The role of bounded rationality in travel choice behavior and implications for transport modeling

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Outline

• Activity-based transport models
  • Why activity-based and what does it involve?
  • New developments in research

• Aspects of bounded rationality

• Examples of exploring new area
  1. Effect of memory and emotion on learning and satisfaction
  2. Group decision making and joint activity choice
Travel demand models

- Micro simulation models
  - Activity-based models
    - Daily activity-patterns
  - Tour-based models
    - Trip records
  - OD trip matrix

- Aggregate trip-based models

Predicting people’s response to policies is notoriously difficult.
Travel demand models

Micro simulation models

Activity-based models
- Daily activity-patterns

Tour-based models

Trip records

OD trip matrix

Dynamic/static traffic simulation/assignment models

Aggregate trip-based models

New model development started in early nineties

Models are now making the transition to practice
Why activity-based modeling?

- **New demands from transport planning and policy making**
  - Switch in focus to travel demand measures
  - Importance of temporal factors (flexible work hours) and task combination
  - Integration of policies: land-use and transport planning
  - More comprehensive evaluation of policies
### Activity-based versus trip-based approach

<table>
<thead>
<tr>
<th>Trip-based</th>
<th>Activity-based</th>
</tr>
</thead>
<tbody>
<tr>
<td>Focus is on trips</td>
<td>Focus is on activities</td>
</tr>
<tr>
<td>Unit is a trip</td>
<td>Unit is a day</td>
</tr>
<tr>
<td>Space-time constraints ignored</td>
<td>Space-time constraints taken into account</td>
</tr>
<tr>
<td>Low resolution time and place</td>
<td>High resolution time and place</td>
</tr>
<tr>
<td>Decision unit is individual</td>
<td>Decision unit is household</td>
</tr>
<tr>
<td>Predicts when, where, transport mode</td>
<td>Predicts which activities, when, where, for how long, trip-chaining and transport mode</td>
</tr>
</tbody>
</table>
New developments in transportation research

- From static to dynamic models
  - expand time frame from one day to multiple days
  - include life trajectories and long-term mobility decisions

- Include social networks and social interactions
  - social influence in decision making
  - group decision making – negotiation

- New survey methods and data sources
  - tracking of movements with GPS or mobile phone positioning
  - social media – big data
# New survey methods

<table>
<thead>
<tr>
<th>Traditional – diary data</th>
<th>New – GPS tracking</th>
</tr>
</thead>
<tbody>
<tr>
<td>One or two days data</td>
<td>Longer time frame – week or multiple weeks</td>
</tr>
<tr>
<td>Location identification is difficult and imprecise</td>
<td>Location identification is automated and precise</td>
</tr>
<tr>
<td>No recording of travelled routes</td>
<td>Recording of travelled routes</td>
</tr>
<tr>
<td>User unaided in memorizing of activities and modes</td>
<td>Automated interpretation + prompted recall</td>
</tr>
</tbody>
</table>
Aspects of bounded rationality

**Habitual life**
- Learning & judgment

**Rational beliefs**
- versus
- Heuristics and memory bias

**Exploration**
- Search & info acquisition

**Choice**
- Evaluation & decision

**No search costs**
- versus
- Sequential search and satisficing behavior

**Absolute utility values**
- versus
- Reference-based utilities and emotional weighting

**Needs and resources**
- ICT tools
- Social network
- Physical - ICT
- Institutional
- Prices
- Technological

**Decision utility**
- versus
- Experienced utility

**Independent decisions**
- versus
- Social influence and group decision making

**Activity and mobility patterns & perceived wellbeing**
Aspects of bounded rationality

Accounting for bounded rationality requires a change from static to dynamic modeling
Time is ripe

- Cumulative evidence from psychology and behavioral economics
  - See recent book of Daniel Kahneman (2011) – Thinking, Fast and Slow

- Human biases are well documented and tools for data collection and modeling available

- Modern survey technologies facilitate a move from one-day to multiple days data collection

- Wide use of smart phones allows new *in-situ* data collection methods
Effect of memory and emotion on learning and satisfaction

Example of exploring new area (1)

How do travelers judge the likelihood of a risky event?

How do travelers judge degree of satisfaction with choice alternatives?
How do travelers judge the likelihood of a risky event?

• This is a relevant question
  • knowing how travelers make likelihood judgements is important for understanding their choice behavior

• Naïve model
  • people count occurrences and store frequency data in memory – their judgments are unbiased

• However, this is not in line with evidence. Two fundamental biases in human likelihood judgements are well-known (Lichtenstein et al., 1978)
Primary bias

- small probabilities are overestimated and large probabilities are underestimated
- this explains why rare events may have a large impact
Secondary bias

• events that are more vividly imagined are overestimated
• this explains why a salient event such as a plane crash tends to have much more impact than a more common event
• Availability / fluency heuristic
  • first formulated by Tversky and Kahneman (1973)
  • supported by numerous empirical studies

• Tversky and Kahneman (1973)
  • people use a byproduct of memory processes to judge the likelihood of some event
  • that is, the *ease* with which examples of the event can be retrieved from memory is used as criterion
  • the easier examples come to mind the more likely the event is judged to be

• This heuristic explains the primary and secondary biases (Hertwig et al. 2005)
Model

- ACT-R cognitive architecture provides a model of memory encoding and retrieval processes (Anderson et al. 2004)

\[ A_{ik} = \ln \left( \sum_{j \in k} (t_{ij})^d \right) \]

\[ Q_{ik} = \frac{A_{ik}}{\sum_j A_{ij}} \]

- This model explains the primary bias
Model

- Extension of the ACT-R memory model to account for effect of arousal on memory

\[
A_{ik} = \ln\left( \sum_{j \in k} (t_{ij})^{d(S)} \right)
\]

\[
Q_{ik} = \frac{A_{ik}}{\sum_j A_{ij}}
\]

- This model also explains the secondary bias
How do travelers judge degree of satisfaction with choice alternatives?

• This is a relevant question
  • knowing how travelers arrive at satisfaction judgements is important for understanding subjective wellbeing and habitual behavior

• Naïve model
  • decision utility is the same as experienced utility
    ➢ utilities can be derived from choice behavior

• However, Kahneman (2000) points to known biases:
  • neglect of duration of episodes
  • dominance of end outcome of episodes
  • disproportional impact of peak experiences
Model

- Again, the memory model of ACT-R offers a way to describe this process

\[ A_{ij} = \ln\left( (t_{ij})^{d(S)} \right) \]

\[ U_i = \sum_j A_{ij} \cdot U_{ij} \]

- This model explains the disproportional impact of extreme events on satisfaction
What data do we need to test and estimate the models and how can the data be collected?

Data collection

• In-situ measurement of affective experiences of travelers (Ettema et al. 2014)

• Small questionnaire on the smartphone completed on every trip
  • data of the trip (mode, route, purpose, etc.)
  • emotional state of the traveller during the trip (arousal and valence)
  • satisfaction judgment (experienced utility)
What are the implications for policy making and transport modeling?
Implications

• **Policy making - theory stresses:**
  • importance of reliability of transport services on satisfaction and judgement
    – avoid negative peak experiences
  • importance of avoiding losses in the behavior change targeted
    – losses generate negative emotion

• **Transport modeling**
  • the memory-based models of learning and judgement can be incorporated in dynamic travel-demand models
Group decision making
- joint activity choice

A negotiation model of group decision making
# Modeling joint activity choice

<table>
<thead>
<tr>
<th>Standard model</th>
<th>New approach</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interactions between persons within households</td>
<td>Extended to social networks of persons</td>
</tr>
<tr>
<td>Assumes a group utility function</td>
<td>No group utility function, just individual preferences</td>
</tr>
<tr>
<td>Ignores the process of group decision making</td>
<td>Assumes a negotiation process</td>
</tr>
<tr>
<td>Rational model</td>
<td>Bounded rationality – human biases</td>
</tr>
</tbody>
</table>
Background and objective

• Recent work on group decision making in travel behavior research
  • agent-based modeling (Ma et al. 2011, 2012)
  • stated-choice experiments a.o.
    – household location choice (Molin et al. 1999)
    – logistics supply chains (Hensher et al. 2007)
    – household vehicle purchase (Beck et al. 2012)

• This is an emerging field in travel behavior research
  – many aspects

• The purpose of this study (Arentze 2014) is to empirically estimate a model of group decision making
Framework – process model

• Assumptions of the group process
  • persons communicate the preferences for choice options among each other
  • they do proposals and respond to proposals of others until agreement is reached

• Characteristics of the process
  • no group utility function
  • no central controller
  • persons know each others preferences
  • group decision is the result of group interaction
Theory and hypothesis

• When doing proposals or responding to proposals, individuals have to take into account preference differences.

• Findings from bargaining studies in social psychology:
  • Fairness plays an important role.
  • Asymmetry in behavior (Loewenstein et al. 1989):
    - Fairness more important when negotiation is about costs a.o.t rewards.
The social utility function

The social utility person \( k \) assigns to a proposal \( i \)

\[
U_{ik} = \beta_{1k} \cdot Z_{ik} + \beta_{2k} \cdot \sum_{m \neq k} Z_{im} + \beta_{3k} \cdot D(Z_i) 
\]

Own preference value  Preference values of others  Differences preference values across the group

when it is a proposal from someone else

\[
U_{ik} = \beta_{0k} + \beta_{1k} \cdot Z_{ik} + \beta_{2k} \cdot \sum_{m \neq k} Z_{im} + \beta_{3k} \cdot D(Z_i) 
\]

Added constant: basic inclination to follow someone else
Imagine you are planning a joint activity with two friends.

Three options for the activity have been identified.

The preferences in the group are as follows:

<table>
<thead>
<tr>
<th></th>
<th>Activity A</th>
<th>Activity B</th>
<th>Activity C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yourself</td>
<td>9</td>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td>Friend 1</td>
<td>5</td>
<td>9</td>
<td>7</td>
</tr>
<tr>
<td>Friend 2</td>
<td>5</td>
<td>7</td>
<td>9</td>
</tr>
</tbody>
</table>

Which proposal would you do?
- Activity A: Maximizes own outcome
- Activity B: Maximizes group outcome
- Activity C
Joint choice task – doing a proposal

Another example

The preferences in the group are as follows

<table>
<thead>
<tr>
<th>Activity A</th>
<th>Activity B</th>
<th>Activity C</th>
</tr>
</thead>
<tbody>
<tr>
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<td>5</td>
<td>9</td>
</tr>
<tr>
<td>Friend 1</td>
<td>9</td>
<td>5</td>
</tr>
<tr>
<td>Friend 2</td>
<td>5</td>
<td>9</td>
</tr>
</tbody>
</table>

Which proposal would you do?

- **Activity A**
  - Maximizes group and own outcome

- **Activity B**
  - Equal outcomes

- **Activity C**
Joint choice task – variant

This time one of the friends does a proposal

The preferences in the group are as follows

<table>
<thead>
<tr>
<th></th>
<th>Activity A</th>
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<th>Activity C</th>
</tr>
</thead>
<tbody>
<tr>
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<td>9</td>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td>Friend 1</td>
<td>5</td>
<td>9</td>
<td>7</td>
</tr>
<tr>
<td>Friend 2</td>
<td>5</td>
<td>7</td>
<td>9</td>
</tr>
</tbody>
</table>

Friend 1 proposes to do: **Activity B**

What would you do?

- Accept the proposal

Do another proposal, namely

- Activity A
- Activity C
Joint choice task – variant

This time the travel times differ

The travel times for the group are as follows

<table>
<thead>
<tr>
<th></th>
<th>Location A</th>
<th>Location B</th>
<th>Location C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yourself</td>
<td>5</td>
<td>15</td>
<td>25</td>
</tr>
<tr>
<td>Friend 1</td>
<td>5</td>
<td>25</td>
<td>15</td>
</tr>
<tr>
<td>Friend 2</td>
<td>25</td>
<td>15</td>
<td>5</td>
</tr>
</tbody>
</table>

Which proposal would you do?

- Location A
- Location B
- Location C
Sample and data collection

- 315 persons participated
- Random sample from a national panel
- Each person received
  - 8 tasks – 4 x initiating and 4 x responding
- Scenarios
  - Activity versus travel time
  - High versus low consequences
- Outcome tables were varied by an efficient design
## Results – basic MNL model

### Activity

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value ((\beta))</th>
<th>t-value ((\beta))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Self-interest ((\beta_1))</td>
<td>0.532</td>
<td>14.0</td>
</tr>
<tr>
<td>Other ones interest ((\beta_2))</td>
<td>0.319</td>
<td>11.1</td>
</tr>
<tr>
<td>Inequity ((\beta_3))</td>
<td>-1.16</td>
<td>-11.9</td>
</tr>
<tr>
<td>Proposal status ((\beta_0))</td>
<td>0.928</td>
<td>9.21</td>
</tr>
<tr>
<td>Scale - small consequences</td>
<td>1.33</td>
<td>2.15</td>
</tr>
<tr>
<td>Scale - large consequences</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

```
Equity plays a significant role
inequity / self = 2.18
Proposal status plays a significant role
```

### Travel time

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value ((\beta))</th>
<th>t-value ((\beta))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Self-interest ((\beta_1))</td>
<td>-0.063</td>
<td>-9.55</td>
</tr>
<tr>
<td>Other ones interest ((\beta_2))</td>
<td>-0.027</td>
<td>-7.01</td>
</tr>
<tr>
<td>Inequity ((\beta_3))</td>
<td>-0.215</td>
<td>-10.5</td>
</tr>
<tr>
<td>Proposal status ((\beta_0))</td>
<td>1.58</td>
<td>13.0</td>
</tr>
<tr>
<td>Scale - small consequences</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Scale - large consequences</td>
<td>0.608</td>
<td>-4.72</td>
</tr>
</tbody>
</table>

```
Equity has a bigger influence
inequity / self = 3.40
Proposal status has a bigger influence
```
Results – discrete mixture model

### Activity

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Mass point</th>
<th>Value (β)</th>
<th>t-value (β)</th>
<th>Probability (π)</th>
<th>t-value (π)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Self-interest (β₁)</td>
<td>1</td>
<td>1.10</td>
<td>11.3</td>
<td>0.687</td>
<td>10.8</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>0.062</td>
<td>0.74</td>
<td>0.313</td>
<td>4.94</td>
</tr>
<tr>
<td>Other ones interest (β₂)</td>
<td>1</td>
<td>0.718</td>
<td>8.74</td>
<td>0.777</td>
<td>13.8</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>-0.085</td>
<td>-1.27</td>
<td>0.223</td>
<td>3.95</td>
</tr>
<tr>
<td>Inequity (β₃)</td>
<td>1</td>
<td>0.250</td>
<td>0.85</td>
<td>0.288</td>
<td>4.62</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>-2.50</td>
<td>-9.03</td>
<td>0.712</td>
<td>11.4</td>
</tr>
<tr>
<td>Proposal status (β₀)</td>
<td>1</td>
<td>1.17</td>
<td>7.92</td>
<td>0.930</td>
<td>25.7</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>5.80</td>
<td>3.73</td>
<td>0.070</td>
<td>1.94</td>
</tr>
</tbody>
</table>

### Travel time

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Mass point</th>
<th>Value (β)</th>
<th>t-value (β)</th>
<th>Probability (π)</th>
<th>t-value (π)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Self-interest (β₁)</td>
<td>1</td>
<td>-0.020</td>
<td>-1.64</td>
<td>0.525</td>
<td>7.11</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>-0.190</td>
<td>-8.39</td>
<td>0.475</td>
<td>6.43</td>
</tr>
<tr>
<td>Other ones interest (β₂)</td>
<td>1</td>
<td>-0.121</td>
<td>-5.26</td>
<td>0.364</td>
<td>3.46</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>-0.019</td>
<td>-2.11</td>
<td>0.636</td>
<td>6.04</td>
</tr>
<tr>
<td>Inequity (β₃)</td>
<td>1</td>
<td>-0.601</td>
<td>-9.02</td>
<td>0.550</td>
<td>6.74</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>-0.079</td>
<td>-1.80</td>
<td>0.450</td>
<td>5.51</td>
</tr>
<tr>
<td>Proposal status (β₀)</td>
<td>1</td>
<td>8.19</td>
<td>5.95</td>
<td>0.261</td>
<td>5.08</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>1.39</td>
<td>6.98</td>
<td>0.739</td>
<td>14.42</td>
</tr>
</tbody>
</table>

There is considerable heterogeneity
Social styles

Meaningful styles can be defined as particular combinations of parameter mass points

<table>
<thead>
<tr>
<th></th>
<th>Self interest</th>
<th>Others interest</th>
<th>Fairness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Balanced</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Selfish</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Altruistic</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Social</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Rational</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

Identification of styles

- assign each case to the pattern that maximizes the likelihood of the choice observations
Results

- **Balanced style:** self & others & equity
- **Rational style:** self & others
- **Selfish style:** self
- **Social style:** equity, equity & self / others
- **Else:** others; none

**Strong asymmetry**

*Activity*
Balanced style dominates

*Travel time*
Social style dominates
### Style memberships: estimation results MNL model

<table>
<thead>
<tr>
<th>Style</th>
<th>Parameter</th>
<th>Activity</th>
<th></th>
<th>Travel time</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Value</td>
<td>t-value</td>
<td>Value</td>
<td>t-value</td>
</tr>
<tr>
<td>Balanced</td>
<td>Constant</td>
<td>1.67</td>
<td>5.95</td>
<td>-0.762</td>
<td>-2.35</td>
</tr>
<tr>
<td>Rational</td>
<td>Constant</td>
<td>0.074</td>
<td>0.19</td>
<td>-0.819</td>
<td>-1.99</td>
</tr>
<tr>
<td></td>
<td>age &lt; 35 years</td>
<td>0.230</td>
<td></td>
<td>-1.37</td>
<td></td>
</tr>
<tr>
<td></td>
<td>age 35-&lt; 55 years</td>
<td>-1.28</td>
<td>-2.49</td>
<td>0.309</td>
<td>0.69</td>
</tr>
<tr>
<td></td>
<td>age 55+ years</td>
<td>1.05</td>
<td>2.94</td>
<td>1.06</td>
<td>2.49</td>
</tr>
<tr>
<td>Selfish</td>
<td>Constant</td>
<td>-1.10</td>
<td>-2.13</td>
<td>-0.693</td>
<td>-2.19</td>
</tr>
<tr>
<td>Social</td>
<td>Constant</td>
<td>0.847</td>
<td>2.75</td>
<td>1.02</td>
<td>4.69</td>
</tr>
<tr>
<td></td>
<td>Male</td>
<td></td>
<td></td>
<td>-0.541</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td></td>
<td></td>
<td>0.541</td>
<td>3.29</td>
</tr>
<tr>
<td>Else</td>
<td>Constant</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Adjusted rho-square</td>
<td></td>
<td>0.207</td>
<td></td>
<td>0.169</td>
<td></td>
</tr>
</tbody>
</table>

**Older age group more often rational style**

**Females more often social style in case of travel times**
Conclusions

• Considerable heterogeneity in styles
• Group process bias
  • fairness (equity) is important
  • process is important (proposal status)
  • asymmetry costs and rewards
• Implications
  • people favor equity for joint activities / travel
  • e.g., they are willing to travel further when this leads to more equal distribution of travel times
• The new model of joint activity choice takes process bias into account
Future research

• The model can be incorporated in activity-based models to predict joint activity choice

• Simulations must be conducted to explore the properties of the model
  • extent to which it has an impact on outcomes

• It is interesting to see if the model can be validated based on revealed preference data

• The model is basic – extensions in many directions are possibly fruitful
Conclusions - overall

- Bounded rationality is important in
  - Learning & judgment
  - Search & information acquisition
  - Decision making
  - Subjective wellbeing
  - Social life

- Examples of exploring new area were given
  - memory and emotion
  - mental representations
  - negotiation in group decision making
Literature references

Mental representations


Group decision making

Literature references cont’d


Memory and emotion effects
Thank you for your attention

Questions