A System Dynamics approach applied to rural-urban regions

Nina Schwarz, Dagmar Haase
Outline

1. The challenge
2. System dynamics approach
   - Qualitative & comprehensive model
   - Quantitative example: first results
3. Conclusions
Land use change in a RUR in Europe
Challenge
Understanding land use dynamics in RURs

- Aim: Generic view on land use changes in rural-urban regions to coordinate modelling efforts
  - Demand for land, impacts, ...
  - Applicable to rural-urban regions in Europe

- Present simulation models
  - focus on urban sprawl
  - do not include feedbacks (e.g. from ecosystem impacts to human decision-making)

→ Causal loop diagrams
Causalities of land use dynamics in a RUR
Overview: comprehensive model

- Quality of life
- Land use change
- Policy implementation (e.g. costs)
- Ecosystem services
- Demand for land
- Mediation of land use change
Causalities of land use dynamics in a RUR
Overview: demand for residential land

quality of life

demand for land

demand for service provider

demand of residents

demand of commerce and industry

shopping / cultural infrastructure / education / medical care / kindergardens

travel

transport

urban green / open land

fertility

population

mortality

household

housing

residential area

income

migration

electricity / water
Quantification of causal loops
Example case: shrinkage in Leipzig, Germany

✓ Case study
  ▪ ~ 500,000 inhabitants
  ▪ After German re-unification: de-industrialisation, population loss, residential vacancies

✓ Simulation model
  ▪ Focus on housing and real estate market
  ▪ System dynamics approach
  ▪ Time horizon: until 2025
  ▪ Representation of 8 different urban structural types (“Stadtstrukturtypen”) in urban and peri-urban area
  ▪ Scenarios for different demographic conditions
Model structure I
Demand

HHT preferences
1. Green
2. Costs
3. Neighbourhood
4. Crime

Site conditions
1. Green
2. Costs
3. Neighbourhood
4. Crime

Housing demand
HHT/UST

Real estate housing area of UST*

* Urban structural type
Model structure II
Supply

* For each of eight structural types
## First results

### Scenarios on population dynamics

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Fertility</th>
<th>Migration</th>
</tr>
</thead>
<tbody>
<tr>
<td>S 1</td>
<td>1999</td>
<td>1999</td>
</tr>
<tr>
<td>S 2</td>
<td>1999 &amp; trend</td>
<td>1999 &amp; trend</td>
</tr>
<tr>
<td>S 3</td>
<td>1999 &amp; trend x 2</td>
<td>1999 &amp; trend</td>
</tr>
<tr>
<td>S 4</td>
<td>1999 &amp; trend x 2</td>
<td>1999 &amp; trend x 2</td>
</tr>
<tr>
<td>S 5</td>
<td>2005 &amp; trend</td>
<td>2005 &amp; trend</td>
</tr>
<tr>
<td>S 6</td>
<td>2005 &amp; trend</td>
<td>1999 &amp; inversed trend</td>
</tr>
</tbody>
</table>
First results
Birth rate and residential land

Although birth rate declines, demand on residential land still increases until 2015
First results

Household types and urban structure types I

[Graphs showing changes in population distribution over years for Elderly cohabitation, Elderly singles, and Single parent families, alongside a bar graph illustrating settlement area in structural type [ha] from 1999 to 2023.]
First results
Household types and urban structure types II

Migration within the region
Demand per capita

Single houses

HELMHOLTZ CENTRE FOR ENVIRONMENTAL RESEARCH – UFZ
Conclusions
System Dynamics approach

✔ Potentials
  - Understanding of the system
  - Explicit feedback loops

✔ Problems
  - Conflicts, negotiation processes … better captured with agent-based model
  - No spatial representation
Conclusions

Next steps

✓ Further development of housing module
  ▪ Feedback of resource supply (urban green) on quality of life and migration

✓ New module: Population dynamics and transport
  ▪ Accessibility
  ▪ Negative environmental effects of individual traffic
Thank you for your attention!

And many thanks to Steffen Lauf and PLUREL Module 4 partners for their contributions!

nina.schwarz@ufz.de
http://www.plurel.net