An Agent-Based Information System for Electric Vehicle Charging Infrastructure Deployment

Timothy Sweda, Diego Klabjan
Northwestern University

June 7, 2013

Outline

- Background on EVs
- Proposed model
- Implementation
- Results

Electric Vehicles (EVs)

- An electric vehicle (EV) is a vehicle powered entirely or in part by electricity
- A plug-in EV (PEV) can plug into the electrical grid to recharge

Electric Vehicles (EVs)

HEV

PEV

PHEV

BEV

Electric Vehicles (EVs)

- The case for EVs:
  - Lower emissions
  - Lower maintenance costs
  - Lower (and more stable) fuel costs
  - Reduced dependence on foreign oil
  - Symbolism

Electric Vehicles (EVs)

- Barriers to mass PEV adoption:
  - High vehicle prices
  - Gas prices still (relatively) low
  - New technology
    - Uncertainties
    - Limited choices
  - Lack of charging infrastructure
  - Range anxiety

Research Goals

- Facilitate transition of consumer vehicle fleet to PEVs
- Explore relationship between infrastructure presence and PEV adoption
- Develop strategies for deploying new charging stations

Motivation

- "Chicken-and-egg" problem:
  - Consumers will not buy PEVs unless public charging access is readily available
  - Infrastructure providers will not install charging stations unless there are PEV drivers who will use them

Motivation

- Infrastructure providers want to know:
  - Where to locate charging stations
    - Near urban centers
    - Along highways
    - Clustered or dispersed
  - How many charging stations to locate
    - Too few: missed profit opportunities
    - Too many: cannibalized sales

Related Research

- Facility location
  - *p*-median
  - Set covering
  - Flow intercepting/refueling
- Demand forecasting
  - Discrete choice (logit)
  - Simulation (agent-based)

Related Research

- Shortcomings of previous models:
  - Do not consider interaction between PEV adoption and infrastructure growth
  - Limited study of competition among different EV types
  - For ABMs, patch-based environments prohibit micro-level analyses

Proposed Model

- Contributions:
  - Simulation model that incorporates GIS shapefiles and street-level data
  - Capture charging decisions made by PEV drivers
  - Study effect of charging infrastructure presence on PEV adoption
  - Analyze adoption trends of different EV types

Proposed Model

- Agent-based model (ABM)
- Agents = drivers
  - Income
  - Preferred vehicle class
    - Compact, midsize, luxury, SUV
  - Greenness
  - Vehicle
    - Type (ICE, HEV, PHEV, BEV)
    - Fuel efficiency
    - Period of ownership

Proposed Model

- Environment
  - Roads
  - Houses
  - Workplaces
  - Points of interest
  - Charging stations

Proposed Model

- Each agent has weekly errands
  - Local
  - Distant
  - Work
- Spheres of social influence
  - Neighbors
  - Coworkers

Proposed Model

- PEV drivers must recharge their vehicles periodically
- BEV drivers accumulate inconvenience and worry
  - Inconvenience: extra distance to recharge
  - Worry: distance traveled while battery is low

Proposed Model

- Driving behavior
  - All agents:
    - Must work from 9AM-5PM on weekdays
    - When not at work, may run errands
    - Must obey morning/evening curfews
  - BEV agents:
    - Must seek recharging when battery gets low
    - May recharge at home, charging station, or other destination with charging access
  - PHEV agents:
    - Do not actively seek recharging
    - Recharge only at home and at destinations with charging access

Proposed Model

- Purchasing a new vehicle
  - When vehicle's age equals length of ownership period, driver replaces vehicle with new one
  - Notation:
    - $y(a,t)$ = optimal vehicle choice for agent a at time t
    - $V(a)$ = set of vehicles available to agent a

Proposed Model

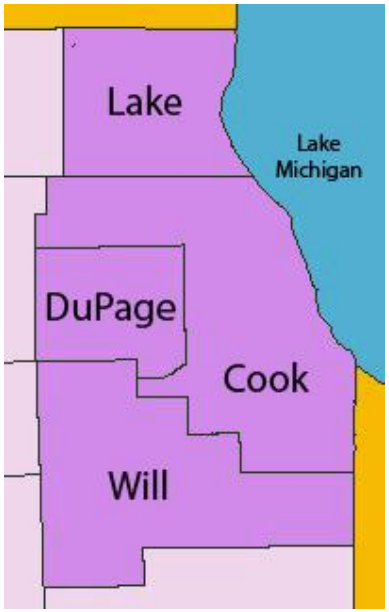
- Optimal vehicle expression:

$$y(a,t) = \underset{v \in V(a)}{\arg\min} \left\{ A(v,t) + B(v,a,t) - C(v,a) - D(v,a,t) + E(v,a) + F(v,a,t) + G(v,a) \right\}$$

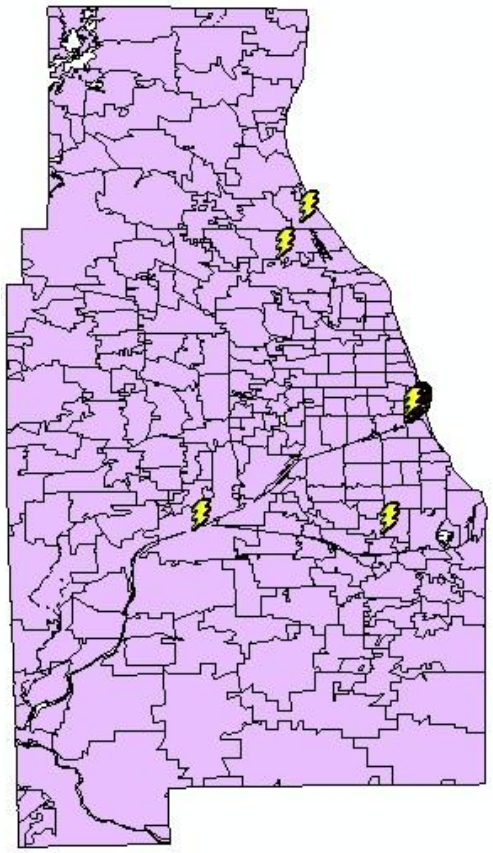
- A : Sticker price
- B : Expected fuel cost
- C : Green bonus
- D : Social influence
- E : Long distance penalty
- F : Infrastructure penalty
- G : Feature tradeoff penalty

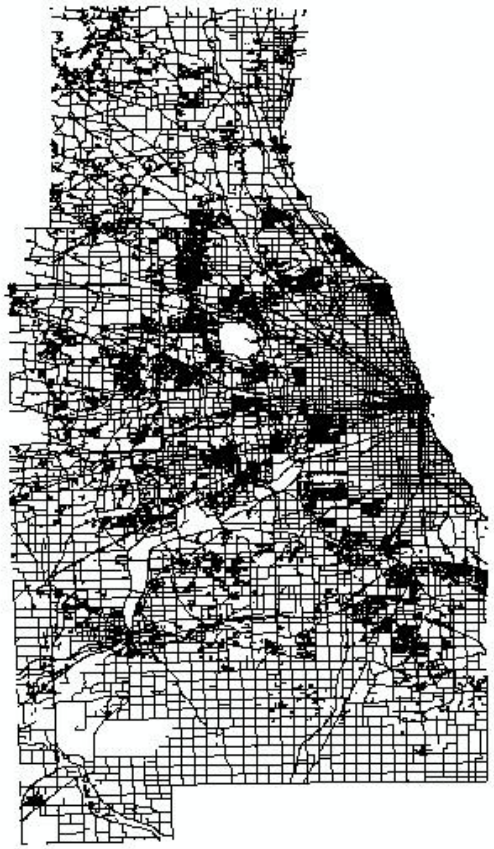
Model Implementation

- Modeling platform: Repast
- Environment: Cook, DuPage, Lake, Will counties (IL)



Model Implementation





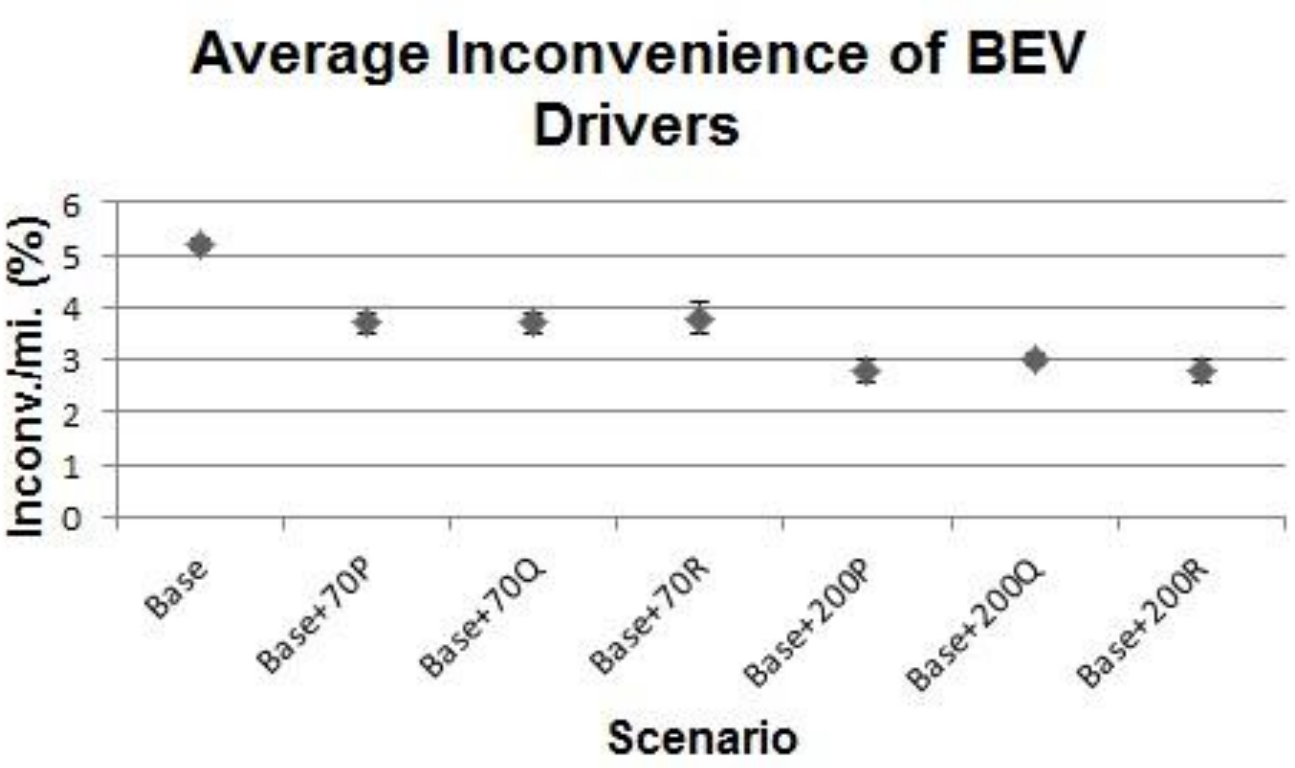
Images based on 2010 U.S. Census data

Model Implementation

- Infrastructure Deployment Scenarios:
  - Base case (18 stations)
  - # stations
    - Base+70
    - Base+200
  - Location weights
    - Population (P)
    - Population^2 (Q)
    - Unweighted (R)

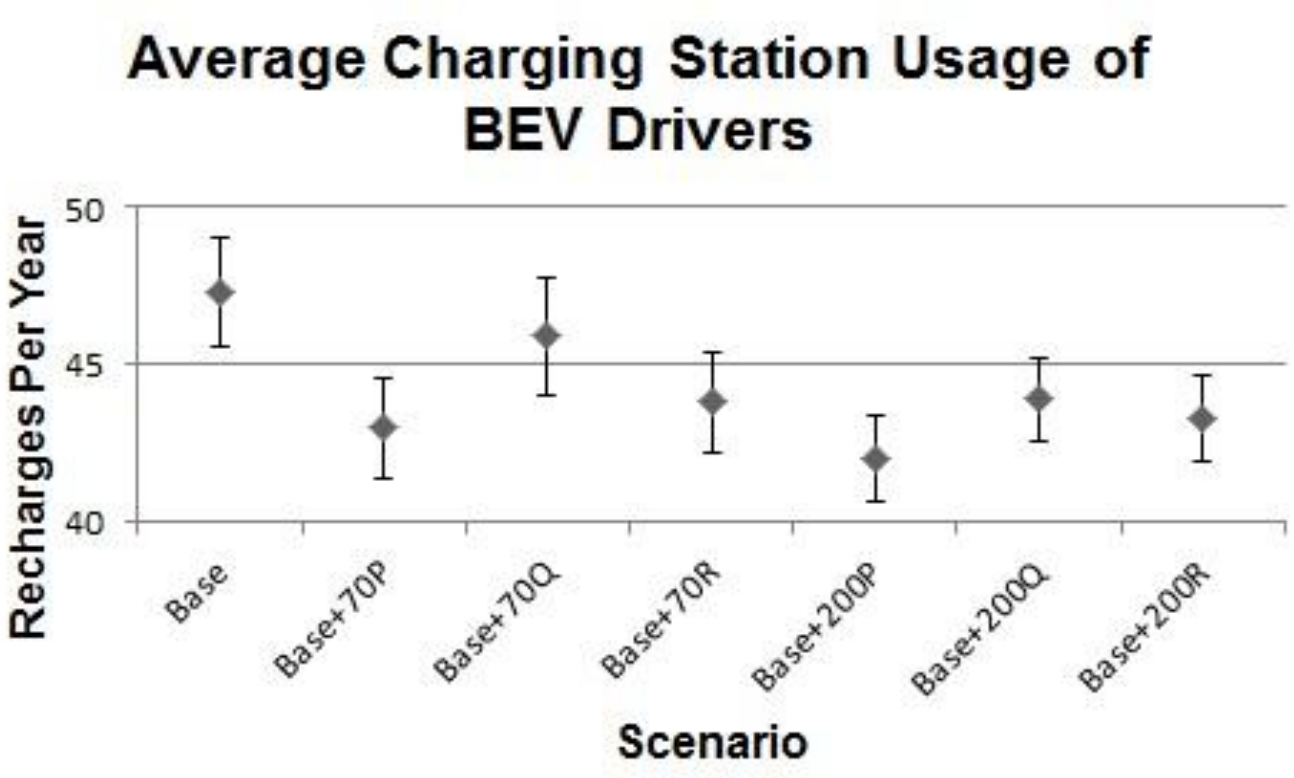
Results

- BEV driver statistics



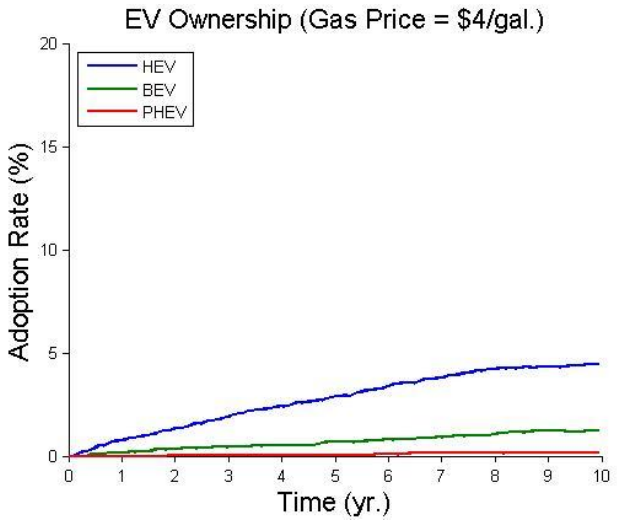
Results

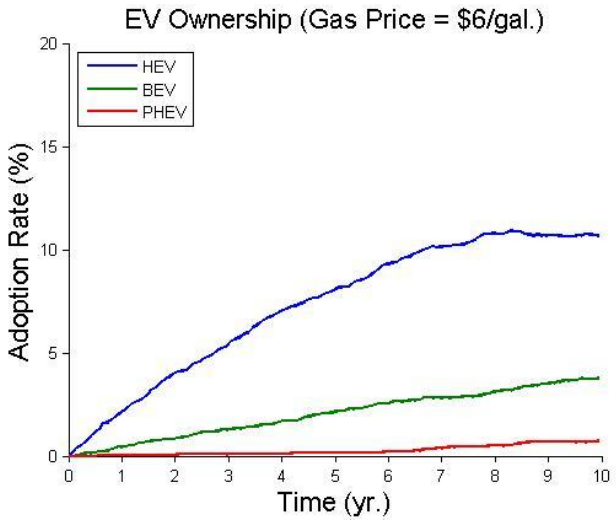
- BEV driver statistics

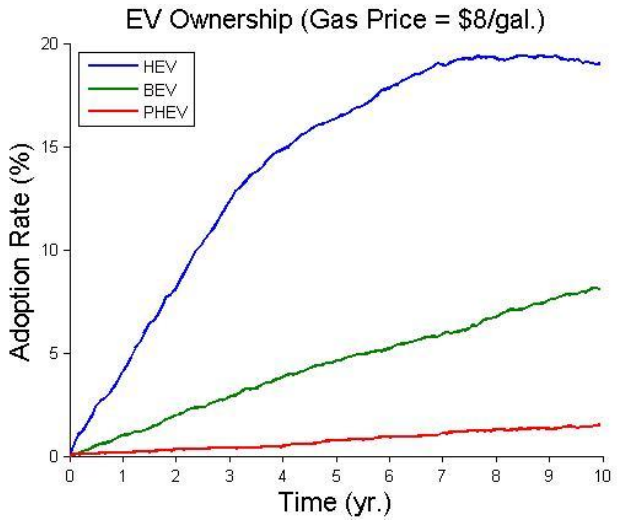


Results

- EV adoption
  - adoption vs. time vs. gas price







Ongoing/Future Work

- Develop better model of PEV driving and recharging behaviors
- Calibrate simulations based on new data as it becomes available
- Optimize placement of new charging stations

Thank You