Preferred citation style

Accessibility, mobility tools (and some LUTI models)

KW Axhausen

IVT
ETH
Zürich

November 2016
Acknowledgments

A Loder for the mobility tool ownership work

G Sarlas and R Fuhrer for the work on Swiss wages/productivity

L Sun for the big data analysis

FCL M8 for the SG MATSim model

B Bodenmann for FALc
Current problems in Singapore
Bus speeds in Singapore by time of day (2012)
Headways along a bus line in Singapore (2012)
What type of model would be enough?
A model of Singapore’s travel demand and traffic
Would this be enough?

- $\text{tax}_{\text{income}}$
- $\text{tax}_{\text{car}}$
- $\text{tax}_{\text{GA}}$
- $\text{fee}_{\text{car}}$
- $\text{fee}_{\text{PT}}$
- $\text{budget}_{\text{transport}}$

Income $\rightarrow$ Productivity

Number $\rightarrow$ Pop, Firm

$\text{Acc}_{\text{car}}$, $\text{Acc}_{\text{bus}}$, $\text{Acc}_{\text{rail}}$

$\text{mMFD}$

$\text{q}_{\text{car}}$, $\text{q}_{\text{bus}}$, $\text{q}_{\text{rail}}$

$\text{n}_{\text{car}}$, $\text{n}_{\text{GA}}$

$\%\text{cap}_{\text{car}}$, $\%\text{cap}_{\text{bus}}$, $\%\text{cap}_{\text{rail}}$

$\text{v}_{\text{car}}$, $\text{v}_{\text{bus}}$, $\text{v}_{\text{rail}}$

$\text{income}$

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What do we know?
Access and productivity: Switzerland

Income \rightarrow Productivity

Acc_{car}
Acc_{bus}
Acc_{rail}
Population accessibility by public transport: 2010

Axhausen et al., 2015

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Income levels: 2010

Grey: less than 20 observations
Pink to purple: Low to high wages
## Spatial error model – (some variables not shown)

<table>
<thead>
<tr>
<th></th>
<th>Estimate</th>
<th>Sig.</th>
<th>Estimate</th>
<th>Sig.</th>
<th>Estimate</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Y: Ln mean salary</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intercept</td>
<td>6.43***</td>
<td></td>
<td>7.07***</td>
<td></td>
<td>6.89***</td>
<td></td>
</tr>
<tr>
<td><strong>Ln car accessibility</strong></td>
<td>0.01**</td>
<td></td>
<td>0.02***</td>
<td></td>
<td>0.01**</td>
<td></td>
</tr>
<tr>
<td><strong>Ln public transport accessibility</strong></td>
<td>0.01**</td>
<td></td>
<td>0.01***</td>
<td></td>
<td>0.01*</td>
<td></td>
</tr>
<tr>
<td><strong>Ln number of local employed</strong></td>
<td>0.02***</td>
<td></td>
<td>0.01***</td>
<td></td>
<td>0.01***</td>
<td></td>
</tr>
<tr>
<td>From outside Switzerland</td>
<td>-0.11***</td>
<td></td>
<td>-0.09***</td>
<td></td>
<td>-0.09***</td>
<td></td>
</tr>
<tr>
<td><strong>Average duration in-post</strong></td>
<td>0.00*</td>
<td></td>
<td>0.01***</td>
<td></td>
<td>0.01***</td>
<td></td>
</tr>
<tr>
<td><strong>Ln average age</strong></td>
<td>0.36***</td>
<td></td>
<td>0.24***</td>
<td></td>
<td>0.32***</td>
<td></td>
</tr>
<tr>
<td>Men</td>
<td>0.17***</td>
<td></td>
<td>0.07***</td>
<td></td>
<td>0.13***</td>
<td></td>
</tr>
<tr>
<td><strong>lamda parameter</strong></td>
<td>0.33***</td>
<td></td>
<td>0.41***</td>
<td></td>
<td>0.40***</td>
<td></td>
</tr>
<tr>
<td>Nagelkerke pseudo-R-squared</td>
<td>0.693</td>
<td></td>
<td>0.665</td>
<td></td>
<td>0.623</td>
<td></td>
</tr>
<tr>
<td># observations</td>
<td>1448</td>
<td></td>
<td>2298</td>
<td></td>
<td>2229</td>
<td></td>
</tr>
</tbody>
</table>

Axhausen et al., 2015
Accessibility and mobility tools: Swiss case
Accessibility and car ownership in Switzerland

![Graph showing the relationship between household income and mean car and motorcycle ownership per licence, with different quintiles represented by distinct lines. The x-axis represents household income in CHF, and the y-axis represents mean car and motorcycle ownership per licence.]
Switzerland: general accessibility
Switzerland: Probabilities by general accessibility

Univariate probabilities

Joint probabilities

Pr(Car)  Pr(Ticket)  Pr(GA)

Pr(Car & ticket)  Pr(None)
Switzerland: Probabilities by log of income

Univariate probabilities

Joint probabilities
Switzerland: Conditional probabilities by log of income

- $\Pr(\text{Ticket} \mid \text{Car})$
- $\Pr(\text{Car} \mid \text{Ticket})$
- $\Pr(\text{GA} \mid \text{Car})$
- $\Pr(\text{Car} \mid \text{GA})$
Mobility tools and use: Swiss case
Travel, car and season-ticket ownership (CH, 1984-2010)

- Trips with motorized vehicles/day
- Public transport trips/day

Mikrozensus Schweiz 1984
Mikrozensus Schweiz 1989
Mikrozensus Schweiz 1994
Mikrozensus Schweiz 2000
Mikrozensus Schweiz 2005
Mikrozensus Schweiz 2010

Vehicle and season ticket
No vehicle, but season ticket
Vehicle, but no season ticket
Neither

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Fleet size and speeds
Macroscopic fundamental diagram MFD (Yokohama)
Fleet size and speeds

\[ q_{\text{car}} \rightarrow \text{mMFD} \]

\[ q_{\text{bus}} \]

\[ q_{\text{rail}} \]

\[ v_{\text{car}} \rightarrow v_{\text{bus}} \rightarrow v_{\text{rail}} \]
3d MFD (Zürich, FCD & loops) City centre
3d MFD (Zürich, FCD & loops) city centre

- Transit vehicle density [veh/km]
- Car density [veh/km]
- Vehicle flow [veh/h]
3d MFD (Zürich, FCD & loops) city centre - max speed

![Graph showing average speed vs. share of transit users for different pax/km ratios (20, 50, and 100 pax/km)]
Our LUTI experience
Our LUTI experience

- Two large projects:
  - ZUK – Zukunft urbaner Kulturlandschaften (ETH-funded)
  - SustainCity (7th Framework funded)

- Implementation of a parcel-fine UrbanSim (with MATSim)
  - Set up of a (semi-)automatic data pipeline

- Estimation of the necessary models, e.g.
  - Hedonics (including urban morphology)
  - Land-use change models
  - Residential choice (including vicinity of core social network and work place location)

- Labour market interaction still missing (wages as a function of competition)
Our LUTI experience

• My conclusions:
  • Too wide an intellectual span for one chair without a second permanent colleague/staff member
  • Need for a short-cut transport model
  • Too fine a resolution for many questions
  • Focus on choice models directly related to movement (long and short term)
  • Focus on direct demand models
Our LUTI experience translated
Our LUTI experience translated

• Much lower resolution:
  • Municipalities @ 2500 inhabitants on average
  • Land use from existing and projected numbers/plans

• Focus on population synthesis and updating

• Transport interfaces to
  • aggregate national model
  • Native spatial regression model of speeds & shortest paths

• Future issues:
  • Improved modelling of land prices/rents
  • Improved modelling of wages/incomes
FALc: St. Gall Projects

Neubauprojekte Raum St. Gallen
- Siedlungsgebiet
- Gemeinden GG25

Autobahnen und Autostrassen
- Autobahnen und Autostrassen
- Neubauprojekte Raum St. Gallen

Autobahnanschlüsse
- 0
- 1

(Various data sources mentioned at the bottom of the page)
FALC: St. Gall simulated impact residents (10 years later)

Neubauprojekte Raum St. Gallen

Einfluss auf die Einwohner [Personen]

-205.4 - -100
-100 - -50
-50 - -30
-30 - 30
30 - 50
50 - 100
100 - 535.4
Siedlungsgebiet

Autobahnen und Autostrassen

Autobahnen und Autostrassen
Neubauprojekte Raum St. Gallen

Autobahnanschlüsse

0
1

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OpenStreetMap © OpenStreetMap contributors (OSMF, 2015); Gemeinden GG25 © Bundesamt für Landestopographie (2015); Siedlungsgebiet (Stand 2012) © Kantonale Raumplanungsfachstellen, INFOPLAN-ARE (2015)
What next?
What next?

• Close knowledge gaps for Switzerland
  • Budget allocation process
  • Budget capacity link

• Replicate results beyond Switzerland

• Add estimates of externalities

• Formulate a closed form optimisation model
  • For desired speed (accessibility) level
  • For welfare maximisation
What next?

- For MATSim
  - Modelling expenditures and quality/price/social worth trade-offs
  - Modelling bargaining in social networks
  - ‘Predicting’ social network structures
- Better integration with land use and labour market models
Questions? See also [www.ivt.ethz.ch](http://www.ivt.ethz.ch) and [TUM 2016](http://www.ivt.ethz.ch/TUM2016).


Appendix
Model formulation 1/2

Choice environment

<table>
<thead>
<tr>
<th>Case</th>
<th>Choice</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>None</td>
<td>( P_1 = \Phi_2(-x_1\beta_1; -x_2\beta_2; P_2) )</td>
</tr>
<tr>
<td>2</td>
<td>Car &amp; no ticket</td>
<td>( P_2 = \Phi_2(-x_1\beta_1; x_2\beta_2; P_2) )</td>
</tr>
<tr>
<td>3</td>
<td>Car &amp; local ticket</td>
<td>( P_3 = \Phi_3(x_1\beta_1; x_2\beta_2; -x_3\beta_3; P_3) )</td>
</tr>
<tr>
<td>4</td>
<td>Car &amp; GA</td>
<td>( P_4 = \Phi_3(x_1\beta_1; x_2\beta_2; x_3\beta_3; P_3) )</td>
</tr>
<tr>
<td>5</td>
<td>No car &amp; local ticket</td>
<td>( P_4 = \Phi_3(x_1\beta_1; -x_2\beta_2; -x_3\beta_3; P_3) )</td>
</tr>
<tr>
<td>6</td>
<td>No car &amp; GA</td>
<td>( P_5 = \Phi_3(x_1\beta_1; -x_2\beta_2; x_3\beta_3; P_3) )</td>
</tr>
</tbody>
</table>

Likelihood function

\[
\mathcal{L}(\alpha) = \delta \int_{x_{\text{low}}}^{x_{\text{up}}} \int \int \phi_3(\beta_1 \hat{x}_1, \beta_2 \hat{x}_2, \beta_3 \hat{x}_3; P_3) d\hat{x} + (1 - \delta) \int_{x_{\text{low}}}^{x_{\text{up}}} \int \int \phi_2(\beta_1 \hat{x}_1, \beta_2 \hat{x}_2; P_2) d\hat{x}
\]

Estimation method:
- Maximum simulated likelihood in Stata using Newton Raphson technique
- Using draws to compute the integral
Model formulation 2/2

- $\delta$: Sample selection dummy, equal to 1 if observation holds season ticket
- $\Phi_n$: N-dimensional cumulative distribution function of the normal distribution
- $\phi_n$: N-dimensional probability density function of the normal distribution
- $\beta$: Parameters of the model
- $\Sigma$: Symmetric correlation matrix with typical elements $\rho_{ij}$ and $\rho_{ii} = 1$. The same correlations appear in both $\Sigma_2$ and $\Sigma_3$ by using their Cholesky decomposition and estimating the Cholesky factors in the model
- $\alpha$: Parameter vector to be estimated that contains all $\beta$ and Cholesky factors of $\Sigma$
- $x_{\text{up},\text{low}}$: Upper and lower limits of integration domain, determined by values of each observation
### Switzerland: Ownership models (1/2)

<table>
<thead>
<tr>
<th></th>
<th>Season-ticket owner</th>
<th>Car available</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>-0.059</td>
<td>***</td>
</tr>
<tr>
<td>Age squared</td>
<td>0.052</td>
<td>***</td>
</tr>
<tr>
<td>Male</td>
<td>-0.132</td>
<td>***</td>
</tr>
<tr>
<td>Working</td>
<td>0.066</td>
<td>***</td>
</tr>
<tr>
<td>University level education</td>
<td>0.146</td>
<td>***</td>
</tr>
<tr>
<td>Log of monthly household income</td>
<td>0.075</td>
<td>***</td>
</tr>
<tr>
<td>Center of agglomeration</td>
<td>0.132</td>
<td>***</td>
</tr>
</tbody>
</table>
| Constant       | 0.052               | -6.039        | ***

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### Switzerland: Ownership models (2/2)

<table>
<thead>
<tr>
<th></th>
<th>Season-ticket owner</th>
<th>Car available</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Local access to public transport: E</td>
<td>-0.474 ***</td>
<td>0.505 ***</td>
</tr>
<tr>
<td>Local access to public transport: D</td>
<td>-0.348 ***</td>
<td>0.384 ***</td>
</tr>
<tr>
<td>Local access to public transport: C</td>
<td>-0.253 ***</td>
<td>0.286 ***</td>
</tr>
<tr>
<td>Local access to public transport: B</td>
<td>-0.097 ***</td>
<td>0.154 ***</td>
</tr>
<tr>
<td>General accessibility</td>
<td>0.089 ***</td>
<td>-0.028 ***</td>
</tr>
<tr>
<td>Surplus public transport acc.</td>
<td>-0.005 ***</td>
<td>-0.066 ***</td>
</tr>
<tr>
<td>Surplus workplace accessibility</td>
<td>0.729 ***</td>
<td>-0.527 ***</td>
</tr>
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</table>

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## Switzerland: GA given season ticket (2/2)

<table>
<thead>
<tr>
<th></th>
<th>General abonnement</th>
<th></th>
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</thead>
<tbody>
<tr>
<td>Secondary residence</td>
<td>0.302</td>
<td>***</td>
</tr>
<tr>
<td>Log of monthly household income</td>
<td>0.128</td>
<td>***</td>
</tr>
<tr>
<td>Self-reported distance [1000km]</td>
<td>0.005</td>
<td>***</td>
</tr>
<tr>
<td>Constant</td>
<td>-2.188</td>
<td>***</td>
</tr>
</tbody>
</table>

### Error correlations

<table>
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<tr>
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<th>GA</th>
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<tbody>
<tr>
<td>Season ticket</td>
<td>-0.44</td>
<td>0.62</td>
</tr>
<tr>
<td>Car available</td>
<td>-0.24</td>
<td></td>
</tr>
</tbody>
</table>