From Trend Spotting to Trend Setting: Behavioral Analysis to Guide Transformative Mobility

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Outline

- Motivation
- Travel Behavior Modeling Framework & Gaps
- Modality Style Models
  - Concept and Formulation
  - Findings
- Nudging Modality Styles
- Conclusions
Sustainability Needs

• CO₂ emission targets
  – By 2050 be 80% below 1990 levels (CA, Japan, EU, ...)

• US      25% of CO₂ from transport   15% from passenger cars
Japan    18%      ”        5%    ”

• How to meet GHG reduction goals for transportation?
  – Technology
  – Behavior

• Even most optimistic technology scenarios for 2050 are insufficient
  (Sager et al., 2011; Dray et al., 2012)
Transformative Mobility

• Clean *
• App-driven
• Shared
• Connected
• Autonomous
• Virtual mobility **

* JAFOE 2016
** JAFOE 2016
Energy Storage theme
3D Printing theme

Will a World of Driverless Cars Be Heaven or Hell?
The answer depends in large part on whether we own autonomous vehicles or share them.

ROBIN CHASE | @rmchase | Apr 3, 2014 | 179 Comments
“Hang on—I’ll Uber us a school bus.”

New Yorker, May 2016
Transformative Time for Travel Behavior Analysis

Critical need
New travel paradigms here and on horizon
Tremendous potential from data goldmine*

RESEARCH OBJECTIVE
To develop behavioral analysis tools that focus on modeling and influencing trends of travel behavior to guide transformative mobility towards a more sustainable, efficient, and equitable system.

*JAFOE 2016 Big Data theme
Modeling Framework

TECHNOLOGY, SERVICES, POLICY

MODELING
- Land use patterns
- Adoption of technologies and services
- Travel and Activity Patterns

OUTCOMES
(Efficiency, Sustainability)
Gaps in Behavioral Modeling

1. Flexibility around uncertainty of future technologies and services
2. Diffusion of new technologies and services
3. Location, travel, and activity behavior conditional on adoption
4. Effective nudges/policies to achieve desired outcomes
5. Attitudinal and behavioral trends
Vital Decision Missing in Modeling Framework

The influence of modality styles in the context of a comprehensive forecasting model system  
(adapted from Bowman, 1995)

Vij, Waddell, Walker (2015)
Models of Travel Behavior

Traditional Models

- Trip-based decision
  - Consider all transportation alternatives
  - Evaluate time and cost (and other)
  - Make rational decision
- Limited heterogeneity

Modality style Model

- Higher-level decision
  - Lifestyles built around particular travel modes

Vij, Carrel, Walker (2013)
Latent Modality Style Formulation

Individual Characteristics ($S$)

Transportation and Land Use Attributes ($Z$)

Travel-Related Behaviors ($B$)
Latent Modality Style Formulation

Individual Characteristics ($S$)

Modality Style ($m$)

Transportation and Land Use Attributes ($Z$)

Travel-Related Behaviors ($B$)
Latent Modality Style Formulation

• Latent Modality Style Segments; each segment \((m=1, \ldots, M)\) has its own people and behavior
  – Set of transportation alternatives considered
  – Willingness to pay and attitudes
  – Demographic distributions

• Data mining of travel diary data determines
  – Number of segments \(M\)
  – Behavior of each segment \(P(B|Z,m)\) for \(m=1, \ldots, M\)
  – Demographics of each segment \(P(m|S)\)
1. Produces Meaningful Segments

1. Inveterate Drivers
2. Car Commuters
3. Moms in Cars
4. Transit Takers
5. Multimodals
6. Empty Nesters

Vij (2013)
2. Explains Interdependencies of Decisions

Variation in SOCIO-DEMOGRAPHICS

1. Young Urbanists
4% of the sample population.
Most likely to be young unemployed individuals, often students, with low household incomes.

2. Multimodals
6% of the sample population.
Most likely to be single employed individuals in households with no kids, living in rented apartments, with a carshare membership.

3. Nonworking Suburbanites
14% of the sample population.
Most likely to be high income hhs with kids, live in single-family homes, have on average 2.5 cars, and unemployed or retired.

Vij, Waddell, Walker (2015)
2. Explains Interdependencies of Decisions

Variation in TRIP-CHAINING and TRIP PURPOSES

1. Young Urbanists
   - 66% individuals make a mandatory tour; equally likely to trip chain or not.

2. Multimodals
   - 77% individuals make a mandatory tour; strongly inclined to trip chain.

3. Nonworking Suburbanites
   - Only 1% individuals make a mandatory tour; equally likely to trip chain.
2. Explains Interdependencies of Decisions

Variation in MODE CHOICES

1. Young Urbanists

Strong preference for walking: half of their mandatory tours and a fifth of their non-mandatory tours are made on foot.

2. Multimodals

Drive for half of their tours.

3. Nonworking Suburbanites

Drive everywhere.
2. Explains Interdependencies of Decisions

Variation in DESTINATIONS

1. Young Urbanists

Attracted to places with higher mixed use and better walkability.

2. Multimodals

Attracted to places with higher mixed use and less walkability.

3. Nonworking Suburbanites

Attracted to places with lower mixed use and less walkability.
3. Provides Insights Regarding Behavioral Trends

Percentage of the Population

<table>
<thead>
<tr>
<th>Year</th>
<th>Complete Car Dependents</th>
<th>Partial Car Dependents</th>
<th>Car Preferring Multimodals</th>
<th>Car Desisting Multimodal</th>
<th>Car Independents</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>40%</td>
<td>10%</td>
<td>20%</td>
<td>5%</td>
<td>5%</td>
</tr>
<tr>
<td>2012</td>
<td>35%</td>
<td>5%</td>
<td>25%</td>
<td>3%</td>
<td>2%</td>
</tr>
</tbody>
</table>

Vij, Gorripaty, Walker (2015)
3. Provides Insights Regarding Behavioral Trends

Vij, Gorripaty, Walker (2015)
4. Critically Impacts Forecasts

Vij, Gorripaty, Walker (2015)
5. Predicts Trends via Integration with HMM

Introduction of Transantiago (shock) 

El Zarwi, Vij, Walker (2016)
5. Predicts Trends via Integration with HMM

Introduction of Transantiago (shock)
time = 0 months

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El Zarwi, Vij, Walker (2016)
Transformative Mobility

- Clean
- App-driven
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- Autonomous

To Change Behavior, Need to Change Modality Styles

Will a World of Driverless Cars Be Heaven or Hell?

The future will depend in large part on whether we own autonomous vehicles...
Changing Modality Styles: From Trend Spotting to Trend Setting

- Quantified Traveler
  - Creating a more mindful traveler
  
- San Francisco Bay Area Travel Quality Study
  - Importance of personal experience

- Intervening on Residential Choice
  - Using psychological theories to shift habits

- New App-based, Shared Services (Uber, Lyft, Zipcar)
  - Shedding private cars versus shedding transit

- Adoption of new technologies and services
  - Impact of design, policies, social influences, personalized info

- Future technologies (Automation)
  - Infer from present-day analogies
Conclusions

• Developing behavioral analysis tools to guide transformative mobility
• Must concern ourselves with potential heaven or hell outcomes today
  – Key is to model and influence trends
• Modality style concept is essential
  – Key driver of aggregate travel outcomes
  – Provides ability to model attitudes and trends in travel behavior
  – Behavior change efforts must focus on changing modality styles
• Ongoing work
  – Studying influence of Uber, Lyft, Zipcar, etc. on modality styles
  – Using present-day analogies to model future technologies (e.g., automation)
  – Experiments nudging towards sustainable modality styles, residential locations
  – Collecting more and better dynamic behavioral data from mobile devices
VMT Trends in the US... peak auto?

Estimated Vehicle Miles Traveled on All Roads

- Recessions
- Population-Adjusted Growth
- Current Level

VMT per capita

Jan 1971: 81 months total, 26 months to 6.0% trough

Jan 2005

Total VMT

A Close Look Since 2007

Population adjusted using the BLS Civilian Noninstitutional Population Age 16 and Over [FRED CNP16OV]
Latent Modality Style Formulation

**Individual Characteristics ($S$)**

**CLASS-MEMBERSHIP PROBABILITY**

$$P(m | S)$$

that the individual has modality style $m$ conditional on characteristics of the individual $S$.

**CLASS-SPECIFIC CHOICE PROBABILITY**

$$P(B | Z, m)$$

that individual chooses behaviors $B$ conditional on alternative attributes $Z$ and modality style of the individual $m$.

**MARGINAL CHOICE PROBABILITY**

$$P(B | S, Z) = \sum_{m=1}^{M} P(B | Z, m)P(m | S)$$

unconditional on modality style $m$. 

**Transportation and Land Use Attributes ($Z$)**

**Travel-Related Behaviors ($B$)**
Latent Modality Style Formulation

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\]

unconditional on modality style \(m\)
Latent Modality Style Formulation

**CLASS-MEMBERSHIP PROBABILITY**

\[ P(m \mid S, E(Z)) \]

that the individual has modality style \( m \) conditional on characteristics of the individual \( S \) and expected benefit of each modality style \( E \).

**CLASS-SPECIFIC CHOICE PROBABILITY**

\[ P(B \mid Z, m) \]

that individual chooses behaviors \( B \) conditional on alternative attributes \( Z \) and modality style of the individual \( m \).

**MARGINAL CHOICE PROBABILITY**

\[ P(B \mid S, Z) = \sum_{m=1}^{M} P(B \mid Z, m)P(m \mid S, E(Z)) \]

unconditional on modality style \( m \).

*Vij and Walker (2014)*