Preferred citation style

Modelling infrastructure gains: An experiment

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IVT
ETH
Zürich

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Road travel-time scaled Switzerland 1950 and 2000

Scherer, 2004
Von Thünen’s model of land use for the isolated city

Based on Von Thünen (1910)
Size of goods markets and productivity: A hypothesis

Economies of scale
Economies of scope

Activity

GDP

Fleet comfort

Slots: possibilities to move goods or people

vtts et al.

vkm

Tours

t/pkm

Market size

Energy costs

Elasticity > 0
Elasticity < 0

Slots: possibilities to move goods or people
For a given infrastructure and commercial and private fleet
## Short-term benefits and costs after an improvement

<table>
<thead>
<tr>
<th>Public</th>
<th>Private</th>
<th>Firms</th>
<th>Land owners</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower travel times</td>
<td>Higher reliability</td>
<td>Lower logistics costs</td>
<td></td>
</tr>
<tr>
<td>Higher reliability</td>
<td>Smaller scheduled delays</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Medium-term benefits and costs after an improvement

<table>
<thead>
<tr>
<th>Public</th>
<th>Private</th>
<th>Firms</th>
<th>Land owners</th>
</tr>
</thead>
<tbody>
<tr>
<td>Higher externalities</td>
<td>Mode choice change</td>
<td>Changed customer structure</td>
<td>Changed (higher) emissions</td>
</tr>
<tr>
<td>Higher maintenance costs</td>
<td>Higher VMT</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Higher transit subsidies</td>
<td>Larger selection</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Larger fuel tax receipts</td>
<td>More out-of-home activities</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Higher travel expenditures</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
# Long-term benefits and costs after an improvement

<table>
<thead>
<tr>
<th>Public</th>
<th>Private</th>
<th>Firms</th>
<th>Land owners</th>
</tr>
</thead>
<tbody>
<tr>
<td>More competition</td>
<td>New residential location</td>
<td>Better match of employees</td>
<td>Higher land prices</td>
</tr>
<tr>
<td>More innovation</td>
<td>Better job match</td>
<td>Higher productivity</td>
<td></td>
</tr>
<tr>
<td>Higher growth</td>
<td>Higher incomes</td>
<td>More competition for employees</td>
<td></td>
</tr>
<tr>
<td>More social capital</td>
<td>Lower consumer prices</td>
<td>and customers</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Lower transit supply</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>More stable social networks</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Loosers

Firms:
• Not enough capital/cash flow to expand/adapt
• Not enough expertise to innovate/adapt

Individuals:
• Not enough education to adapt
• Not enough savings/cash flow to adapt
• Not enough degrees of freedom to adapt
• Loss of “vicinity”
• Loss/increased generalised costs of the vehicle-less option
Ideal model: Activity scheduling

- Number and type of activities
- Sequence of activities
  - Start and duration of activity
  - Composition of the group undertaking the activity
  - Expenditure division
  - Location of the activity
  - Movement between sequential locations
    - Location of access and egress from the mean of transport
      - Parking type and location
    - Vehicle/means of transport
    - Route/service
    - Group travelling together
    - Expenditure division
Ideal model: Individual long(er) term choices

- Social network geography
- Social commitments
- Amount and type(s) of occupation
  - Working hours
  - Work location(s)
  - School location
  - Home location
- Mobility tools
- Discount cards
- Season tickets
- Vehicles (by body type, fuel, energy efficiency)
Ideal model: Supply-side long(er) term choices

- Network links and capacities
- Housing
- Office and factory space
- Firm structure and size
  - Logistics system choice
  - Production technology and scale
  - Public transport lines and service frequency
    - Firm location(s)
    - Distribution channel(s)
    - Service points (stops and stations)
    - Prices
Change in:

- Travel time
- Reliability
- User operating costs
- VAT income change of public transport firms
- Accidents
- Noise
- Emissions (local and global)
- Soil sealing
- External costs of energy use for infrastructure operations
- Landscape impacts
Research questions for MiniStadt: An agent-based model

- Can you capture the total benefits with travel time savings alone?
- Construct the simplest necessary model
- Find plausible parameter set
- Experiment with various degrees of freedom of adaptation
MiniStadt: Form (including additional link S7)
MiniStadt: Choice dimensions

1000 agents returning home

• Work locations (1)

• Residential locations (3) with 600 homes each

• Time slots (24 of 5 minutes)

• Connections/routes (15/17)
Systematic utility of a connection:

Systematic utility of a departure time:

Systematic utility of a residential location:
MiniStadt: Experiments

Four experiments starting from RTD before equilibria:

- Connection (R)
- Connection * time (RT)
- Connection * destinations (RD)
- Connection * time * destinations (RTD)
MiniStadt: Convergence
## MiniStadt: Occupancy rates

<table>
<thead>
<tr>
<th>Experiment</th>
<th>B [%]</th>
<th>C [%]</th>
<th>D [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>High</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>RTD</td>
<td>76</td>
<td>8</td>
<td>9</td>
</tr>
<tr>
<td>RT</td>
<td>82</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>R</td>
<td>82</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>Before</td>
<td>82</td>
<td>6</td>
<td>3</td>
</tr>
</tbody>
</table>

Source: Zöllig and Axhausen, 2010
## MiniStadt: Changes

<table>
<thead>
<tr>
<th></th>
<th>ΔRTD</th>
<th>ΔRT</th>
<th>ΔR</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ΣTravel time [min]</strong></td>
<td>-1187</td>
<td>-1647</td>
<td>-1505</td>
</tr>
<tr>
<td><strong>ΣTravelled distance [km]</strong></td>
<td>874</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Accident costs [sFr/a]</strong></td>
<td>-479’100</td>
<td>-472’700</td>
<td>-154’500</td>
</tr>
<tr>
<td><strong>Traffic noise costs [sFr/a]</strong></td>
<td>9’800</td>
<td>4’600</td>
<td>2’400</td>
</tr>
<tr>
<td><strong>Air pollution costs [sFr/a]</strong></td>
<td>26’500</td>
<td>13’600</td>
<td>7’200</td>
</tr>
<tr>
<td><strong>Climate costs [sFr/a]</strong></td>
<td>5’700</td>
<td>2’700</td>
<td>1’400</td>
</tr>
</tbody>
</table>

Source: Zöllig and Axhausen, 2010
## MiniStadt: Utility gains

<table>
<thead>
<tr>
<th></th>
<th>ΔRTD</th>
<th>ΔRT</th>
<th>ΔR</th>
</tr>
</thead>
<tbody>
<tr>
<td>ΔEMU</td>
<td>303</td>
<td>167</td>
<td>159</td>
</tr>
<tr>
<td>Σ External costs</td>
<td>-437’100</td>
<td>-451’800</td>
<td>-143’400</td>
</tr>
<tr>
<td>ΔV&lt;sub&gt;routes&lt;/sub&gt;</td>
<td>69</td>
<td>111</td>
<td>103</td>
</tr>
<tr>
<td>ΔV&lt;sub&gt;time&lt;/sub&gt;</td>
<td>74</td>
<td>53</td>
<td>-15</td>
</tr>
<tr>
<td>ΔV&lt;sub&gt;destination&lt;/sub&gt;</td>
<td>133</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>ΔRealised utility</td>
<td>276</td>
<td>165</td>
<td>87</td>
</tr>
</tbody>
</table>

Source: Zöllig and Axhausen, 2010
What next?

• Enrich the models
  • Add time, location choice (and reliability impacts)
  • Build full land user transport models

• Add winner/looser analysis

• Adopt (monetarised) EMU as measure of user benefit
www.ivt.ethz.ch

www.matsim.org
References

Von Thünen, J.F. (1910) Der Isolierte Staat in Beziehung auf Landwirtschaft und Nationalökonomie, G. Fischer, Jena (reprint of the 1826 original)


MiniStadt: Procedure

1. Load the initial conditions and set the number of iterations \( n = 0 \).
2. Calculate \( M \), the number of agents deciding, as number of agents/\((n + 1)^2\).
3. Sort the agents in descending order of their maximal potential utility gains.
4. Randomize the order of the \( M \) agents with the highest potential utility gains.
5. Let these agents decide one after the other and update the network after each decision.
6. Update the utilities across of all possible choices for all agents (choice set).
7. Calculate the maximal potential utility gain for each agent.
8. Calculate the system-wide statistics
9. Return to step 2 as long as \( n < 20 \) or sum of potential utility gains ≠ minimum of potential utility gains in the preceding iterations. Also stop iterating if no agent finds a better alternative, oscillation occurs, the maximum number of iterations is reached.