Incorporating Consumer Heterogeneity in Choice Modeling of Advanced Vehicles

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Integrated DEsign Automation Laboratory (*IDEAL*)

http://ideal.mech.northwestern.edu/

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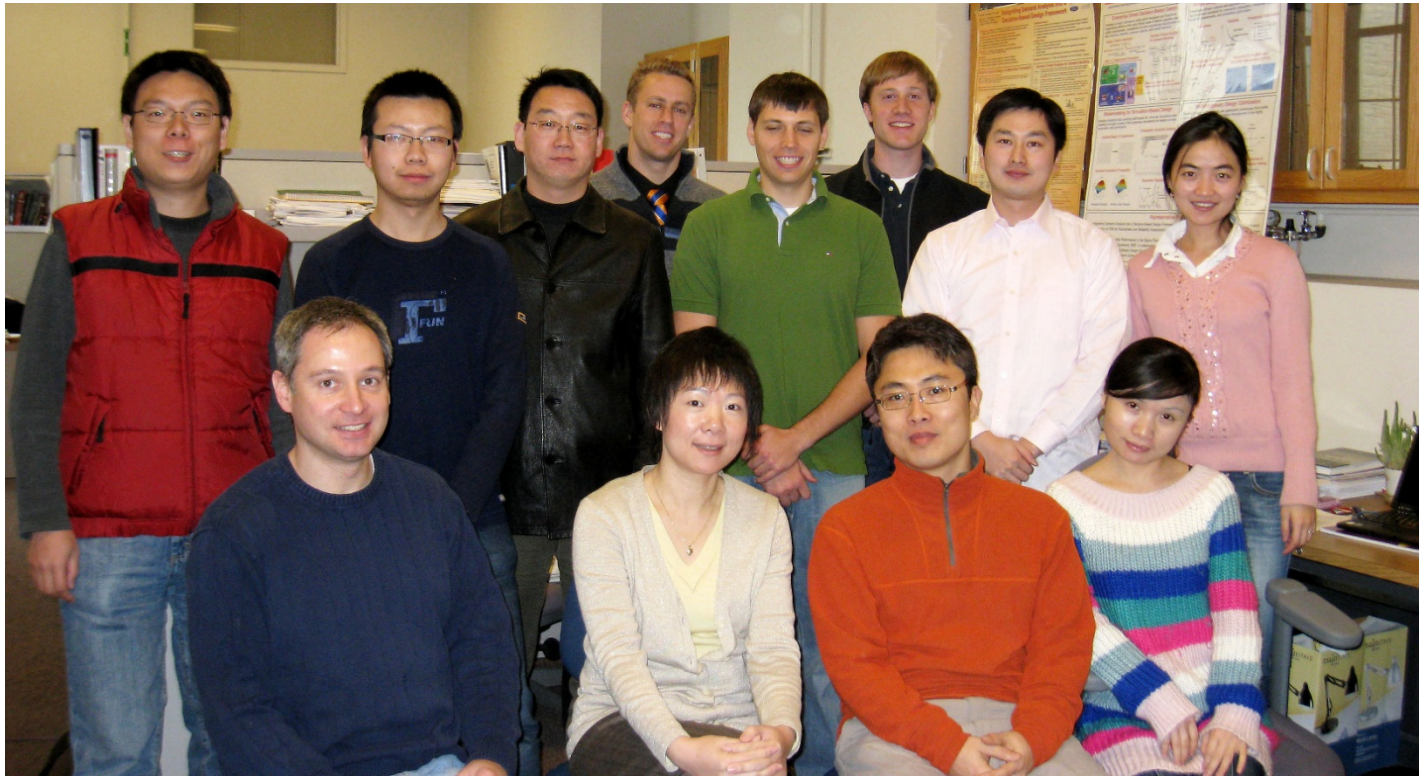
Goal: To develop rational design methods based on advanced computational and statistical techniques to support engineering design and product realization.



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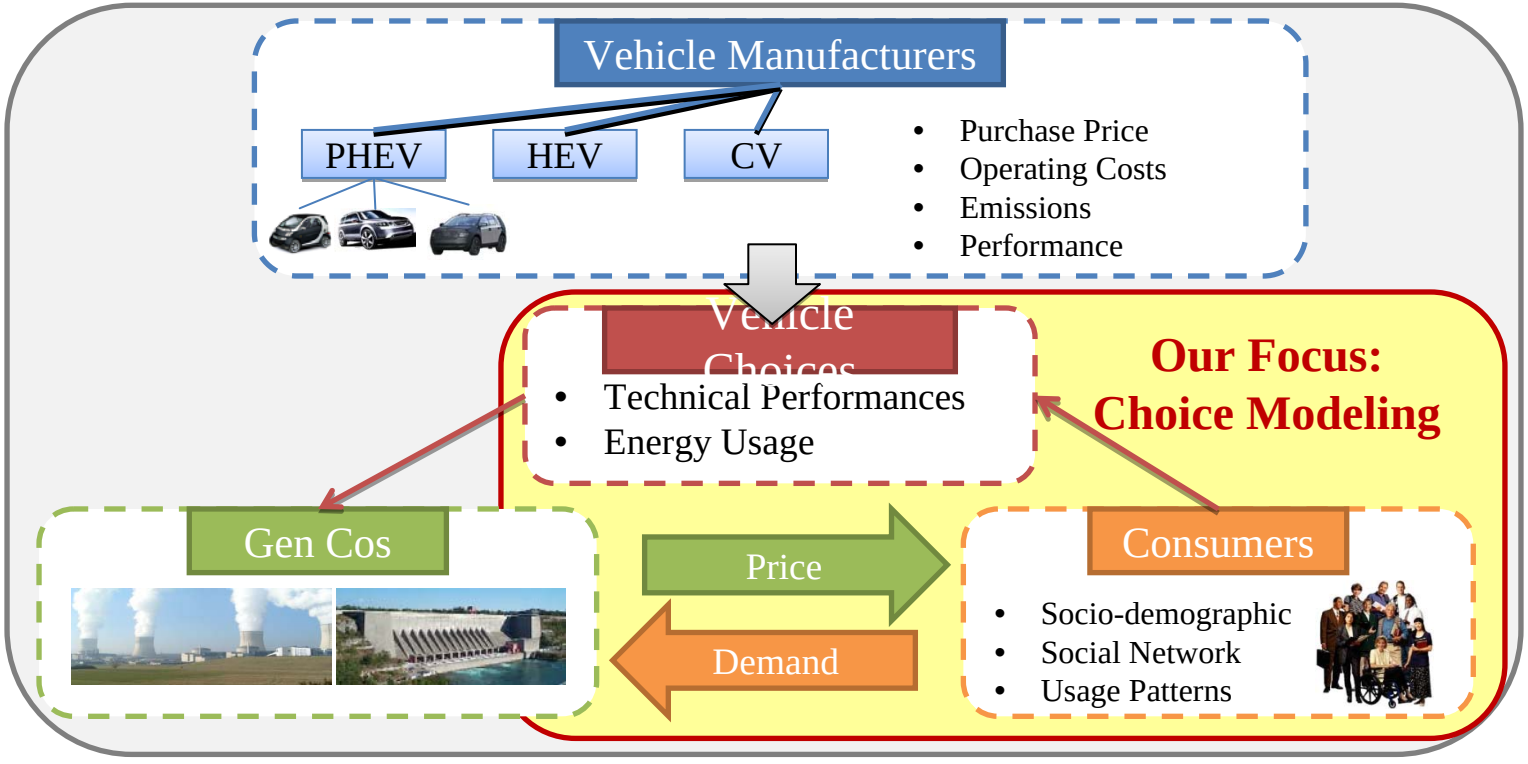
Assessing Energy Generation Needs Considering Consumer Preferences for Advanced Vehicles

- **Goal:** to develop a **comprehensive consumer choice modeling approach** for assessing energy generation needs considering the heterogeneity in consumer preferences for **advanced vehicles**.



*ISEN (Initiative of Sustainability and Energy at Northwestern) Booster Grant, in collaboration with **Argonne National Lab**.*

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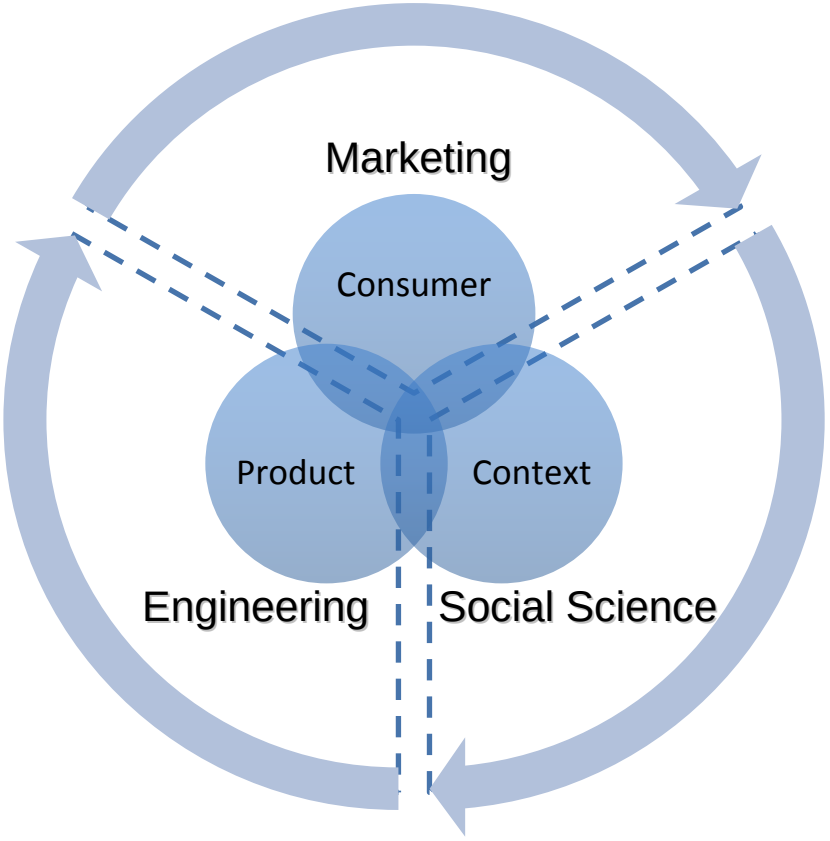
Research Focus

- Develop analytical techniques
  - To explore the intersection and interaction of ***consumer***, ***product***, and ***context*** in design research;
  - To integrate ***engineering***, ***marketing***, and ***social science*** domains.



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Proposed Choice Modeling Framework

- Usage and Social Context-Based Choice Modeling

$$W_{in,t} = W(\beta : \mathbf{A}_i, \mathbf{S}_n, \mathbf{E}_n, \mathbf{N}_n, t)$$

Terms	Customer Desired Attributes	Customer Demographics	Usage Context	Social Impact
Examples	✓ Exterior Styling ✓ Interior Dimension ✓ Horsepower ✓ MPG ✓ Quality	✓ Gender ✓ Age ✓ Income ✓ Children under 18 ✓ Education	✓ Local / highway driving condition ✓ Miles driven daily	✓ Neighbor effect ✓ Influence from distant links with similar lifestyle

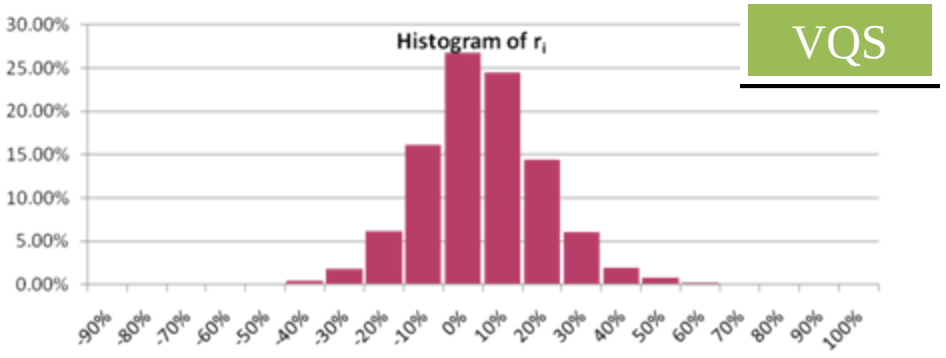
- Our research interests:
  - How to incorporate each of the terms into choice modeling?
  - How to integrate all of them into a single choice modeling framework to support engineering design?

Choice Modeling for Hybrid Electric Vehicles (1)

- Hybrid Electric Vehicle (HEV) based on JD Power Data
  - Revealed preferences data: VQS;
  - 8025 respondents, 288 car models in 2007 including 11 HEVs.
- Customer desired attribute **A**
  - Price
  - Vehicle origin (Domestic / European / Japanese / Korean)
  - Vehicle size (Compact / Midsize / Large / Premium)
  - Vehicle type (Mini / Car / SUV / Minivan / VAN / MAV / Pickup)
  - Mileage Per Gallon (MPG)
- Customer profile **S**
  - Gender
  - Age
  - Household income
  - Number of children under 18
  - Education level
- Attitudes toward Technology **N**
  - Hybrid (0 for conventional, or 1 for hybrid)

Choice Modeling for Hybrid Electric Vehicles (2)

- Usage context attribute **E**
  - Local / highway indicator
    (0 – local, 1 – highway)



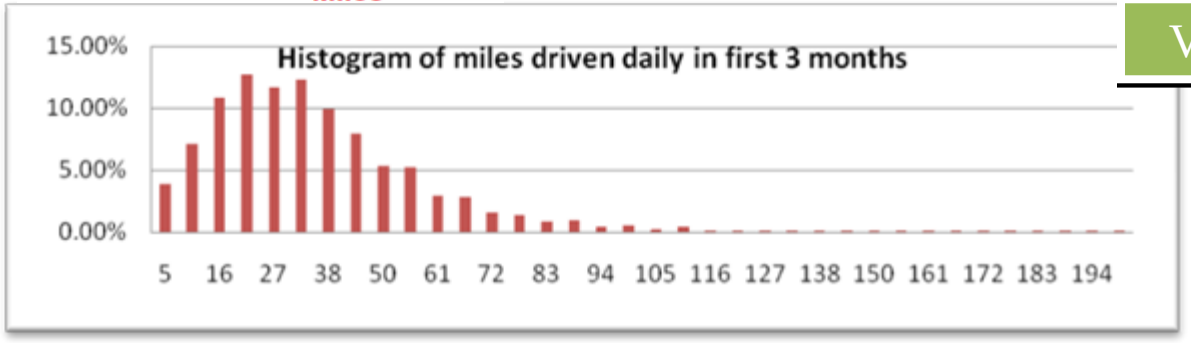
VQS

6. Your average miles-per-gallon □□ M.P.G.

$$r_i = \frac{MPG_{real,i} - MPG_{EPA,i}}{MPG_{EPA,i}} \times 100\% \quad \Rightarrow \quad E_{local/highway} = \frac{r_i + 1}{2}$$

  - Miles driven daily

5. Current mileage □□,□□□ Miles



VQS

Choice Modeling for Hybrid Electric Vehicles (3)

- Truncated utility function:

Price | MPG | Attitude toward hybrid electric vehicle

$$W = \beta_1 \cdot A_1 / S_3 + (\beta_{20} + \beta_{21} \cdot E_1 + \beta_{22} \cdot E_2) \cdot A_2 + (\beta_{30} + \beta_{31} \cdot E_1 + \beta_{32} \cdot E_2) \cdot N_{Hybrid} + \ldots$$

Income | Local/highway indicator | Miles driven daily

- Selected coefficient estimators:

Parameter	Variables	Description	Coefficient
β_1	A_1/S_3	Price / Income	-0.00048 *
β_{20}	A_2	MPG	-2.88 *
β_{21}	E_1*A_2	Local/Highway indicator * MPG	5.40 *
β_{22}	E_2*A_2	Miles driven daily * MPG	0.00 *
β_{30}	N_{hybrid}	Attitude toward hybrid electric vehicle	62.51 *
β_{31}	E_1*N_{hybrid}	Local/Highway indicator * HEV attitude	-111.59 *
β_{32}	E_2*N_{Hybrid}	Miles driven daily * HEV attitude	0.00

Local drivers prefer hybrid vehicle, while highway drivers don't.

* Significant with p value <=0.05.

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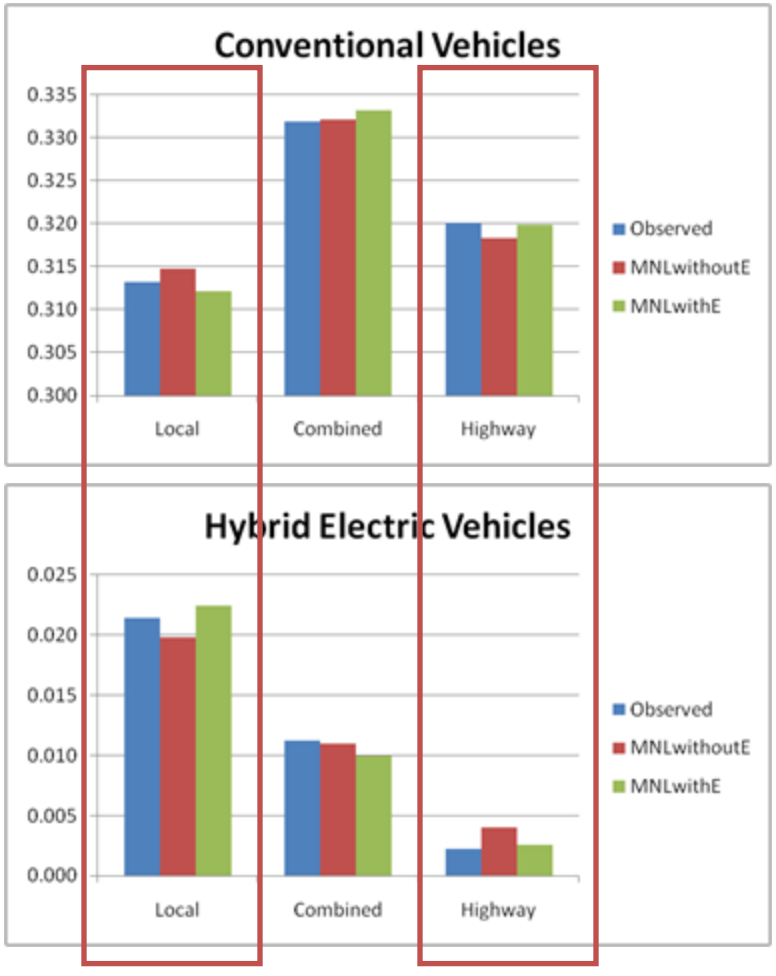
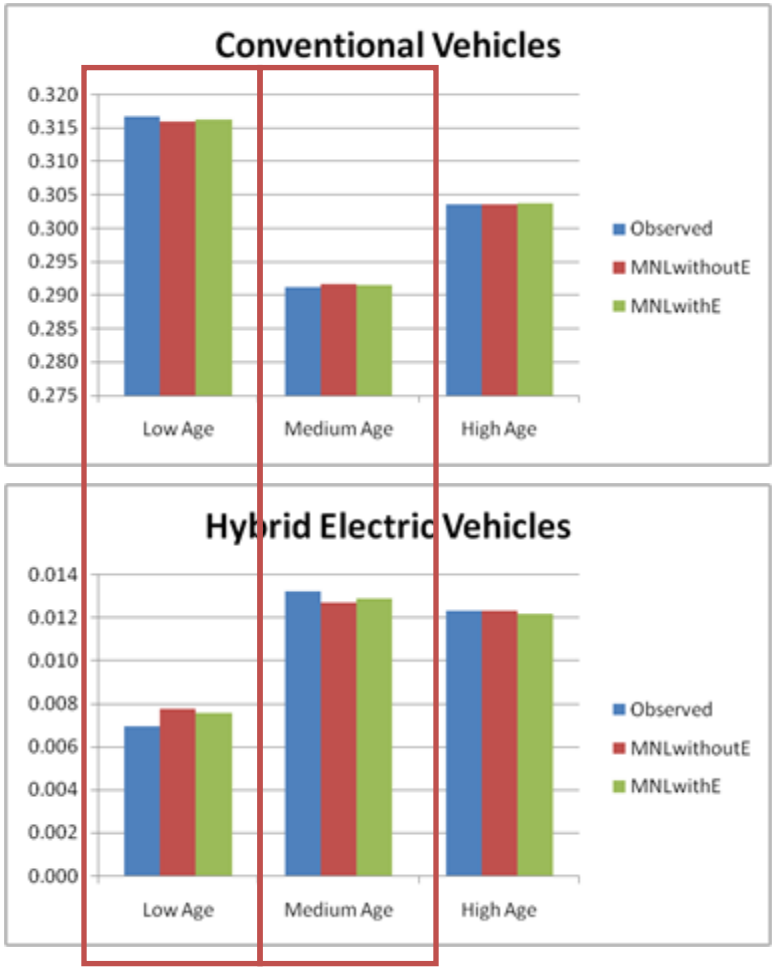
Market Segment Prediction Test

- Driving Condition Segments



- Age Segments



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Integrated Usage & Social Context-Based Choice Modeling

- Major challenges in modeling new product adoption:
  - Lack of market data;
  - Integration of discrete choice analysis and agent-based simulation.
- Choice modeling with combined SP and RP data
  - PHEVs: the 2nd generation of HEVs with larger battery capacity and the option to charge-at-home.
  - Assumption: customers' attitudes toward the new HEV and PHEV technology are roughly on the same scale.

$$W_{in,t} = W(\beta : \mathbf{A}_i, \mathbf{S}_n, \mathbf{E}_n, \mathbf{N}_n, t)$$