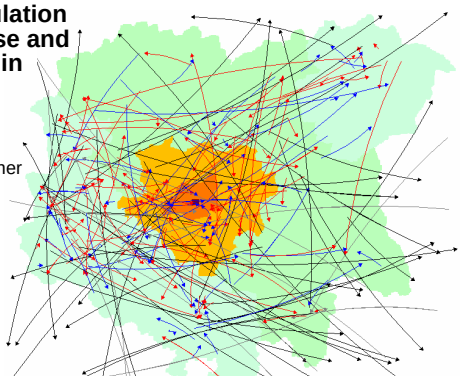
Microsimulation of Land Use and Transport in Cities

Michael Wegener



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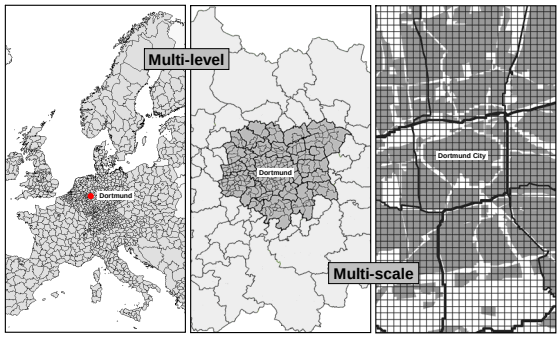
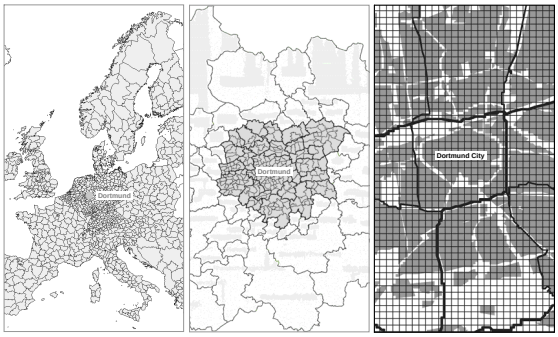
Model levels



Model levels



Microsimulation

Microsimulation

Theory

Microsimulation is the reproduction of a ***macro process*** by many ***micro events***.

Events:

The basic building block of microsimulation is the ***event***.

No ***deterministic*** assertions (that are valid with certainty) can be made about events, only ***probabilistic*** assertions (that are valid with probability) are possible.

Microsimulation

There are two types of events:

- ***Transitions*** are changes of an individual or object from one state to another subject to ***transition probabilities*** (e.g. ageing of persons or buildings) .
- ***Choices*** are selections between alternatives by an individual as a function of their ***perceived utility*** (e.g. modal choice, residential location).

If the causal chain behind choices is of no interest, also choices are modelled as transitions (e.g. birth, marriage, divorce).

Microsimulation

The method of microsimulation consists of generating a ***sequence of* events** as a function of their probability of occurrence.

To generate an event, a ***lottery*** is drawn the result of which is one of the possible outcomes of the event and subject to their probability. This is why microsimulation is also called Monte-Carlo simulation.

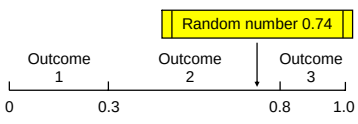
Another term for microsimulation models is ***agent-based*** models (ABM). ***Cellular automata*** (CA) models are raster-based models of transitions of raster cells based on neigh-bourhood properties.

Microsimulation

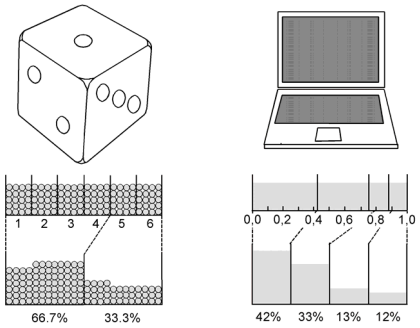
The ***lottery*** consists of the mapping of a random number between 0 and 1 to the vector of cumulated probabilities of possible outcomes of the event.

Example:

An event has three possible outcomes with probabilities 0.3, 0.5 and 0.2. If the random number 0.74 is drawn, Outcome 2 is the event.



Random number generators



Random number generator Pseudo random number generator

Micro database

Microsimulation models require ***micro data***.

In reality micro data are rarely available or where available cannot be used because of privacy concerns.

Synthetic micro data are micro data generated from available spatially aggregate data with which they are consistent in all known attribute distributions.

Microsimulation models can be operated with synthetic micro data instead of real micro data.

Micro database

Buildings

Residential buildings (micro location)
- Dwellings (type, size, quality)

Nonresidential buildings (micro location)
- floorspace (industrial, retail, offices)

Households/Businesses

Households (micro location)
- Households (size, income,cars)
- Persons (age, sex, education, job)

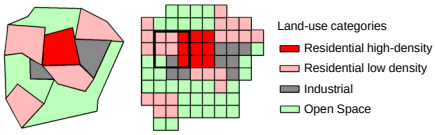
Businesses (micro location)
- Firms (industry, size, vehicles)
- Employment (skill)

Spatial disaggregation

For the synthetic micro database zone data are allocated to raster cells. Two steps are performed:

(1) Conversion of polygons to raster cells

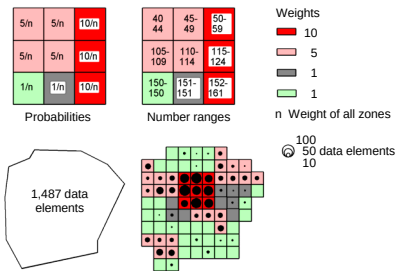
The polygons of a land-use map are converted to raster cells and each raster cell is assigned a land-use category.



Spatial disaggregation

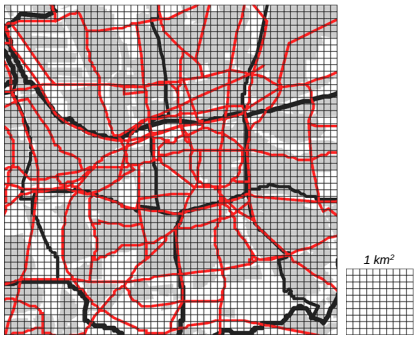
(2) Allocation of zone data to raster cells

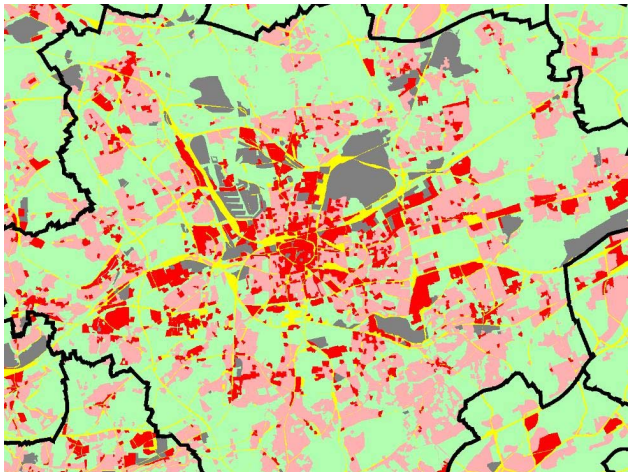
The data elements are allocated to raster cells by Monte-Carlo simulation according to their density.

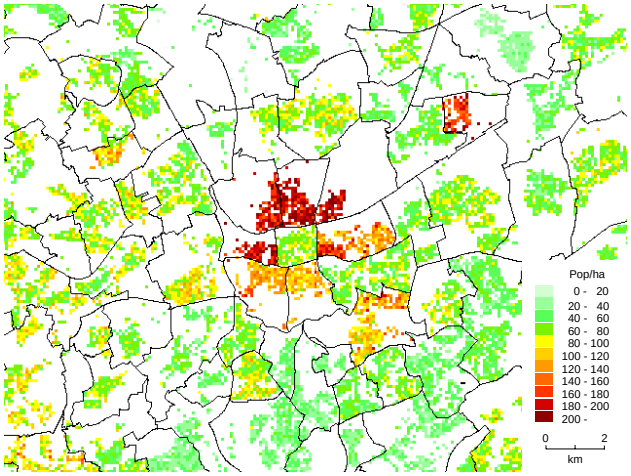


Spatial disaggregation

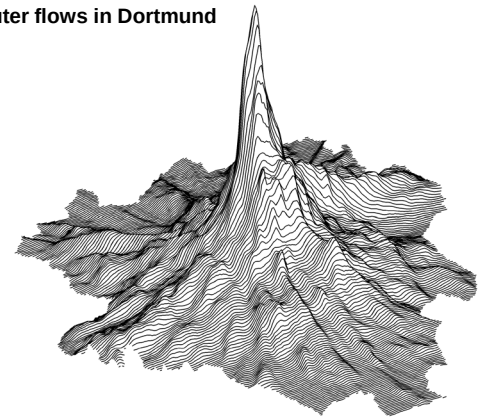
100 x 100 m raster cells







Commuter flows in Dortmund



The ILUMASS Model

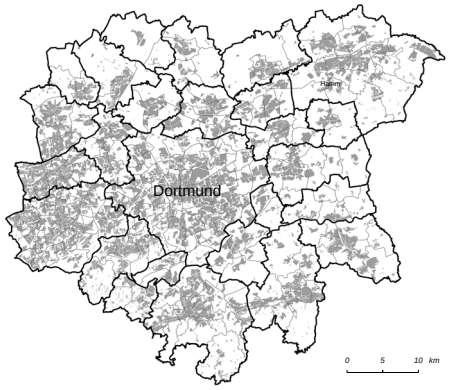
The ILUMASS Project (2001-2006)

The project ILUMASS (Integrated Land-Use Modelling and Transport Systems Simulation) embedded a microscopic dynamic simulation model of urban traffic flows into a comprehensive model system incorporating both changes of land use and the resulting changes in transport demand as well as their environmental impacts.

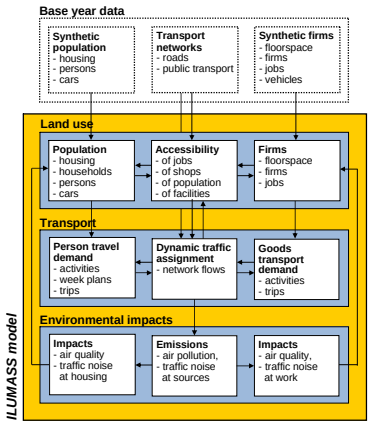
For ***testing*** the ***land use submodels***, the transport and environmental submodels were replaced by the ***aggregate transport model*** of the IRPUD model and simpler envir-onmental impact models ***(= reduced ILUMASS model)***.

Study area

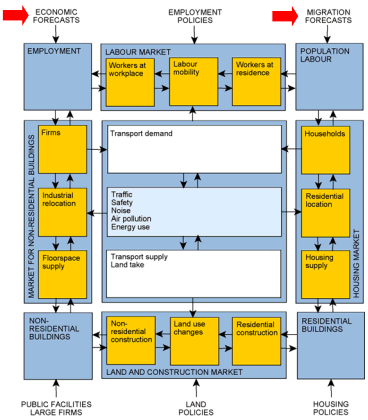
Study area



ILUMASS model



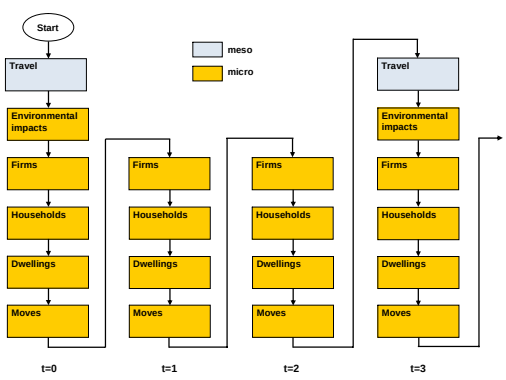
Reduced ILUMASS model



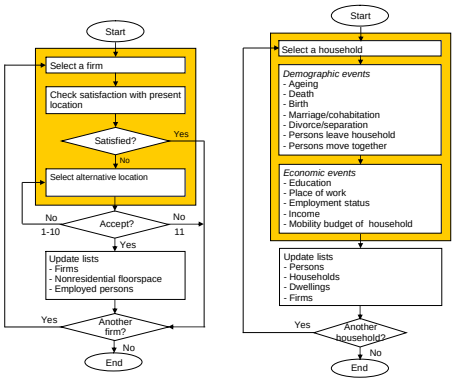
Forecast of SASI model

Microsimulation

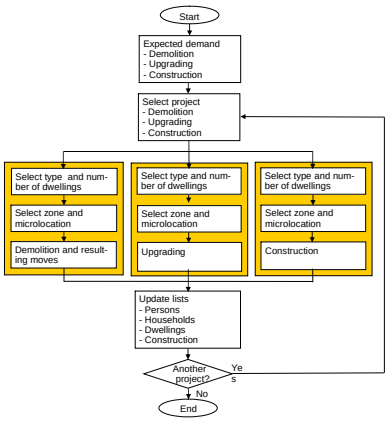
Modules



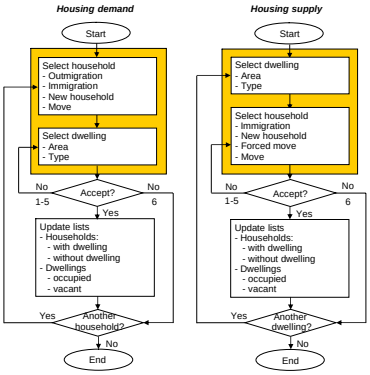
Firms and households



Dwellings



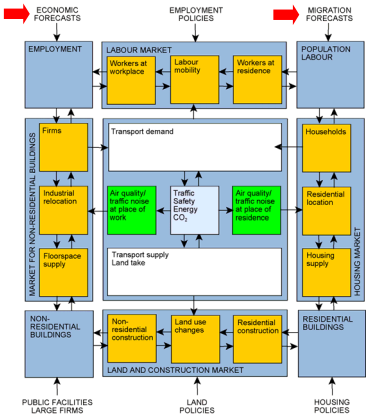
Moves



Environmental Impacts

Reduced ILUMASS model

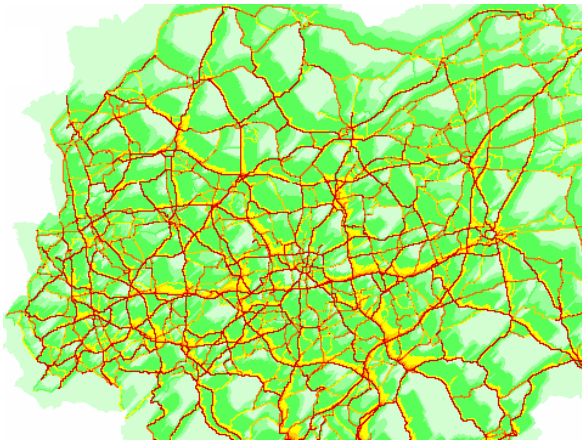
Environmental impacts



Forecast of SASI model

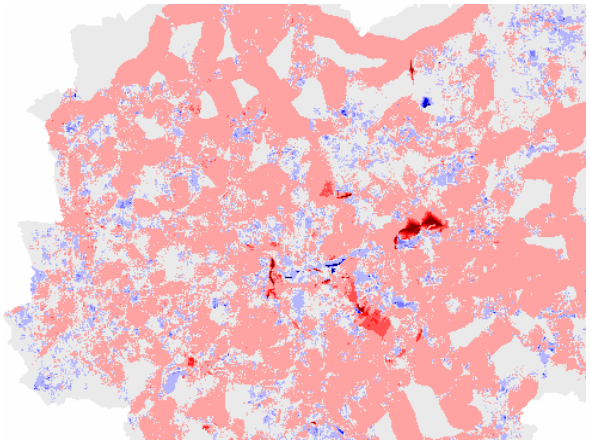
Microsimulation

Environmental impacts

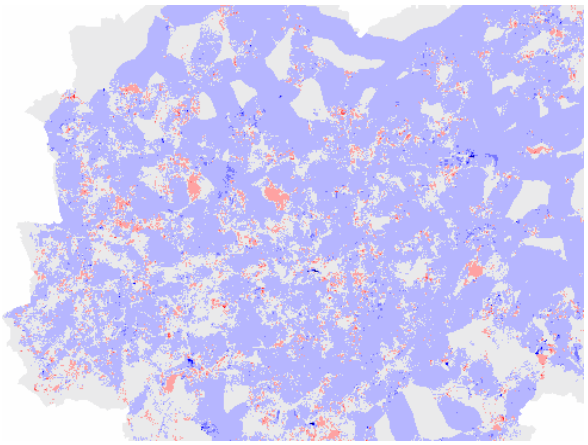


Air quality

Traffic noise

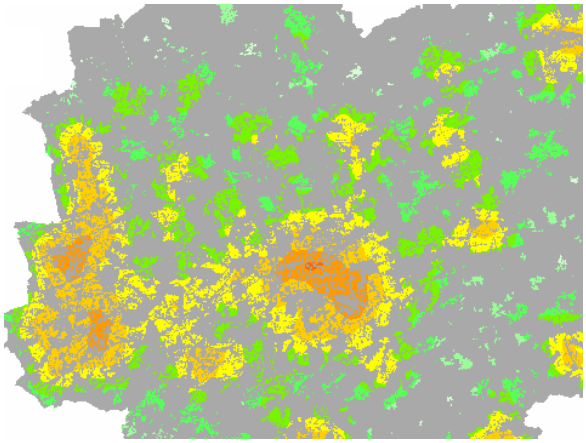


Change in traffic noise 2001-2021



Change in traffic noise relative to reference scenario in 2021

Quality of open space



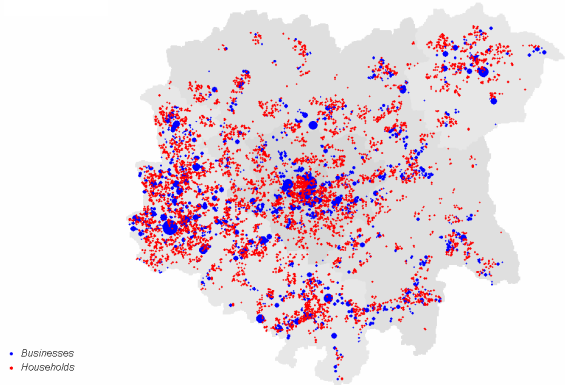
Access to open space

Typical Model Run

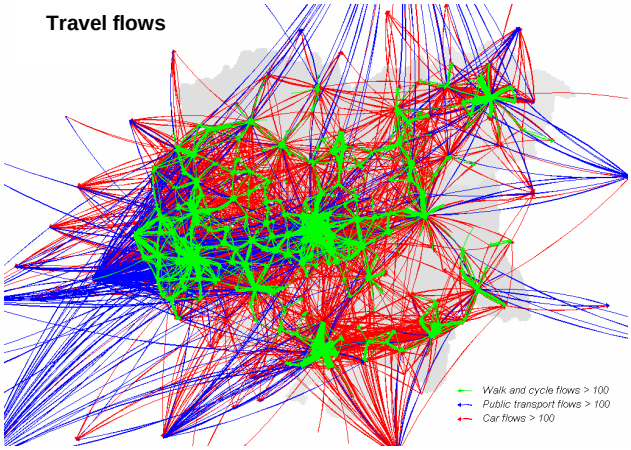
Model dimensions

1.2 million	households
2.6 million	persons
1.2 million	dwellings
80,000	firms
92,000	industrial sites
8,400	public transport links
848	public transport lines
13,000	road links
246/54	internal/external zones
209,000	raster cells
30	simulation periods (years)
90	minutes computing time

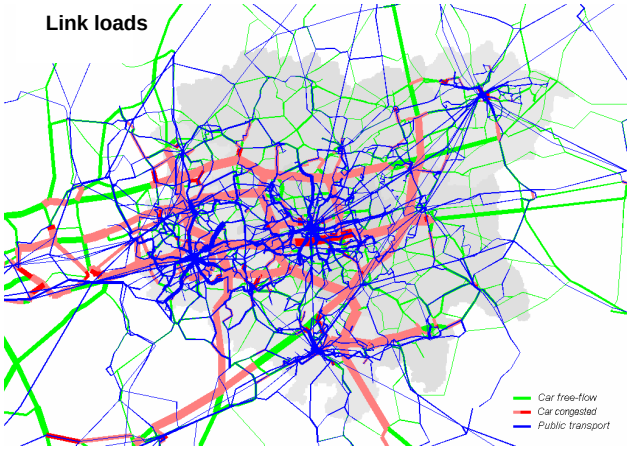
Micro data



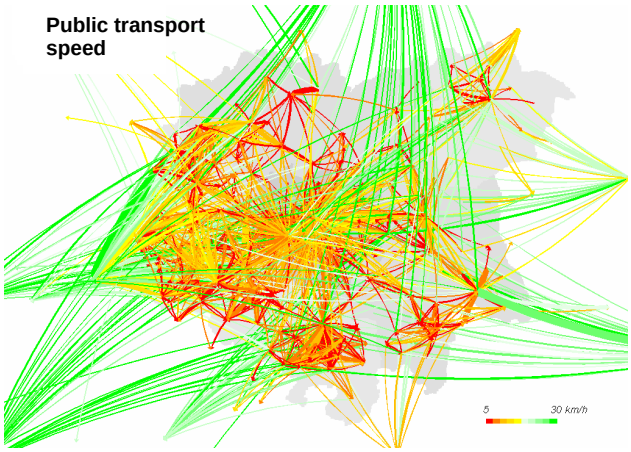
Travel flows



Link loads



Public transport speed



Public transport speed

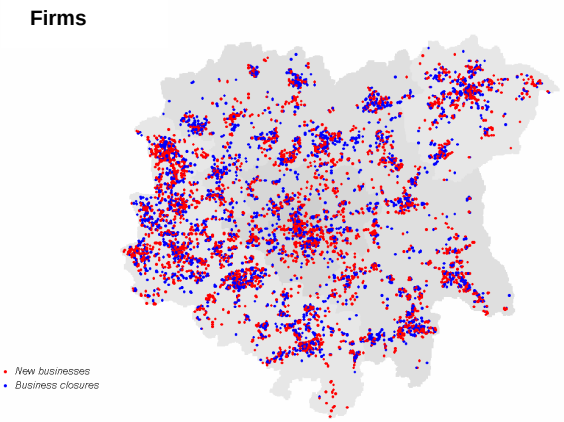
Air quality

NO_2

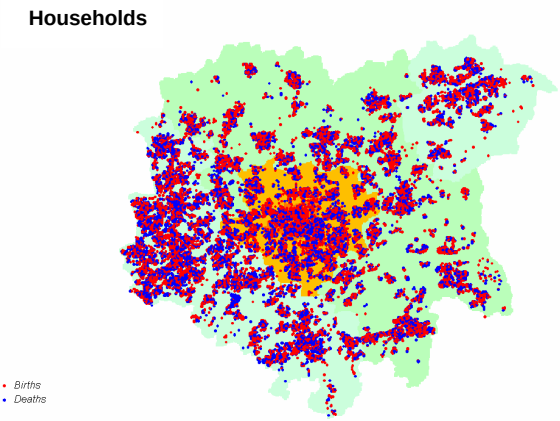
Traffic noise

dB(A)

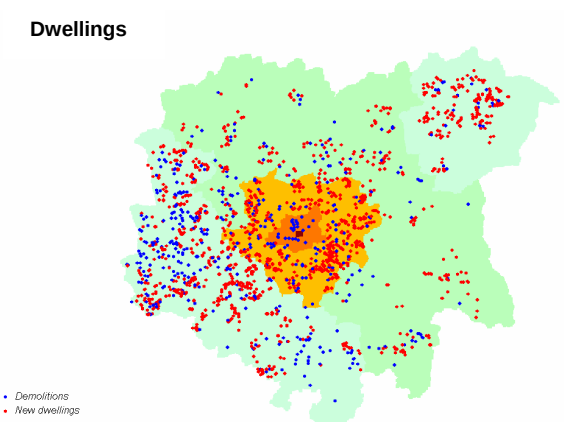
Firms



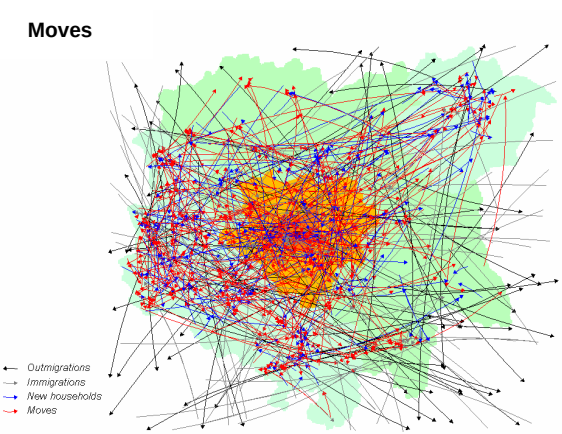
Households



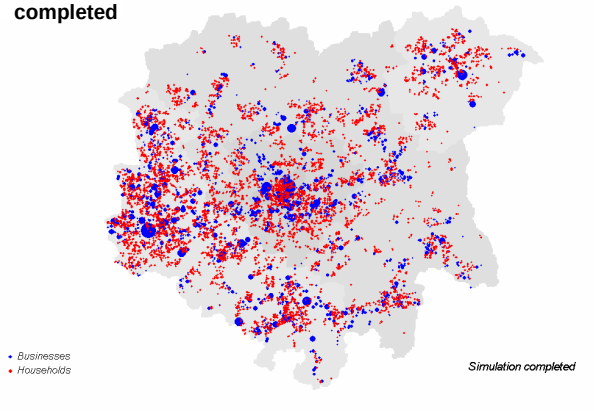
Dwellings



Moves



Simulation completed



Conclusions

Microsimulation

New activity-based ***microsimulation models*** improve urban simulation models:

- ***Lifestyles*** can be represented, i.e. households and individuals can be disaggregated to the agent level.
- ***Environmental impacts*** and ***feedback*** can be modelled with the required spatial resolution.
- ***Population*** and ***employment*** can be represented by their decision making units, i.e. ***households*** and ***firms***.
- ***Microlocations*** can be represented. Households affected by environmental impacts can be localised.

However ...

To date, no full-scale microsimulation model of urban land use, transport and environment has become operational.

There are still unresolved problems regarding the ***inter-faces*** between the submodels.

The ***feedback*** between transport and environmental quality and location has not yet been implemented.

Serious problems of ***calibration***, ***instability*** and ***random fluctuations*** have not yet been solved.

The ***computing time*** for existing models is calculated in terms of ***weeks*** or ***days,*** not ***hours***.

Limits of microsimulation

There are ***ultimate limits*** to increasing the substantive, spatial and temporal resolution of behavioural models:

- There are ***theoretical limits*** when the number of pro-cesses simulated is too small to yield reliable results.
- There are ***empirical limits*** when the marginal costs of obtaining micro data are larger than their added value.
- There are ***practical limits*** when the computing time of the models exceeds the duration of the modelled processes.
- There are ***ethical limits*** to the collection of data about private lives for purposes of research.

How much micro is enough?

There seems to be little consideration of the benefits and costs of microsimulation:

- Where is microsimulation really needed?
- What is the price for microsimulation?
- Would a more aggregate model do?

For spatial planning models, the answer to these questions depends on the planning task at hand.

Conclusion

These considerations lead to a reassessment of the hypo-thesis that in the future all spatial modelling will be micro-scopic and agent-based.

Under constraints of ***data collection*** and of ***computing time***, there is for each planning problem an optimum level of ***conceptual***, ***spatial*** and ***temporal*** resolution.

This suggests to work towards a ***theory*** of balanced ***multi-level models*** which are as ***complex*** as necessary for the planning task at hand and – to quote Albert Einstein – "as simple as possible but no simpler".

More information

Moeckel, R., Schwarze, B., Spiekermann, K., Wegener, M. (2007): Simulating interactions between land use, transport and environment. *Proceedings of the 11th World Conference on Transport Research*. Berkeley, CA: University of California at Berkeley.

Wagner, P., Wegener, M. (2007): Urban land use, transport and environmental models: Experiences with an integrated microscopic approach. *disP* 43(170):45–56.

More information on the development of the ILUMASS model can be found at http://www.spiekermann-wegener.de/mod/ilumassmod_e.htm.

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