Preferred citation style

Engineering growing networks: Some ideas

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IVT
ETH
Zürich

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Acknowledgements

- Boris Jäggi
- Alejandro Marmolejo
- Basil Vitins
- Claude Weis
Engineering is

= Analysis

+ Design

+ Optimisation

+ Talk to convince

+ Implementation

+ Operation
Engineering is

= Analysis
  e.g. Understanding traffic growth
+ Design
  e.g. Developing better guidelines
+ Optimisation
  e.g. Making better informed choices
+ Talk to convince
+ Implementation
+ Operation
A brief detour: IVT
A brief detour: IVT about 45 researchers

Travel and spatial behaviour
Demand modelling,
Cost-benefit analysis

Public transport

Network design
Supply planning

Production planning
Infrastructure operations

Operations/Safety

Individual transport

Network design
Infrastructure operations

Traffic engineering
Traffic safety

Physical design, project management, maintenance
Understanding traffic growth
Travel demand: km/Head (1950 – 2005)

CH: Drivers of traffic growth: BITRE, Report 128
Drivers of traffic growth

\[
\text{VKT} = \frac{\text{AVKT}}{\text{Capita}} \times \text{Pop} \\
= \frac{\text{AVKT}}{\text{Car}} \times \frac{\text{Cars}}{\text{Capita}} \times \text{Pop} \\
= \frac{\text{AVKT}}{\text{Car}} \times \frac{\text{Cars}}{\text{Lic}} \times \frac{\text{Lic}}{\text{Capita}} \times \text{Pop} \\
= 365 \times \frac{\text{Act}}{\text{Day}} \times \frac{\text{Trip}}{\text{Act}} \times \frac{\text{KT}}{\text{Act}} \times \text{Car\%} \\
\times \frac{\text{Cars}}{\text{Lic}} \times \frac{\text{Lic}}{\text{Capita}} \times \text{Pop} \\
= 365 \times \frac{\text{Act(X)}}{\text{Day}} \times \frac{\text{Trip}}{\text{Act}} \times \frac{\text{KT(Car, X, I)}}{\text{Act(X)}} \times \text{Car\%(Car, X, I)} \\
\times \frac{\text{Cars(X)}}{\text{Lic}} \times \frac{\text{Lic(X, I)}}{\text{Capita}} \times \text{Pop(I, Y)}
\]
Driving licences
CH: Driving licence holding by gender

[Graph showing driving license ownership by gender and average cohort age for different decades from 1910 to 2010.]
CH: Driving licence holding by location (5 year cohorts)
CH: Car always available by income tercile

Average Cohort Age [Years]

Car Availability [%]
Daily number of activities
CH: Number of activities: All purposes

Number of Activities vs. Average Cohort Age [Years]

- Number of activities before 1910!
- Number of activities between 1910-1919:
- Number of activities between 1920-1929:
- Number of activities between 1930-1939:
- Number of activities between 1940-1949:
- Number of activities between 1950-1959:
- Number of activities between 1960-1969:
- Number of activities after 1969:

Note: The graph shows the trend of average cohort age across different decades, indicating the number of activities per cohort age group.
CH: Daily number of trips
Durations and distances travelled
CH: Daily duration travelled

Average Cohort Age [Years]

Sum of daily trips' durations [min]
CH: Daily distance travelled (10 year cohorts)

- 3rd Tercile
- 2nd Tercile
- 1st Tercile

Average Cohort Age [Years]
Daily distance travelled [%]
Mode share
CH: Trip main mode share: Car

Average Cohort Age [Years]

Share of Car Trips [%]

1910-29
1930-39
1940-49
1950-59
1960-69
1970-79
1980-89
1990-99

3rd Tercile
2nd Tercile
1st Tercile

Wegs Analysis
CH: Daily number of car and public transport trips

![Graph showing the daily number of car and public transport trips in Switzerland over different years. The graph compares the number of trips with motorized vehicles/day against the number of public transport trips/day. The graph includes data from Mikrozensus Schweiz 1984, 1989, 1994, 2000, 2005, and 2010. The categories include vehicle and season ticket, no vehicle but season ticket, vehicle but no season ticket, and neither.](image-url)
But look at long distance travel
Distances between home locations of friends
Accessibility and induced demand
Stable (ln) accessibilities, e.g. Switzerland 1850 – 2000

Source: Axhausen, Fröhlich and Tschopp (2006) S.10
### Mean elasticities (1970-2000) with respect to

<table>
<thead>
<tr>
<th>Accessibility</th>
<th>Share out-of-home</th>
<th>0.61</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number of trips</td>
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<tr>
<td></td>
<td>Number of trips per journey</td>
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<tr>
<td></td>
<td>Time out-of-home</td>
<td>0.10</td>
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<tr>
<td></td>
<td>Distance travelled</td>
<td>1.14</td>
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</table>

<table>
<thead>
<tr>
<th>Price index for travel</th>
<th>Share out-of-home</th>
<th>-0.06</th>
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<tr>
<td></td>
<td>Number of trips</td>
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<td></td>
<td>Number of trips per journey</td>
<td>-1.66</td>
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<tr>
<td></td>
<td>Time out-of-home</td>
<td>-1.95</td>
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<tr>
<td></td>
<td>Distance travelled</td>
<td>-0.84</td>
</tr>
</tbody>
</table>

Source: Weis and Axhausen (2011)
CH: Municipal accessibility change for:

- All travel times -25%
- All travel times -10%
- All roads +30 km/h
- All motorways +10 km/h
- All motorways +1 lane
- All road in ZH +1 land

Increase in accessibility [%]
Developing better guidelines
Traditional motorway cross-section design

Desired LOS >

Expected LOS = Function of

Chosen cross-section
Expected flow in an arbitrarily chosen \( n^{\text{th}} \) hours of an assumed annual flow profile
Developing better guidelines, e.g. Switzerland

<table>
<thead>
<tr>
<th>Guideline</th>
<th>Considers</th>
<th></th>
<th></th>
<th></th>
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<tbody>
<tr>
<td></td>
<td>Long term dynamics</td>
<td>Short term flow variance</td>
<td>Short term capacity variance</td>
<td>Generalised costs</td>
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<tr>
<td>Crosssection</td>
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<td>No</td>
<td>No</td>
<td>No</td>
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<tr>
<td>Signals</td>
<td>Yes, hour</td>
<td>Yes</td>
<td>No</td>
<td>IVT only</td>
</tr>
<tr>
<td>Roundabouts</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>IVT only</td>
</tr>
<tr>
<td>Intersection w/o signals</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>IVT only</td>
</tr>
<tr>
<td>CBA</td>
<td>(Yes)</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>
Proposal of Bernard and Axhausen (2008)

Generalised costs (travel time, SDE, SDL) [CHF]

Breakdown costs = Function of

- breakdown probability = function of
  - (5min - variance of flow,
  - 5min variance of capacity)
- breakdown depth (speed loss)
- breakdown duration (flow)

across all hours of an assumed annual flow profile
Weekly demand profile (4, A1) used for the comparison
2 lanes: Comparison with Brilon et al.'s simulation
In which ways better guidelines?

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<td>(Yes)</td>
<td>(Yes)</td>
<td>Yes</td>
</tr>
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</table>
Making better informed (design) choices
Words of power

.......The world will little note nor long remember what we say here but it can never forget what they did here. It is for us the living rather to be dedicated here to the unfinished work which they who fought here have thus far so nobly advanced. It is rather for us to be here dedicated to the great task remaining before us, that from these honored dead we take increased devotion to that cause for which they gave the last full measure of devotion, that we here highly resolve that these dead shall not have died in vain, that this nation under god shall have a new birth of freedom and that government of the people by the people for the people shall not perish from the earth.
The world will little note nor long remember what we say here but it can never forget what they did here. It is for us the living rather to be dedicated here to the unfinished work which they who fought here have thus far so nobly advanced. It is rather for us to be here dedicated to the great task remaining before us, that from these honored dead we take increased devotion to that cause for which they gave the last full measure of devotion, that we here highly resolve that these dead shall not have died in vain, that this nation under god shall have a new birth of freedom and that government of the people by the people for the people shall not perish from the earth
We hold these truths to be self-evident...

...government of the people by the people for the people shall not perish from the earth.

Liberte, fraternite, equalite

Allons enfants de la patrie ...

Die Würde des Menschen ist unantastbar.

Völker hört die Signale, auf zum letzten Gefecht ...
Images of power
Images of power: Llyod Wright’s Broad acre city
Images of power: Le Corbusier‘s city of the future
Images of power: Friedrich‘s Greifswald, 1821
Images of power: Howard’s garden city, 1899
Are our (incremental) guidelines any better?
How to demonstrate the quality of our guidelines?

Incremental decisions:

- Short run social benefits larger then their full costs
- Consistency with urban and social vision

Cumulative effect:

- Consistency with self-image
- Minimize longer term costs
Example grammars: Savannah

Quelle: Jacobs (1993) S.244
Example grammars: Paris

Quelle: Jacobs (1993) S.234
Example grammars: Manhattan
Example grammars: Irvine

Quelle: Jacobs (1993) S.222
Testing design grammars using optimisation
Testing design grammars using optimisation

Define grammars

Test grammar
  Vary grammar parameters
  Generate optimal networks
  on the featureless plain
  Evaluate

Select grammar
# Testing hierarchies

<table>
<thead>
<tr>
<th></th>
<th>Average score</th>
<th>Difference</th>
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<tbody>
<tr>
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<td>-</td>
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<td>Hierarchical shape grammar, optimized type share</td>
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</tbody>
</table>

User Costs and Accessibility

Source: Vitins, Garcia-Dorado, Vanegas, Aliaga and Axhausen (2013)
Intersection types with the lowest total turn delays

3 arm intersections

4 arm intersections

Source: Vitins and Axhausen (2013)
## Rules for intersection type choice and network topology

<table>
<thead>
<tr>
<th>Total turn volumes</th>
<th>low</th>
<th>medium</th>
<th>high</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equally distributed turn flows</td>
<td><img src="image" alt="Equally distributed turn flows" /></td>
<td><img src="image" alt="Equally distributed turn flows" /></td>
<td><img src="image" alt="Equally distributed turn flows" /></td>
</tr>
<tr>
<td>High through traffic flows</td>
<td><img src="image" alt="High through traffic flows" /></td>
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<td><img src="image" alt="High through traffic flows" /></td>
</tr>
</tbody>
</table>

- **3 arm intersection**
- **4 arm intersection**
- **Signalized**
- **Right-of-way**
- **Roundabout**

Source: Vitins and Axhausen (2013)
Comparison of optimized and pattern networks

Networks with right-of-way intersections

Networks with signalized intersections

Source: Vitins and Axhausen (2013)
Sensitivity analysis of networks with signal lights

Source: Vitiins and Axhausen (2013)
Sensitivity analysis of networks with roundabouts

Source: Vitins and Axhausen (2013)
Summary
Summary

• Build and support the best possible guidelines early
• Improve the rules and methods for incremental choices
• Account for induced demand
• Remember the saturation phase
Questions?

www.matsim.org
www.ivt.ethz.ch
www.futurecities.ethz.ch
www.senozon.ch
References

