Modeling route choice using aggregate models

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Agenda

1. Introduction
2. Correlation of alternatives
3. Aggregate route choice
4. Application
5. Conclusion
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Route choice

Identify the route that a traveler would choose to go from the origin (O) to the destination (D).

- Key travel demand model.
- At the core of traffic assignment.
- Off-line and real time services and applications:
  - Decision-aid tools and transportation policies.
  - Real time operations and route guidance.

→ Random utility models
  - Understand, describe and predict route choice behavior.
Challenges

**Operational difficulties**
- Data
- Choice set
- Structural correlation

**Behavioral aspect**
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Correlation of alternatives

Simple example

Assumption: only the length influences the choice

<table>
<thead>
<tr>
<th>Link</th>
<th>Length (m)</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Link 1</td>
<td>10</td>
<td>1/2</td>
</tr>
<tr>
<td>Link 2</td>
<td>10</td>
<td>1/2</td>
</tr>
</tbody>
</table>

Logit probabilities:

- \( P(\text{link}1|\{\text{link}1, \text{link}2\}) = 1/2 \)
- \( P(\text{link}2|\{\text{link}1, \text{link}2\}) = 1/2 \)
Simple example

*Now let’s assume that a new link is added*
Correlation of alternatives

Simple example

What happens to the logit choice probabilities?

Adapted from Vovsha and Bekhor (1998)
Dealing with correlation

1. In the determinist part of the utility.
   - Simple but less realistic.
   - C-logit (Cascetta et al., 1996); Path size logit (Ben-Akiva and Bierlaire, 1999).

2. In the stochastic part of the utility.
   - More realistic but complex.
   - Link nested/ cross nested logit (Vovsha and Bekhor, 1998; Lai and Bierlaire, 2015); Logit kernel (Bekhor et al., 2002; Frejinger and Bierlaire, 2007).
Capturing correlation

The nested logit model
Capturing correlation

*The cross nested logit model*
But what happens when...
Capturing correlation

From logit to CNL the # of parameters to be estimated explodes

\[
P(i|C_n) = \frac{e^{\mu V_{in}}}{\sum_{j \in C_n} e^{\mu V_{jn}}}
\]

\[
P(i|C) = \frac{e^{\mu_m V_i}}{\sum_{j \in C_m} e^{\mu_m V_j}} \frac{\left( \sum_{\ell \in C_m} e^{\mu_m V_{\ell}} \right) ^{\frac{\mu}{\mu_m}}}{\sum_{p=1}^{M} \left( \sum_{\ell \in C_p} e^{\mu_p V_{\ell}} \right) ^{\frac{\mu}{\mu_p}}}
\]

\[
P_n(i) = \sum_{m=1}^{M} \frac{\left( \sum_{j \in C_n} \alpha_{jm}^{\mu_m/\mu} e^{\mu_m V_{jn}} \right) ^{\frac{\mu}{\mu_m}}}{\sum_{p=1}^{M} \left( \sum_{j \in C_n} \alpha_{jp}^{\mu_p/\mu} e^{\mu_p V_{jn}} \right) ^{\frac{\mu}{\mu_p}}} \frac{\alpha_{im}^{\mu_m/\mu} e^{\mu_m V_{in}}}{\sum_{j \in C_n} \alpha_{jm}^{\mu_m/\mu} e^{\mu_m V_{jn}}}
\]
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Considerations

1. Availability of data
2. Needs of the application
   → Route choice at the aggregate level
Towards aggregate route choice

How can we represent a route in a behaviorally realistic way without increasing the model complexity?

→ Model the **strategic** decisions of people instead of the **operational** ones.

★ Mental Representation Item (MRI)
Objective

Specify and apply an aggregate model to a large network with limited data.

1. Description of alternatives based on prominent elements of the network.
2. Less dependent on detailed data.
3. Lower structural model complexity and computational cost.

→ Mental representation item (MRI) model.
→ Challenge: the definition of the simplified structure.

Goals

1. Generalization of the MRI choice model.
   - Conceptual model that is meaningful, operational and useful.
   - Definition of an *abstract graph* that is compatible with the standard specification and estimation procedures.
     - Link additive attributes.
     - Choice set generation; sampling of paths; link-based formulation.
   - Identification of attributes.

2. Application to Québec city.
A trivial example of a MRI model
First step: Outline of the MRI model

Build the image: case dependent

1. Identification of prominent elements of the area of study.
   - **Paths**: major arterials, bridges.
   - **Districts**: the city center(s), areas generating and attracting trips.

2. Identification of their interactions and interdependencies.

3. Decision on the level of aggregation.
   - How long the description *needs* to be?
     Scale and needs of the application.
   - How long the description *can* be?
     Availability and resolution of data.
Second step: Definition of the MRI graph

Structure of the model

\[ G^M = (\mathcal{L}, \mathcal{M}) \sim G = (A, V) \]

1. For each MRI add a node \( m \) in the MRI graph.
2. For each \( O \) and \( D \) zone add a node in the MRI graph.
3. For each pair of nodes in the MRI graph create a link \( \ell \) if a transfer between the nodes is allowed.
4. Associate observations with elements of \( G^M \).
Third step: Specification and estimation

Operational aspects of the model

1. Path-based formulation


2. Link-based formulation: the Recursive Logit (RL) (Fosgerau et al., 2013)

1. Sequential link choice in a dynamic framework.
2. Consistently and efficiently estimated on the full choice set of paths without sampling of alternatives.
3. Equivalent to a multinomial logit.
Overview of the RL model

- At each state $k$ the traveler chooses the next state $a$ that maximizes the sum of the instantaneous utility $u_n(a \mid k)$ and the expected downstream utility $V^d(a)^*$ to the destination $d$.

$$u_n(a \mid k) = v_n(k \mid a) + \mu \varepsilon_n(a).$$

$$P^d_n(a \mid k) = \frac{e^{\frac{1}{\mu} (v_n(a \mid k) + V^d(a))}}{\sum_{a' \in A(k)} e^{\frac{1}{\mu} (v_n(a' \mid k) + V^d(a'))}}.$$

- Output: destination specific link transition probabilities.

- A path $p$ is realized as a sequence of link choices, with probability

$$P^d_n(p \mid U) = \prod_{k=o}^{d-1} P^d_n(a \mid k).$$

* $V^d(a)$ are value functions computed using the Bellman equation.
Fourth step: Addressing correlation

CNL with MRIs

- Each MRI corresponds to a nest.
- An alternative \( r \) belongs to nest \( m \) if MRI \( m \) appears in the sequence \( r \).

Real network example:

- The physical network is composed of \( \sim 7000 \) links that would correspond to \( \sim 7000 \) nests.
- With the MRI approach we could reduce to 6 nests.
Aggregate route choice

The underlying MRI nesting structure
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Dataset

- Québec city.
- Montrajet smartphone application (McGill university)
- GPS trajectories of more around 4000 individuals.
- More than 20000 trips.

- Trip purpose.
- Departure time.

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Québec city
Origin-Destination survey of 2011

Main destination poles

La mobilité des personnes dans la région de Québec (Mars 2015)
Most visited segments
Moobility vs accessibility

- **Arterials**: higher mobility, low degree of access
- **Collectors**: balance between mobility and access
- **Locals**: lower mobility, high degree of access

**Legend**
- Arterial street
- Collector street
- Commercial
- Public

**Source**: Grant Benjamin, “Grand Reductions: 10 Diagrams That Changed City Planning”, The Urbanist, Issue 518, November 2012, SPUR Ideas + Action for a Better City
The $G^M$ of Québec city as a dual graph
Québec city: upper side

**Dual graph**
Québec city: lower side

*Dual graph*
Observed number of links in $G$ vs number of links in $G^M$
Geographical span
Major intersections
Specification of utilities

The instantaneous utility $v(a | k)$ of a link pair is:

$$v(a | k) = \beta_{TravelTime} TT(a) +$$

$$+ \beta_{Upgrade} UP(a | k) + \beta_{Downgrade} DOWN(a | k) +$$

$$+ \beta_{Penalty} Transfer(a)$$

where $Upgrade = 1$ if transfer from primary to highway, $Downgrade = 1$ if transfer from highway to primary, $Penalty = 1$ for all transfers, except those belonging to the same MRI (natural extension), to penalize routes with many transfers.
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Conclusion

1. Simpler model structure.
2. Compatible with route guidance.
3. Specification and imputation of attributes is still an issue.
4. Motivates and can benefit from new data collection approaches.
Legibility

“In the process of way-finding, the strategic link is the environmental image, the generalized mental picture of the exterior physical world that is held by the individual. This image is the product both of immediate sensation and of the memory of past experience, and it is used to interpret information and to guide action. The need to recognize and pattern our surroundings is so crucial, and has such long roots in the past, that this image has wide practical and emotional importance to the individual.”
Thank you!

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