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

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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

PHEV

PEV

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:
    • $y(a, t) = \text{optimal vehicle choice for agent } a \text{ at time } t$
    • $V(a) = \text{set of vehicles available to agent } a$
Proposed Model

- Optimal vehicle expression:

\[ y(a,t) = \arg\min_{v \in V(a)} \{ A(v,t) + B(v,a,t) - C(v,a) - D(v,a,t) + E(v,a) + F(v,a,t) + G(v,a) \} \]

- \( A \) : 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
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

![Average Charging Station Usage of BEV Drivers](image)

Recharges Per Year

Scenario

Base, Base+70P, Base+70Q, Base+70R, Base+200P, Base+200Q, Base+200R
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