A route choice model suitable for traffic simulation

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Outline

- Route choice modelling in traffic simulation
  - Subnetwork approach
    - Methodology
    - Example
  - Empirical results
    - Borlänge GPS data set
    - Estimation results
    - Forecasting results
- Conclusion and future work
Route choice modelling is critical in traffic simulation.

Models need to meet the following criteria:
- Applicable to real size networks
- Capture correlation among alternatives
- Use available data

C-Logit and Path Size Logit models most commonly used in traffic simulation.

Idea: Multinomial Logit model with deterministic correction of the utility for overlapping paths.
Route Choice and Traffic Simulation

- C-Logit (Cascetta et al., 1996)
  - Several formulations but no guidance on which to use
  - Path Size Logit outperforms C-Logit (Ramming, 2001)

- Path Size Logit (Ben-Akiva and Bierlaire, 1999)
  - Theoretical foundation
  - Original formulation should be used (Frejinger and Bierlaire, 2006)
Route Choice Models

In addition to Path Size Logit (PSL) and C-Logit, few models capturing correlation among alternatives have been used for real size route choice analysis:

- Link-Nested Logit (Vovsha and Bekhor, 1998)
  Difficult to define nesting parameters, outperformed by PSL (Ramming, 2001)
- Logit Kernel model adapted to route choice situation (Bekhor et al., 2002)
  Large number of random terms (one per link in a choice set)

In general, too heavy for traffic simulation.
Subnetworks

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- Which are the behaviourally important decisions?
- Our hypothesis: choice of specific parts of the network (e.g. main roads, city centre)
- Concept: subnetwork
Subnetworks

- Subnetwork approach designed to be behaviourally realistic and convenient for the analyst
- Subnetwork component is a set of links corresponding to a part of the network which can be easily labelled
- Paths sharing a subnetwork component are assumed to be correlated even if they are not physically overlapping
Subnetworks - Methodology

Factor analytic specification of an error component model (based on model presented in Bekhor et al., 2002)

\[ U_n = \beta^T X_n + F_n T \zeta_n + \nu_n \]

- \( F_n \) \((J \times Q)\): factor loadings matrix
- \((f_n)_{i}q = \sqrt{l_{niq}}\)
- \( T_{(Q \times Q)} = \text{diag} (\sigma_1, \sigma_2, \ldots, \sigma_Q)\)
- \( \zeta_n \) \((Q \times 1)\): vector of i.i.d. N(0,1) variates
- \( \nu \) \((J \times 1)\): vector of i.i.d. Extreme Value distributed variates
Subnetworks - Example

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Subnetworks - Example

\[ U_1 = \beta^T X_1 + \sqrt{l_{1a}} \sigma_a \zeta_a + \sqrt{l_{1b}} \sigma_b \zeta_b + \nu_1 \]
\[ U_2 = \beta^T X_2 + \sqrt{l_{2a}} \sigma_a \zeta_a + \nu_2 \]
\[ U_3 = \beta^T X_3 + \sqrt{l_{3b}} \sigma_b \zeta_b + \nu_3 \]

\[ F T T^T F^T = \begin{bmatrix} l_{1a} \sigma_a^2 + l_{1b} \sigma_b^2 & \sqrt{l_{1a}} \sqrt{l_{2a}} \sigma_a^2 & \sqrt{l_{1b}} \sqrt{l_{3b}} \sigma_b^2 \\ \sqrt{l_{1a}} \sqrt{l_{2a}} \sigma_a^2 & l_{2a} \sigma_a^2 & 0 \\ \sqrt{l_{3b}} \sqrt{l_{1b}} \sigma_b^2 & 0 & l_{3b} \sigma_b^2 \end{bmatrix} \]
Empirical Results

- The approach has been tested on two datasets: Boston (Ramming, 2001) and Boränge
- Deterministic choice set generation
  - Link elimination
- **GPS data** from 24 individuals
  - 2978 observations, 2179 origin-destination pairs
- Borlänge network
  - 3077 nodes and 7459 links
- **BIOGEME** (biogeme.epfl.ch, Bierlaire, 2003) has been used for all model estimations
# Subnetwork Components

<table>
<thead>
<tr>
<th></th>
<th>R.50 S</th>
<th>R.50 N</th>
<th>R.70 S</th>
<th>R.70 N</th>
<th>R.C.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Component length [m]</td>
<td>5255</td>
<td>4966</td>
<td>11362</td>
<td>7028</td>
<td>1733</td>
</tr>
<tr>
<td>Nb. of Observations</td>
<td>173</td>
<td>153</td>
<td>261</td>
<td>366</td>
<td>209</td>
</tr>
<tr>
<td>Weighted Nb. of</td>
<td>36</td>
<td>88</td>
<td>65</td>
<td>73</td>
<td>116</td>
</tr>
<tr>
<td>Observations ($N_q$)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\[ N_q = \sum_{o \in O} \frac{l_{oq}}{L_q} \]
Model Specifications

- Six different models: MNL, PSL, EC₁, EC’₁, EC₂ and EC’₂
- EC₁ and EC’₁ have a simplified correlation structure
- EC’₁ and EC’₂ do not include a Path Size attribute
- Deterministic part of the utility

\[ V_i = \beta_{PS} \ln(PS_i) + \beta_{EstimatedTime} EstimatedTime_i + \beta_{NbSpeedBumps} NbSpeedBumps_i + \beta_{NbLeftTurns} NbLeftTurns_i + \beta_{AvgLinkLength} AvgLinkLength_i \]
Parameter estimates for explanatory variables are stable across the different models.

Path size parameter estimates:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>PSL</th>
<th>EC₁</th>
<th>EC₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>Path Size</td>
<td>-0.28</td>
<td>-0.49</td>
<td>-0.53</td>
</tr>
<tr>
<td>Scaled estimate</td>
<td>-0.33</td>
<td>-0.53</td>
<td>-0.56</td>
</tr>
<tr>
<td>Rob. T-test 0</td>
<td>-4.05</td>
<td>-5.61</td>
<td>-5.91</td>
</tr>
</tbody>
</table>

All covariance parameters estimates in the different models are significant except the one associated with R.50 S.
## Estimation Results

<table>
<thead>
<tr>
<th>Model</th>
<th>Nb. σ Estimates</th>
<th>Nb. Estimated Parameters</th>
<th>Final L-L</th>
<th>Adjusted Rho-Square</th>
</tr>
</thead>
<tbody>
<tr>
<td>MNL</td>
<td>-</td>
<td>12</td>
<td>-4186.07</td>
<td>0.152</td>
</tr>
<tr>
<td>PSL</td>
<td>-</td>
<td>13</td>
<td>-4174.72</td>
<td>0.154</td>
</tr>
<tr>
<td>EC₁</td>
<td>1</td>
<td>14</td>
<td>-4142.40</td>
<td>0.161</td>
</tr>
<tr>
<td>EC₁'</td>
<td>1</td>
<td>13</td>
<td>-4165.59</td>
<td>0.156</td>
</tr>
<tr>
<td>EC₂</td>
<td>5</td>
<td>18</td>
<td>-4136.92</td>
<td>0.161</td>
</tr>
<tr>
<td>EC₂'</td>
<td>5</td>
<td>17</td>
<td>-4162.74</td>
<td>0.156</td>
</tr>
<tr>
<td>EC₃</td>
<td>5</td>
<td>18</td>
<td>-4109.73</td>
<td>0.166</td>
</tr>
</tbody>
</table>

1000 pseudo-random draws for Maximum Simulated Likelihood estimation

2978 observations

Null log likelihood: -4951.11

BIOGEME (biogeme.epfl.ch) has been used for all model estimations.
Forecasting Results

- Comparison of the different models in terms of their performance of predicting choice probabilities
- Five subsamples of the dataset
  - Observations corresponding to 80% of the origin destination pairs (randomly chosen) are used for estimating the models
  - The models are applied on the observations corresponding to the other 20% of the origin destination pairs
- Comparison of final log-likelihood values
Forecasting Results

- Same specification of deterministic utility function for all models
- Same interpretation of these models as for those estimated on the complete dataset
- Coefficient and covariance parameter values are stable across models
Forecasting Results

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Models based on subnetworks are designed for route choice modelling of realistic size.

Correlation on subnetwork is explicitly captured within a factor analytic specification of an Error Component model.

Estimation and prediction results clearly shows the superiority of the Error Component models compared to PSL and MNL.
The subnetwork approach is flexible and the trade-off between complexity and behavioural realism can be controlled by the analyst.

Paper to appear in Transportation Research Part B
E. Frejinger, M. Bierlaire, Capturing correlation with subnetworks in route choice models, Transportation Research Part B (2006), doi:10.1016/j.trb.2006.06.003
Future work

- Analysis of the sensitivity of the results regarding the definition of the subnetwork
- More validity tests on other datasets and larger networks
- Influence of choice set generation algorithm