Modeling route choice in Québec city using an aggregate model

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Agenda

1. Introduction
2. Methodology
3. Application
4. Conclusion
Introduction

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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.
Considerations

1. Availability of data
2. Needs of the application
   → Route choice at the aggregate level
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)
→ **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.
Methodology

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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

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

* $V^d(a)$ are value functions computed using the Bellman equation.
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Québec city.

**Montrajet** smartphone application (McGill university)\(^1\)


GPS trajectories of more around 4000 individuals.

More than 20000 trips.

- Trip purpose.
- Departure time.

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\(^1\) Mirando-Moreno L.F., Chung C., Amyot D., Chappon H. (2014), A system for collecting and mapping traffic congestion in a network using GPS smartphones from regular drivers.
Québec city
Mobility vs accessibility

Arterials
higher mobility
low degree of access

Collectors
balance between mobility and access

Locals
lower mobility
high degree of access

Schematic of a Portion of an Urban Street Network

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
Most visited segments
Origin-Destination survey of 2011

Main destination poles

La mobilité des personnes dans la région de Québec (Mars 2015)
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:

$$v(a | k) = \beta_{Travel\,Time} TT(a) +$$

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

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

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.
Results

- Could not reach a solution.
- Many alternative routes and instantaneous utilities $\sim 0 \rightarrow$ expected utility is positive.
  - By definition the deterministic utility is negative but the error terms might be positive.
- All zones have access to all MRIs with some extra utility $\rightarrow$ might have created some artifacts.
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Conclusion

1. I am an *i* person.
2. Simpler model structure.
3. Compatible with route guidance.
4. Specification and imputation of attributes is still an issue.
5. Motivates and can benefit from new data collection approaches.
Future work

1. Attributes for the abstract graph and ways to derive them.
2. Application to more cities.
3. Extension and application to macroscopic traffic assignment.
“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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Schematic of zones
Origins and destinations in the dataset
2321 observed segments