirical, observed data
- The act of building a model clarifies important relationships and interactions
Modeling transport systems

Modeling supply and demand independently

Supply

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

Demand

- How many trips do people take?
- Where do they go?
- What mode do they use?
- What route do they take?


Modeling transport systems

Jointly modeling supply and demand: Four step model

- Generates flows of trips between origins and destinations
- Still very commonly used by many MPOs, can produce very useful results
- Miss out on full-day constraints and interactions
- Struggles to represent some technologies
- Difficult to model multiple modes on a single trip

Figure 2. Overview of the traditional four-step travel demand model.

3. Modal choice - The mode choice step disaggregates trips between the highway and other modes. Mode choice models may include such factors as demographic group, cost, relative travel times, and trip purpose.

4. Trip assignment - The assignment, or loading, of vehicle trips to specific links in the highway network and person trips to links in the transit network occurs in this step. The assignment algorithm is usually based on the assumption that people try to minimize travel time. There are several different approaches that can be used to determine the traffic assignment that results in the smallest travel times. For example, the model may repetitively assign a user-selected percentage of trips incrementally along the network paths that result in the minimum travel time. As certain links fill up with traffic, the speeds on them are reduced and travel time increases, until other links become more attractive. The process continues until all trips are assigned.

Typical travel demand models are data intensive. The basic types of input data required are as follows:

- Land use data
  - The trip generation step requires information about the socioeconomic characteristics of each traffic analysis zone. This may include, for example, population, households, employees, or schools. Any type of land use or economic characteristic that can be quantitatively related to the number of trips produced or attracted may be included. Some of this land use information, e.g., population income levels, may also be used in the modal choice step.

Modeling transport systems

Jointly modeling supply and demand: Mesoscopic ABM

Agent based model
- Discrete agents operate with a set of rules and can interact with each other
- Agents are typically individual travelers
- Computationally hard—difficult to parallelize

Activity based model
- Rather than trip-based, e.g.
- Travelers structure their daily plans around the sequence of activities they participate in
- Captures whole day correlations and constraints
  - You can’t walk to work and drive your car home
  - You can shift activities throughout the day

[Image of a map showing transport routes]
The philosophy of BEAM

- BEAM is not a MPO model—less focus on precise link-by-link calibration, response to marginal changes in transportation system.
- Goal is to develop a model that is more applicable to long-term fundamental changes in the transportation system under different scenarios, including land use change.
- **Mechanics of resource markets:**
  - Road Capacity
  - Vehicle Capacity
  - Personal Schedules
  - Ride Hail Availability
  - Parking Spaces
  - Refueling Access
Modeling across time scales

- BEAM can be run in a larger workflow, collection of DOE-funded models
- Designed to capture effects that happen across vastly different time scales

Scenario generation

Long term
- Land use
- Charging infrastructure
- Vehicle fleet

Day to day
- Mode choice
- Fleet behavior
- Traffic patterns

Second by second
- Energy use
- Vehicle interactions

Scenario evaluation
Modeling across time scales

- BEAM can be run in a larger workflow, collection of DOE-funded models
- Designed to capture effects that happen across vastly different time scales

**Scenario generation**

**Long term**
- UrbanSim
- EVI-Pro
- ADOPT

**Day to day**

**Second by second**
- RouteE/FastSim
- AIMSUN

**Scenario evaluation**
Behavioral modeling in BEAM

- Generate synthetic population with home/work locations
- Simulate within-day decisions, evaluate a “score” at the end of the day
- Iterate until convergence; models equilibrium and allows reinforcement learning

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Diagram showing the process of BEAM:
- Household Coordination
- Initialization
- BEAM
- Replanning
- Scoring
- Mode Choice
- Reroute Choice
- Route Choice
- Refuel Choice
- Refueling
- Parking Choice
MODELING 3 REVOLUTIONS IN BEAM

(Vehicle/ride sharing, automation, and electrification)
Sharing: Ride hail operations

- Dynamic allocation of vehicles to customers, including pooled trips
- Real time price and wait time quotes

Manual

CAV-L4+

Travel Requests
- Pick-up/Drop-off locations & time

Vehicles status
- Vehicle location, passengers & schedule

Request-Trip-Vehicle Graph

Greedy Assignment Solver
- Larger Carpools first
- Min sum of delays

Pooling Assignments

Pooled Rides

Graph showing the allocation of vehicles to customers, including pooled trips, with dynamic allocation and real-time price and wait time quotes.
Automation: Household automated vehicles

- Households coordinate to deploy L4+ CAVs to best serve mobility of all members
- Access to automated vehicles in a household leads to more individual trips and more empty VMT between trips
Electrification: Constrained charging availability

- BEAM simulates limited EV range and charging requirements, separately for personal EVs, human driven ride-hail, and automated ride-hail (AEV).
- Personal EVs charging is part of parking choice process.
- Human driven ride-hail competes with personal vehicles for plugs.
- Automated ride-hail (AEV) has its own network of charging depots.

**BEAM simulation**
- Simulate the driving, parking & charging behaviors of AEVs.
- Whenever an AEV’s state-of-charge drops below the given threshold, it gets charged.

**Record events**
- Record when, where, & how many AEV charging demands that happen in the system.

**Planning**
- Locate a number of charging stations to satisfy all the demands.
- Subject to quality of service constraints.

**Beam simulation**
- Charging demands
- Charging station planning
WHAT KINDS OF QUESTIONS SHOULD WE TRY TO ANSWER?
What are the important interactions in constraints associated with new mobility paradigms?
Examine trade-offs and constraints

- Can reveal important trade-offs and constraints when we extrapolate a mobility paradigm (e.g. ride-hailing) into the future
- Here, we found that operations of ride-hail fleets are critical; increased ride-hailing, even if pooled, also results in increased deadheading (you can’t have your cake and eat it too)
- High penetration of EVs necessary to reduce energy use under any scenario
What are the order-of-magnitude-sized effects of competing processes?
Estimated bounds of large-scale changes

- Can put order-of-magnitude bounds on important quantities as a function of critical assumptions.
- Here, we are looking at grid capacity constraints associated with operating a large fleet of automated, electric ride-hail vehicles.
- We can compare the size of the peaks in electricity demand due to home (slow) charging versus (fast) depot charging of ride-hail CAVs as a function of fleet size.

### Diagram

#### Charging Load (GW) vs. Hour of Day

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<tr>
<th>Fleet Density</th>
<th>Charging Load</th>
<th>DCFC</th>
<th>Public-L2</th>
<th>Work-L2</th>
<th>Home-L2</th>
<th>Home-L1</th>
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<tbody>
<tr>
<td>53 CAVs per 1000 people</td>
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<tr>
<td>14 CAVs per 1000 people</td>
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What can the distributional effects of large scale changes look like?
Look at distributional effects of big changes

- Can trace macro-scale trends back to their impacts on individuals
- Here, modeled scenarios of varying levels of household AV ownership, looked at impacts on households with and without AVs
- As AV ownership increases, total travel decreases (mostly from households without AVs). Empty AV movements lead to congestion, non-AV owners need to adapt
Thank you!

- Questions?

- Source code available: https://github.com/LBNL-UCB-STI/beam

- email: zaneedell@lbl.gov