Modelling travel behaviour with OR tools: From microsimulation to fixed point problems

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November 2005
Should we expand the transport system further?
“Road” - Switzerland (1950)
“Road” - Switzerland (2000)
Accessibility of Swiss districts since 1850

Without own accessibility of the districts
Scaling the travel time matrix

Scale of the problem:

- 3000*3000 travel times (along shortest time paths)

Solution:

- Two stage scaling with subsamples
- Smoothing of remaining points

Carosio, Dolci and Scherer, 2005
What do we want to pay for it?
Willingness to pay for reduction of free-flow travel time

Axhausen, Hess, König, Bierlaire, Bates and Abay, 2006
Willingness to pay for reduction of congested travel time

Axhausen, Hess, König, Bierlaire, Bates and Abay, 2006
Estimating the parameter set (1)

The standard MNL is:

\[ P_{ni} = \frac{e^{V_{ni}}}{\sum_j e^{V_{nj}}} \]

But here:

\[ V_{ni} = K \beta_c \left( \frac{I_n}{I} \right)^{\epsilon_i} \left( \frac{D_n}{D} \right)^{\epsilon_D} c_{ni} K \]
Estimating the parameter set (2)

Allowing for taste variation we obtain:

\[ P_{ni} = \int L_{ni}(\beta)\phi(\beta \mid \theta)d\beta \]

Which requires:

\[ \max_\theta SLL^R(\theta) = \max_\theta \frac{1}{N} \sum_{n=1}^{N} \ln SP^R_{ni_n}(\theta) \]

\[ SP^R_{ni_n} = \frac{1}{R} \sum_{r=1}^{R} L_{ni_n}(\beta_r, \theta) \]
Where do we travel today?
Dimensions of travel behaviour

Out-of-home time \((0; A > 0)\)

Allocation of out-of-home time to travel and activities
Sequence and time of the activities (and therefore travel)
(Persons travelling along and sharing in the activities)

Destination

Mode
Route (Connection)

(Expenditure for travel and activities)
User equilibrium [by road type]
User equilibrium [by distance class]

red = < 50 km
blue = 50-100 km
green = >100 km
## UE differences between 3% and 0.01% relative deviation

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## Computational costs of UE accuracy

<table>
<thead>
<tr>
<th>Relative deviation in equilibrium</th>
<th>Computing time [High end PC]</th>
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<tr>
<td>3%</td>
<td>½ h</td>
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<tr>
<td>1%</td>
<td>2 h</td>
</tr>
<tr>
<td>0.1%</td>
<td>4 h</td>
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<tr>
<td>0.01%</td>
<td>8 h</td>
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<tr>
<td>0.001%</td>
<td>16 h</td>
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Difference between SUE and UE (3% relative deviation)

Schüssler, 2005
Complete fixed point system

The complete aggregate model system is:

\[ k'_{tsmgz} = k[q'_{tsmgz}(k'_{tsmgz}, B_{igz}), A_{tsmz}] \]

- \( k' \): Estimated generalised costs
- \( q \): Estimated demand
- \( A \): Supply (slots, services, opportunities)
- \( B \): Population (natural and legal persons)
- \( t \): Time of day
- \( i \): Origin
- \( j \): Destination
- \( r \): Route
- \( g \): Group
- \( m \): Mode
- \( z \): Year
Challenges

- Estimation of the underlying choice models
- Speed of computation
- Interaction between persons
- Choice of activity schedule
What type of urban space is likely?
Commuter sheds of biggest Swiss cities since 1970
Integrated land use and transport models

ΔBevölkerung
ΔKonjunktur
ΔPreise
ΔKlima

Verkehrs- und Flächen nutzungs model

Umwelt-Wirkungen/ Massen-flüsse

Raum/Massen Erzeugung & Optimierung

GIS³

Konzepte Landschaft
Konzepte Städtebau
Infrastrukturen
Regulation/Verfassung
Nachhaltigkeit
Where to provide fuel?
Current Swiss petrol stations
Problem (Simulated Annealing)

Find

\[ \min SC \]

with

\[ SC : \text{Social costs (construction, operation, CO}_2 \text{reduction, car purchase costs, additional gas station profits)} \]

s.t.

- Additional 300 compressed natural gas stations among the exiting locations
- Customer choice of gas stations
- Acquisition of additional CNG cars
The next 300 CNG stations
How much city does one need?
Chosen locations during a six-week period

Women, 24
Full-time
Single
216 trips / 6 weeks
Measurement approaches

Parametric:
- 95% confidence ellipse (assumption of normality)
- 95% inclusion geometries

Semiparametric:
- Positive probabilities of presence (Kernel density distributions)
- Shortest path network

Non-parametric
- Observed path networks
Inclusion geometries

Find:

$$\min A_i(\beta_{i1} \ldots \beta_{in})$$

s.t.

Area $A_i$ covering $p\%$ of all observed points

with:

i : Type of geometry (Ellipse, bean, Cassini ...)

p : Share, e.g. 95%
Examples of inclusion geometries

- Ellipse
- Superellipse 1
- Superellipse 2
- Bean
- Cassini

Vaze, Schönfelder and Axhausen, 2005
Shortest path network

University

Home location
Distribution of shortest path networks
Map matching

Problem:

Optimally match $3 \times 10^6$ GPS observations (in less then 1 min)

s.t.

- Unknown errors of the GPS observations
- Gaps in the GPS stream
- Known, but not localised errors in the map representation
## Algorithm of Marchal

<table>
<thead>
<tr>
<th>N</th>
<th>Accuracy [m/pt]</th>
<th>Accuracy [%]</th>
<th>CPU [s]</th>
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<tr>
<td>100</td>
<td>10.3</td>
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N: Number of branches; H(igh) and l(ow) quality map
Can we model agents/groups of agents?
The individual in a dynamic social context

- Personal worlds of others
- Social capital: stock of joint abilities, shared histories and commitments
- Personal world
- Projects
- Household locations
- Social network geography
- Mobility tools
- Biography
- Learning
Modelling the personal daily dynamics

Activity repertoire (t) → Activity calendar (t)

Scheduling

Physiological needs
Commitments
Desires
Pending activities

Activity schedule (t) → Rescheduling, Execution

Unexecuted activities

Updates, Innovations

Networks, Opportunities

Activity repertoire (t+1) → Mental map (t+1)

Mental map (t)
Scheduling

Activity calendar (t)
Activity schedule (t)
Mental map (t)

Network, Opportunities
Problem

Problem:

\[ \max F = HUF = \sum_{m} U_m \]

with

\[ U_m = \sum_{i} U_{\text{total},i} \]

\[ U_{\text{total},i} = U_{\text{dur},i} - c_{\text{travel},i} - c_{\text{wait},i} - c_{\text{late},i} - c_{\text{early},i} \]

s.t.

- Time windows
- Minimum times
- Resource constraints (car, time)
Approach: Genetic Algorithm (GA)

Large (partially discrete) solution space:

- 5 variables / activity (participation, timing, duration, location, mode)
- ~ 8 activities / agent
- 2-4 agents / household
- ~ 80-160 variables / household schedule

Large number of agents:

\[10^6\] for Zürich
GA performance ~ 3 seconds/agent
Challenge

Performance of total system for $10^6$ agents:

Relaxation of (~ 50 iterations)

- Scheduling of agents (3 * $10^5$ sec)
- Network simulation (3 * $10^2$ sec)
- I/O (10^2 sec)

-> Month of computing time
References


Marchal, F. J. Hackney and K.W. Axhausen (Forthcoming) Efficient map-matching of large GPS data sets - Tests on a speed monitoring experiment in Zurich, to appear in Transportation Research Record


Hypothesis

- **Economies of scale**
- **Economies of scope**

**Activity**
- + Tours
- + t/pkm
- + vkm

**Market size**
- - k

**GDP**
- + Fleet comfort
- - slots

**Energy costs**
- + Elasticity > 0
- - Elasticity < 0

- + Elasticity > 0 Slots: possibilities to move goods or people
- - Elasticity < 0 For a given infrastructure and commercial and private fleet