Virtual AutoMotive MarketPlace Model

VAMMP

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UMTRI
There is much public discussion of Plug In Hybrid electric vehicles (PHEV).

They are a promising future vehicle technology that can help reduce fossil carbon emission and dependence on foreign oil.

Many are involve in their evaluation; at University of Michigan there are ongoing efforts by:
- Engineering
- ISR
- UMTRI

UMTRI’s focus is on market penetration, market viability.
UMTRI’s Approaches to Anticipating the Market for PHEVs

• Apply its Market (Social) Simulation Model to the PHEV question
  • Approach: Agent Based Modeling

• Apply Economic Modeling
  • Approach: UM Dynamic Household Vehicle Ownership and Use Model
Why Simulate?

Describe

- Common Framework
- Visualize
- Demonstrate
- Convince

Explain
Ways to Study a System

1. Experiment with the Actual system
2. Physical Model
3. Analytical Model
4. Simulation

Experiment with a model of the system

Mathematical model
Complex Adaptive Systems

• Complexity Science methods are available to explore the role of human behavior in the collective social response, i.e. bottoms up modeling
  ➢ Agent Based Modeling: social modeling, Computational Social Science

• Agents of interest here are consumer, regulators, legislators; motivated by:
  ➢ economics, convenience, utility, ethics, principles, concerns

• Important questions:
  ➢ When do agents exhibit unexpected collective behaviors?
  ➢ When do they shift their own behaviors?
  ➢ Where are the tipping points?
  ➢ What happens to markets?
Complex Systems Examples

- Schelling’s segregated neighborhoods of non-racist agents
- Sugarscape: surprising skewed distribution of sugar “wealth” reminiscent of today’s income distribution
- Hammond’s corrupt vs. honest society evolution
- Axtell’s work on Zipf distributions (power laws) of city and company sizes. He and R. Florida, grew artificial companies and cities.
- Epstein’s Artificial Genocide
- Axtell and Epstein’s Cyber Anasazi:
- Riolo et al “Evolution of Cooperation without Reciprocity”
- Axelrod’s “Spontaneous Emergence of Cooperation”
- Electric power distribution
- Financial markets: Brown, LeBaron, Kiyotaki & Wright, Duffy
- Organizational behavior

UMTRI 40 Years... The Science of Driving
Virtual AutoMotive MarketPlace
VAMMP

• It is a virtual marketplace comprised of virtual decision makers in software.

• The decision makers are represented by four classes:
  ✓ consumers
  ✓ government
  ✓ energy providers
  ✓ vehicle providers

• All agents act to achieve either their individual or organizational objectives
Modeling Objectives

• The modeling permits:
  ✓ estimation of PHEV penetration curves
    ➢ robustness of a market penetration
    ➢ rate of penetration
  ✓ elucidation of various influences on the marketplace, e.g.
    ➢ policy instruments (carbon taxes, CAFE, etc.)
    ➢ competing technologies
    ➢ fuel prices
  ✓ identification of circumstances that reveal potential tipping points, if any

• Because the model presents a virtual (surrogate) world, it not a predictive tool.
  ✓ But if sufficiently representative, it can provide:
    ➢ a sense of likelihood of outcome (e.g. successful market penetration)
    ➢ a sense of risk of failure
Region includes a city, a suburban ring, and two towns, each with low, middle and upper income zones.
Consumer Agents

• Agents have:
  - income
  - jobs
  - home and work addresses
  - transportation needs
  - transportation budgets: fixed and variable
  - vehicle preferences: size, performance, cost, brand, etc.
  - a choice of vehicles models
  - access to mass transit
  - sensitivity to fuel prices

• Agents are influenced:
  - By neighbors
  - By colleagues
  - By economics
OEM Agents

• Auto manufactures monitor sales
  ➢ They can change their product mix
  ➢ Introduce new technology
  ➢ They can offer price incentives

• Sales and profits are tracked.

• Two kinds of auto agents:
  ➢ new car manufactures
  ➢ used car sales
Vehicles

• Vehicles Properties:
  ✓ size: small, medium, and large
  ✓ performance levels: low, medium, and high
  ✓ fuel economy: city and highway
  ✓ retail price dependent on size and performance
    (large high performing vehicle have low fuel economy; small low performing vehicles have high fuel economy)

• They are made by three separate OEMs
Fuel Module

• Fuel changes in the model are currently exogenous.
  ➢ demand shocks not considered; supply shocks are

• Fuel considered are: gasoline, electricity, biofuels, etc.

• Fuel is considered ubiquitous
• Government monitors vehicle fleet fuel consumption and carbon dioxide emissions

• Government can act in the following ways:
  - impose a carbon tax
  - impose a fuel tax
  - impose CAFE regulations
  - impose a gas guzzler tax
  - offer tax credits
Model Flow

**Setup**
- Assign homes, jobs, income, transportation budget, car preference, driving distribution

- Initiate exogenous events as per scheduler

**Miles&Fuel**
- Compute miles driven & fuel consumed; adjust if needed

**Sales Analysis**
- Evaluate vehicles sales & revenue; adjust vehicle prices

**Government action**
- Based on environmental metrics, introduce endogenously: fuel taxes, fuel price changes, tax rebated, etc.

**Consumer_Purchase**
- If time to buy, find a vehicle and purchase it

**Energy sector**
- Based on demand and supply, adjust energy product prices.

**Exit**
- If \( t \leq n\_cycles \) yes
- no
Has fuel price changed?

Yes

Estimate impact on budget: if overbudget, reduce mileage at agent specific rate

No

Compute mileage & Fuel consumption

Return to Main
Consumer Agent Purchasing Decision Hierarchy

• When it is time to buy:
  - Screen for available cars, new and used, within budget window
  - Score potential vehicles according to size and performance preferences
  - Rescore the revised list for brand preferences, if any.
    - Select the best; eliminate all others
  - From remaining list select those with agent’s new or used preference
  - In the final list, keep or remove special feature vehicles consistent with agent propensity
Base Case

• No market stimulus
Assigned Distribution

ON ROAD VEHICLES

NUMBER OF VEHICLES

FLEET ID NUMBER

New (t)
Used (t)
NEW (0)
USED (0)
After Conditioning

ON_ROAD VEHICLES

NUMBER OF VEHICLES

FLEET ID NUMBER

New(t)
Used(t)
NEW (t)
USED (t)
At end of run
At end of run

Normalized output

\( \frac{F(t)}{F(1)} \)

YEAR

2000 2006 2012 2018 2024

CAR_VMT
CAR_GASLN
TOT_GASLN
Case 1

• Fuel Price increase: $1.00/gal
$1.00/gal gasoline price increase
$1.00/gal gasoline price increase
$1.00/gal gasoline price increase

Normalized output

2000 2006 2012 2018 2024

YEAR

CAR_VMT
CAR_GASLN
TOT_GASLN
Case 2

- Change in vehicle price for model “2”
  - $-2k
  - $ 2k
Normalized output

$-2k$ price change for “2”

YEAR

CAR_VMT
CAR_GASLN
TOT_GASLN
$ 2k price change for “2”
Introduction of an HEV

\((S,P) = (2,2)\)

With and Without a Gov’t tax subsidy
\[(S, P) = (2, 2)\]
(S, P) = (2, 2); $2k subsidy
(S, P) = (2, 2); $3k subsidy
Introduction of an HEV

$(S,P) = (2,3)$

With and Without Gov’t tax subsidy
\[ (S,P) = (2,3) \]
(S,P) = (2,3); $2k subsidy
Status of VAMMP

• Simulated market responses to various stimuli are quite consistent with actual market behaviors.
  ✓ Its estimates of HEV growth are in good accord with observation
  ✓ Model is now being applied to the more complicated PHEV case

• To be credible and yet fathomable, models must be complex but not too much.
  • Generative sufficiency is the core explanatory necessity
  • Want the essence without the clutter; what matters & what doesn’t
  • Models must be both verified and validated

• Is the model sufficiently detail? I think so and it appears we have the right detail.
  • “Nothing can be less real than realism. Details are confusing. It is only by selection, by elimination, by emphasis that we get at the real meaning of things.”

Georgia O’Keeffe
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