Preferred citation style for this presentation

Schirmer, P. (2011)

Simulating urban dynamics with agent based models, presented at *Brownbag Chair of Architecture and Urban Design*, Zurich, December 2011

Institut für Verkehrsplanung und Transportsysteme
Institute for Transport Planning and Systems

Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

Simulating urban dynamics with agent based models

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Urban Simulation

SustainCity

- EU-funded research-project (2010-2012), Total budget: 3,8 Mio EUR
- 12 research institutions participating
- 3 case-studies of UrbanSim: Brussels, Paris, Zurich
- Previous UrbanSim-experience in all cities (Zurich: Zukunft Urbaner Kulturlandschaften, 2007)
- Aim of Project:
  - adapt 'UrbanSim' to European conditions => version 'UrbanSimE'
  - include additional models (demographics, developers, MatSim-exchange,...)
  - evaluate and compare results of case-studies

Introduction

Outline

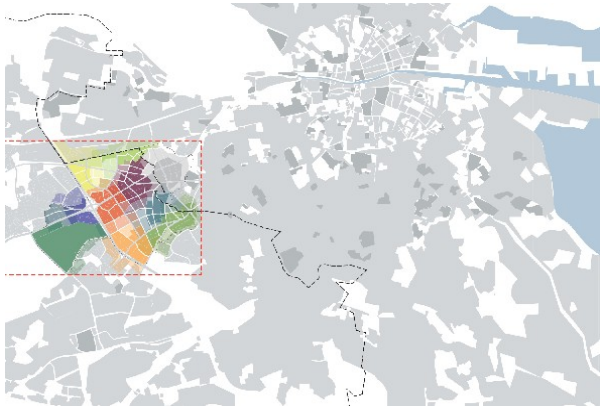
- Introduction to modelling of choice
- Example of behaviour model: Household-Location-Choice
- The Zurich case study of UrbanSim

Introduction

Scale of urban planning projects

- S - the neighborhood (1:1000 – 1:200)
- M - the quarter (1:2000 – 1:500)
- L - the city (1:10000 – 1:2000)
- XL?

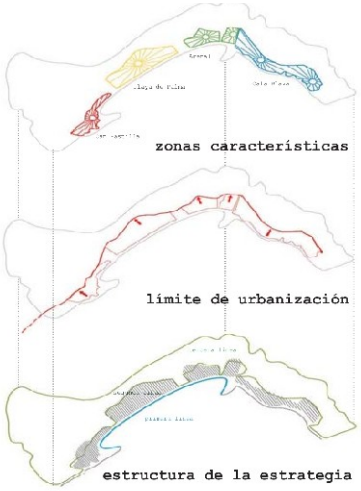
Examples of projects from KCAP Architects&Planners

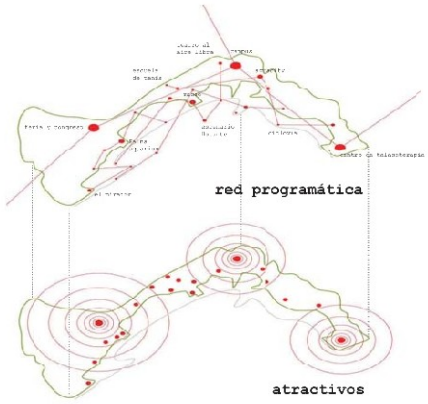


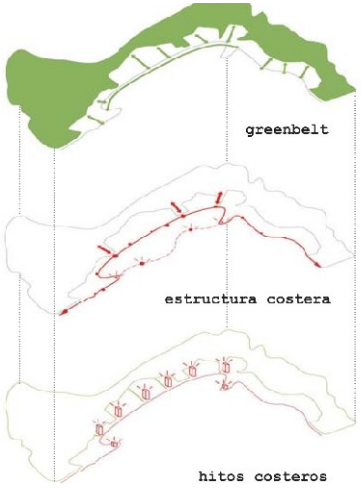
Introduction

Layers

- network (public transport, streets, cycling, pedestrians, …)
- build space (volumes, use, density, …)
- open-space (artificial, natural, public, semi-public, private, …)
- urban cores (urban center, subcenter, neighborhood, ...)
- functions (points of interest, zonal definitions, …)
- social structure (segregation, age, income, lifestyle, …)
- policies (ownership, investors, constraints, …)
- ....







Design-proposal for
Platja del Palma

KCAP Architects&Planners

Introduction

Process and dynamics

What happens if we create

... a new highway

… a new urban center

… a new station/airport

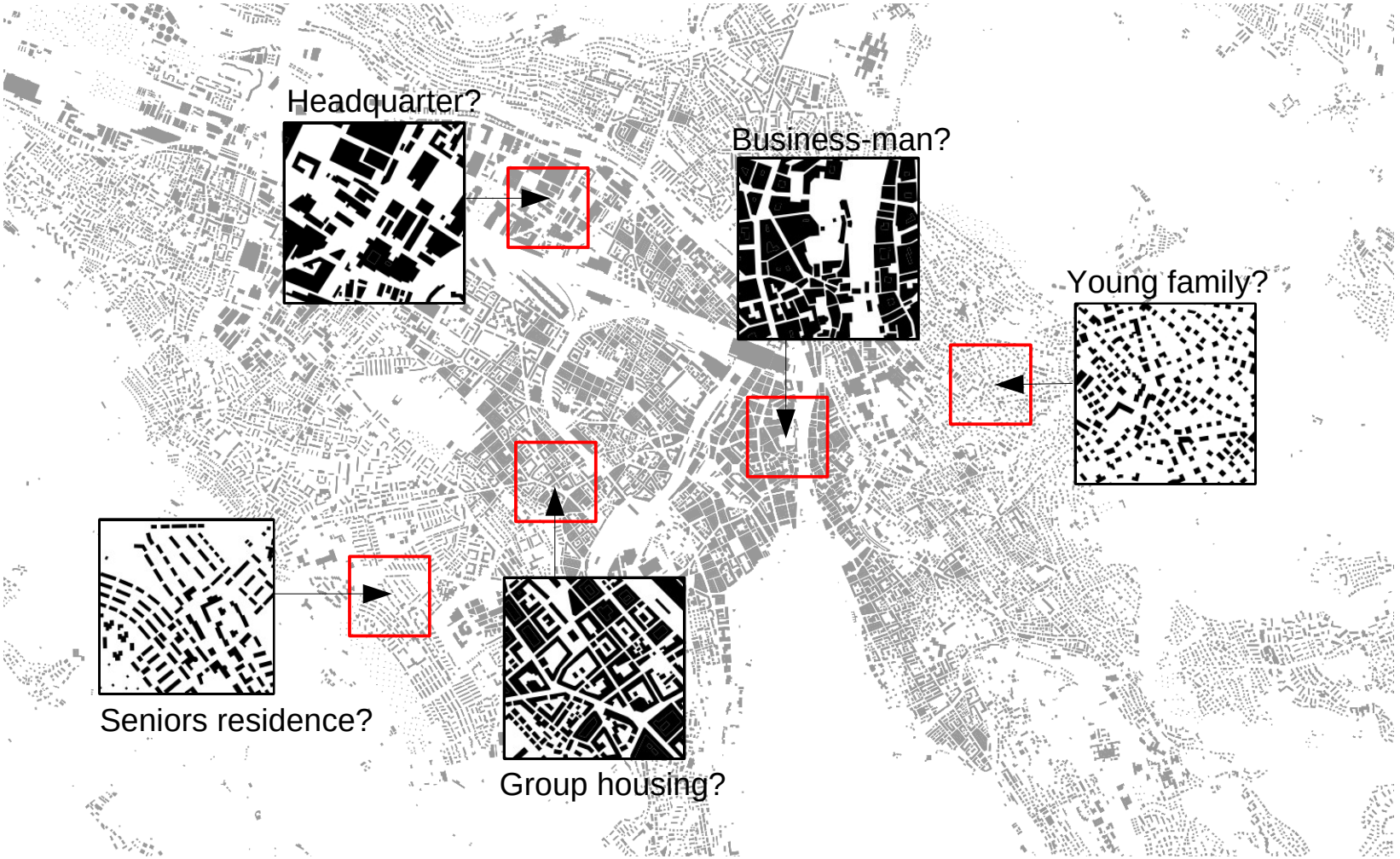
… or if we have a structural change of the economie?

Can we simulate effects of urban planning decisions?

Design-proposal for Dublin

KCAP Architects&Planners

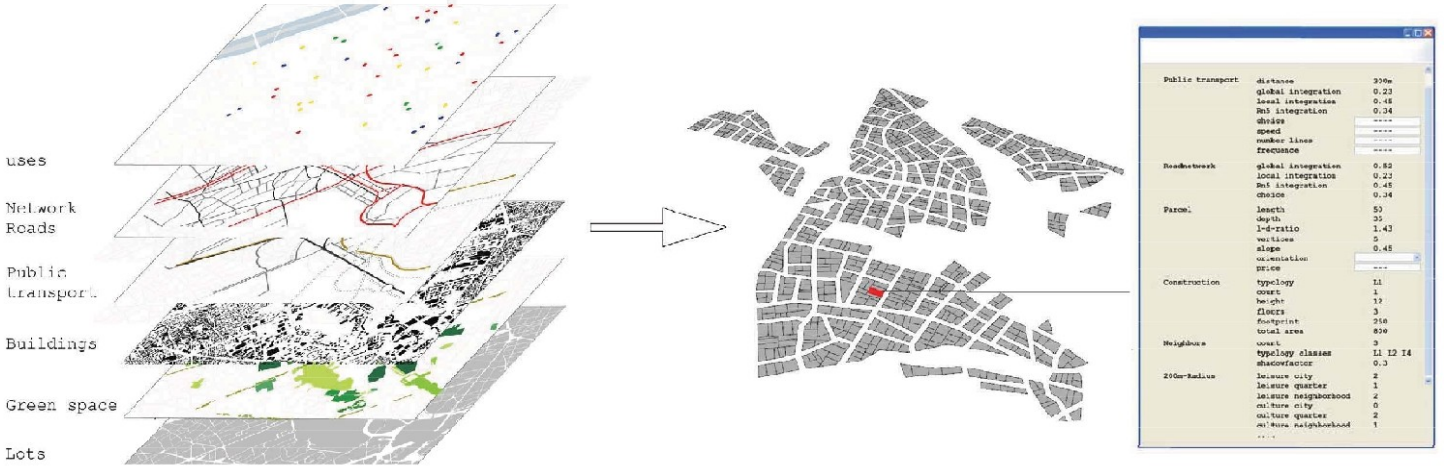
Modelling Behaviour



Modelling Behaviour

Example: relevant attributes of residence for a household

- Size of residence (rooms, sqm)
- Price of residence (rent, buy)
- Size of household
- Income of household
- Distance to workplace
- Distance to center
- ....



Modelling Behaviour

Model of homo economicus

"...humans as rational and narrowly self-interested actors who have the ability to make judgements toward their subjectively defined ends." (Wikipedia)

- Perfect knowledge of all available alternatives and their relevant attributes
- Consistent and stable preferences
- Optimisation of own benefit over arbitrary time horizons
  (respecting costs of search and decission)
- Alternatives j=1,....,n are known for all persons q, q = 1,...r
- Alternatives do not overlap
- Observations for X_{kjq} , $k = 1,... m$
- Parameters α_{kjq} are known
- Utility $U(X_{j*q}) > U(X_{jq})$ for $\forall\ j \neq j*;$

use observed behaviour to simulate <=> natural behaviour vs. "vision" of new behaviour

Modelling Behaviour

Approach

- Calculate utility of an alternative with stochastic approach using probabilities
- Value of an alternative is a sum of different aspects
- Utility includes error term
- Error term is independently irrelevant distributed (IID)
- Impact of each aspects can be estimated via observation
- Assumptions of independent irrelevant alternatives (IIA)

Utility function: $$U(jq) = \sum V(X_{kjq}) + \varepsilon_{jq}$$

Deterministic value: $$V = \beta_{0j} + \sum \beta_{k''j} * p_{k''q} + \sum \beta_{k'j} * s_{k'q} + \sum \beta_{kj} * x_{kjq}$$

β_{0j} Konstante für Alternative j

$p_{k''q}$ Eigentschaft k"=1...m" der Person q

$s_{k'q}$ Eigenschaft j' = m"+1...m' der Situation der Person q

x_{kjq} Eigenschaft k=m'+1...m der Alternative j für Person q

Logit model: $$P(i) = \frac{e^{V(iq)}}{\sum e^{V(nq)}}$$

Modelling Behaviour

Household location, transition and relocation choice

- New survey end of 2010 (Belart, 2011)
  - 5300 persons that moved in July/August 2010 have been asked
    - attributes of the household (incl. workplace)
    - attributes of the current and the previous residence
    - location of members of the social network
    - type of lifestyle of the household

    => 1090 observation of recent movers
  - Integration of lifestyle and social contacts

- Literatur review of variables used in Household location choices (Virani 2011)
  - new model with better results
    - common variables found in Literature
    - variables used in UrbanSim

Modelling Behaviour

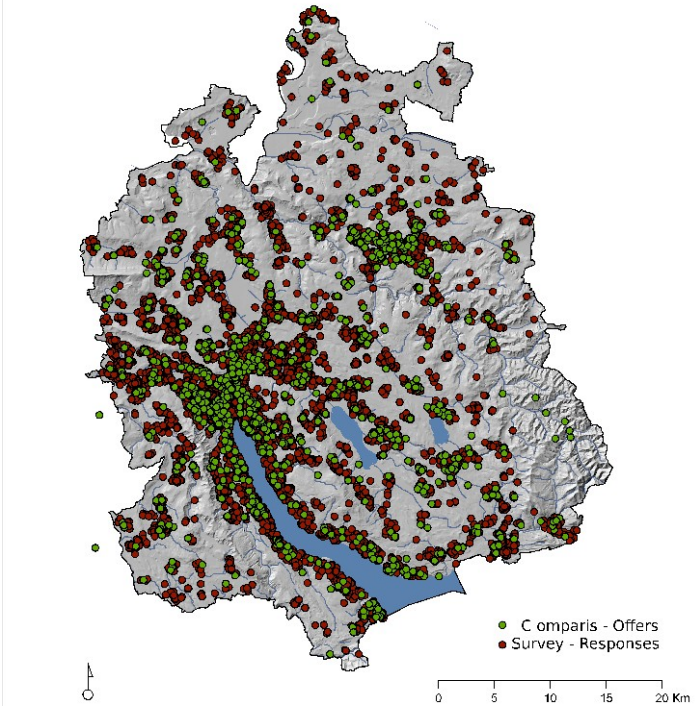
Response

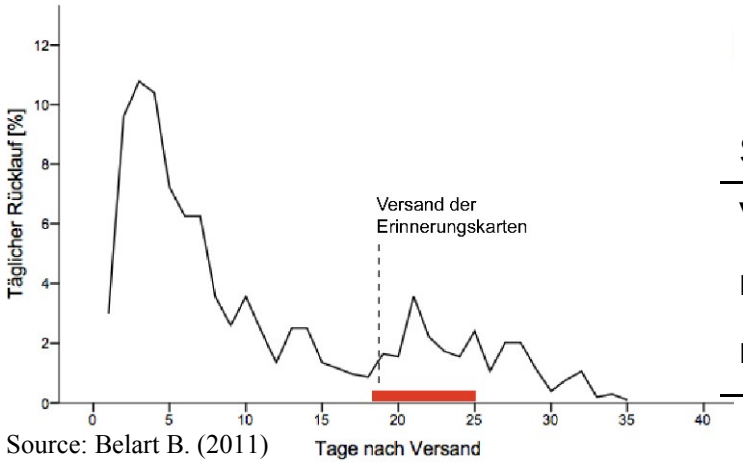
- Survey sent in November 2010
- Reminder (postcard) after 3 weeks
- 1.039 answers for evaluation at end of december
- 16.500 Persons move per month in the Canton of ZH*

  => 16% have been contacted with the survey

  => 3.1% have participated at the survey

* Stastic department Canton ZH: 200.000 moving persons/year





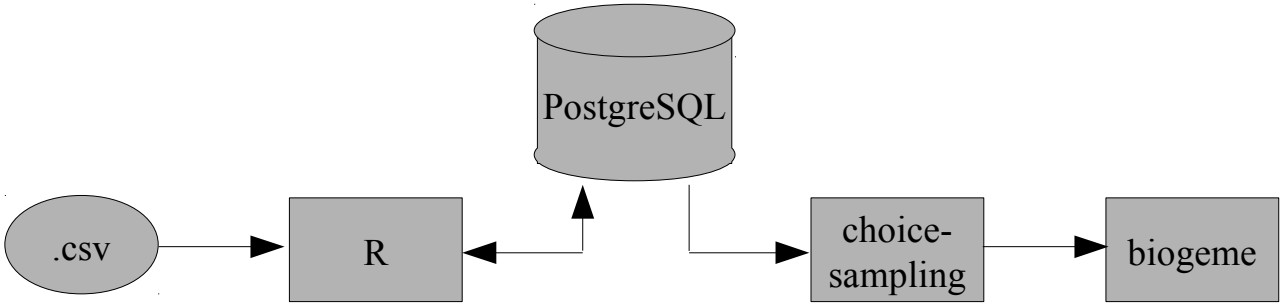
Source: Belart B. (2011)

Survey	A	B	C	D	total
Valid adresses	1‘207	1‘215	1‘209	1‘220	4‘851
response	263	286	257	302	1‘106
response [%]	23.4	25.9	23.6	27.1	22.8

Modelling Behaviour

Choice set sampling

- Non-chosen alternatives based on offers of an immobile-website (www.comparis.ch)
- Weighting of data
  - Comparis rent prices 15.5% higher than in survey
  - Comparis sale prices 16.5% higher than in survey
- Sampling strategy
  - Random sampling strategy (49 alternatives+ 1 chosen alternative)
  - Next stratified sampling strategy



Modelling Behaviour

Comparing to the microcensus 2005

	Survey 2010	MZ 2005 (weigthed)	*Difference*	MZ 2005 (unweighted)	*Difference*
Gender					
male	50.0	48.7	*1.3*	46.1	*3.9*
female	50.0	51.3	*-1.3*	53.9	*-3.9*
Age					
<18	0.0	*ignored*		*ignored*	
18-30	19.2	19.6	*-0.5*	16.1	*3.1*
30-40	31.9	19.1	*12.8*	18.6	*13.3*
40-50	22.0	19.9	*2.1*	18.5	*3.5*
50-60	11.6	16.5	*-5.0*	16.5	*-5.0*
>60	15.0	24.9	*-9.9*	30.3	*-15.3*
Nationality					
Swiss	89.3	80.0	*9.3*	84.8	*4.5*
other	10.7	20.0	*-9.3*	15.2	*-4.5*
Education					
Primary and secondary school	5.0	15.3	*-10.3*	*15.3*	*-10.3*
A-Levels (High-school graduation)	5.6	-	*5.6*	-	*5.6*
Apprenticeship	29.1	39.6	*-10.5*	*39.6*	*-10.5*
Master	17.8	5.4	*12.4*	*5.4*	*12.4*
College of education, technical college, university of applied sciences	19.6	16.3	*3.3*	*16.3*	*3.3*
University	18.5	8.7	*9.8*	*8.7*	*9.8*
Other/Missing	4.4	14.5	*-10.1*	*14.5*	*-10.1*

Modelling Behaviour

Comparing to the microcensus

	Survey 2010	MZ 2005 (weigthed)	*Difference*	MZ 2005 (unweighted)	*Difference*
income [CHF]					
<2000	1.5	3.4	*-1.9*	3.3	*-1.8*
2000 - 3999	9.0	16.3	*-7.3*	15.8	*-6.8*
4000 – 5999	16.5	23.0	*-6.5*	22.1	*-5.6*
6000 – 7999	17.7	17.2	*0.5*	16.5	*1.2*
8000 – 9999	14.9	10.2	*4.7*	10.3	*4.6*
10000 – 11999	11.5	*5.5*	*6.0*	*5.5*	*6.0*
12000 – 13999	7.1	2.7	*4.4*	2.7	*4.4*
14000 – 15999	7.2	1.5	*5.7*	1.4	*5.8*
>16000	10.3	2.3	*8.0*	2.2	*8.1*
Residential type					
Rent	76.7	59.6	*17.1*	57.0	*19.7*
Owned appartment	22.8	39.8	*-17.0*	42.5	*-19.7*
Business appartment	0.1	0.3	*-0.2*	0.4	*-0.3*
missing	-	0.3	*-0.3*	0.1	*-0.1*
Size of Houshold					
1.0	28.3	28.8	*-0.5*	28.8	*-0.5*
2.0	41.4	36.1	*5.3*	36.1	*5.3*
3.0	14.0	13.1	*0.9*	13.2	*0.8*
4.0	11.0	15.3	*-4.3*	15.2	*-4.2*
>4	5.4	6.7	*-1.3*	6.7	*-1.3*
Type of household					
One-person	28.3	28.8	*-0.5*	28.8	*-0.5*
Two persons/couple with no children	38.6	30.9	*7.7*	30.7	*7.9*
Single parent with children under 18	4.2	5.5	*-1.3*	5.7	*-1.5*
Family with children under 18	22.4	31.6	*-9.2*	31.5	*-9.1*
Multiple adult person household	5.4	3.2	*2.2*	3.2	*2.2*

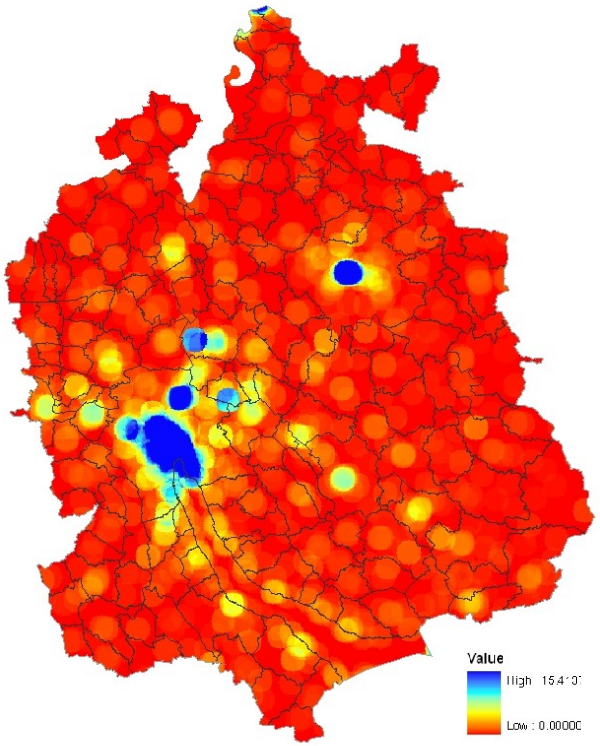
Modelling Behaviour

Enriching with GIS-data

- Geolocating via Google maps:
  - Current and previous residential location
  - Location of members of social network
  - Location of workplace

- Additional variabels on location through GRASS-GIS:
  - Scale of municipality
  - Scale of hectar (data of Bürgle)
  - Scale of parcel (centroid)

  - Data represents different base-years!



Number of jobs within 1km (per ha)

Modelling Behaviour

Enriching the data

Variablename	Reference year	Scale
Location variables		
Distance to primaryschool	2010	centroid of gridcell100mx100m
Distance to CBD Zürich	2010	centroid of gridcell100mx100m
Distamce to CBD Wintertur	2010	centroid of gridcell100mx100m
Distance to closest kindergarten	2010	centroid of gridcell100mx100m
Distance to power line	2010	centroid of gridcell100mx100m
Distance to lake	2010	centroid of gridcell100mx100m
Distance to shopping_facility	2010	centroid of gridcell100mx100m
aircraft noise	2009	
Households of size 'X' in radius of 1km (X=[1:10])	2000	gridcell 100x100m
Density of children (per ha in radius of 500m)	2000	gridcell 100x100m
Density of Population (per ha in 1km radius)	2000	gridcell 100x100m
Density of open space (per ha in radius of 2km)	2006	gridcell 100x100m
Density of jobs (jobs in retail trade; per ha in 1km radius)	2006	gridcell 100x100m
Density of jobs (jobs in hotel and catering industry;amount in 1km radius)	2006	gridcell 100x100m
Travel time to Bürkliplatz (car travel-time, regional transport model)	2008	link (matsim)
Travel time to Bürkliplatz (public transport)	2008	link (matsim)
Public transport accessibility (based on regional transport model)	2005	zone
Private vehicular traffic accessibility	2005	zone

Modelling Behaviour

Model Virani (rent)

Variable	β	t-test	p-value
Age of the House	1.02	8.75	0
Age of the House is unknown	*0*	*fixed*	
Jobs available in the municipality	-0.589	-13.11	0
Population Density (1 km) * Young Household Dummy	0.0266	7.1	0
distance to station	-0.293	-3.5	0
Proximity to previous location	6.52	21.74	0
Proximity to social contacts	6.24	2.18	0.03
Proximity to work	6.3	2.03	0.04
ETA previous location	-0.203	-9.08	0
ETA_sociqal contracts	-0.0291	-1.25	0.21 *
ETA_work	-0.0272	-1.31	0.19 *
Dummy of historical building (construction before 1941)	1.97	11.9	0
Log (net floor space divided by household size)	1.83	12.1	0
Accessibility to public transport * dummy of " no car available "	0.65	5.32	0
Rent Vacancy in the municipality	-0.213	-3.66	0
Ratio of rent to income	-4.99	-8.76	0
Rooms per person	-1.41	-23.46	0
Travel time to Burkliplatz by Car	0.0281	5.1	0
Number of observations	*685*		
LL(0)	*-2615.898*		
LL(max)	*-1170.4*		
ρ2	*0.563*		

Modelling Behaviour

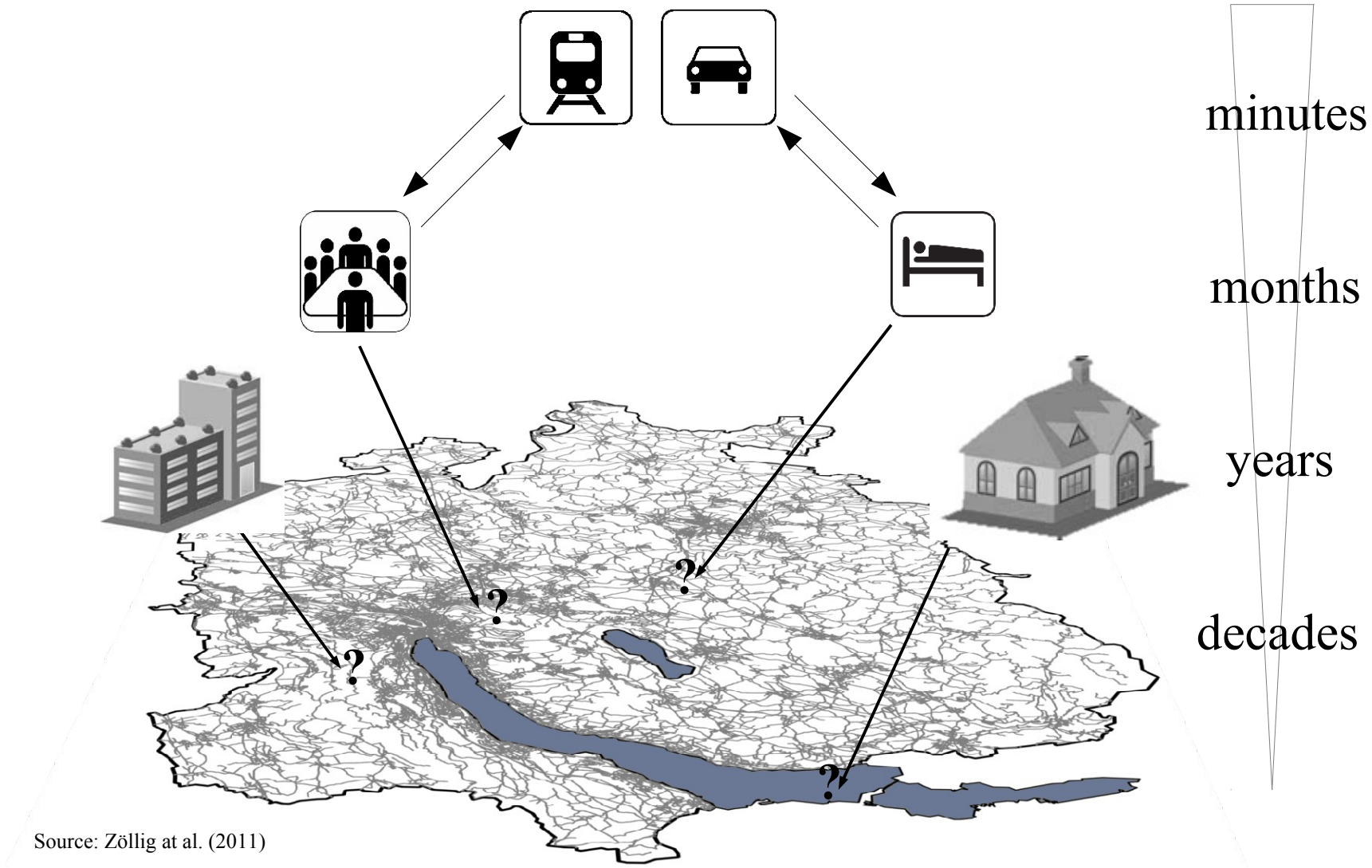
Further work

- Reestimate the models within the new framework
  - Include
    - Socio-spatial variables
    - Lifestyles
    - Search mode and previous location
    - Geometries
  - check for correlations of variables

- Enlarge the dataset for estimation through imputation of distance to social contacts

- Test different configurations of the choice-set-sampling
- Include results into UrbanSim

Urban Simulation



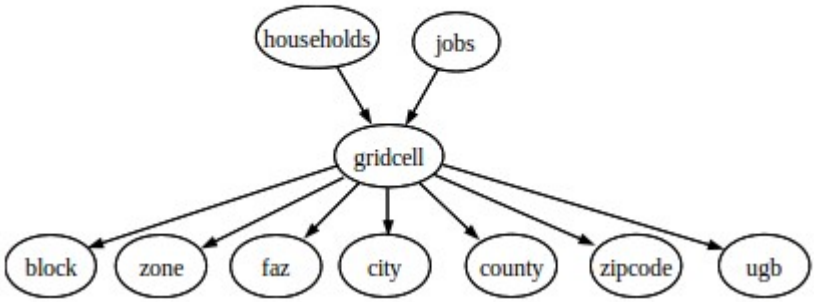
Source: Zöllig at al. (2011)

Urban Simulation

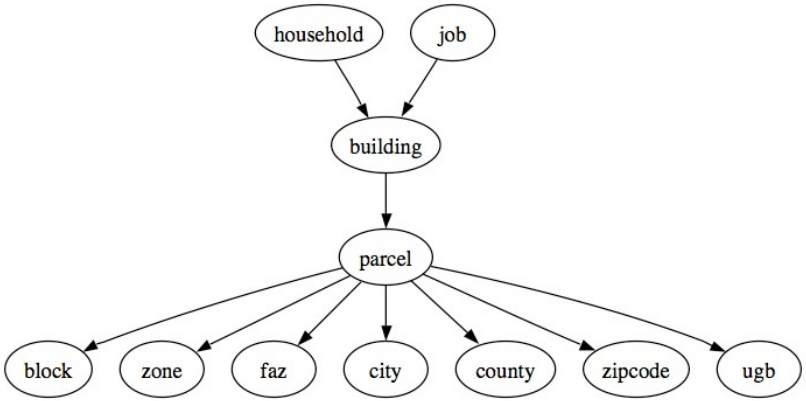
UrbanSim

- Opensource software developed by P. Waddell and colleagues (www.UrbanSim.org)
- Simulation of land use development with interaction to traffic and accessibility
- Microsimulation representing the choice of households, businesses and landowners
- Previously gridcell-based approach, now geometries (zoning and parcel) as reference objects
- Various case studies world wide (in Zurich: Zukunft Urbaner Kulturlandschaften, 2007)

(a) Basic model structure of grid cell versionv



(b) Basic model structure of parcel version

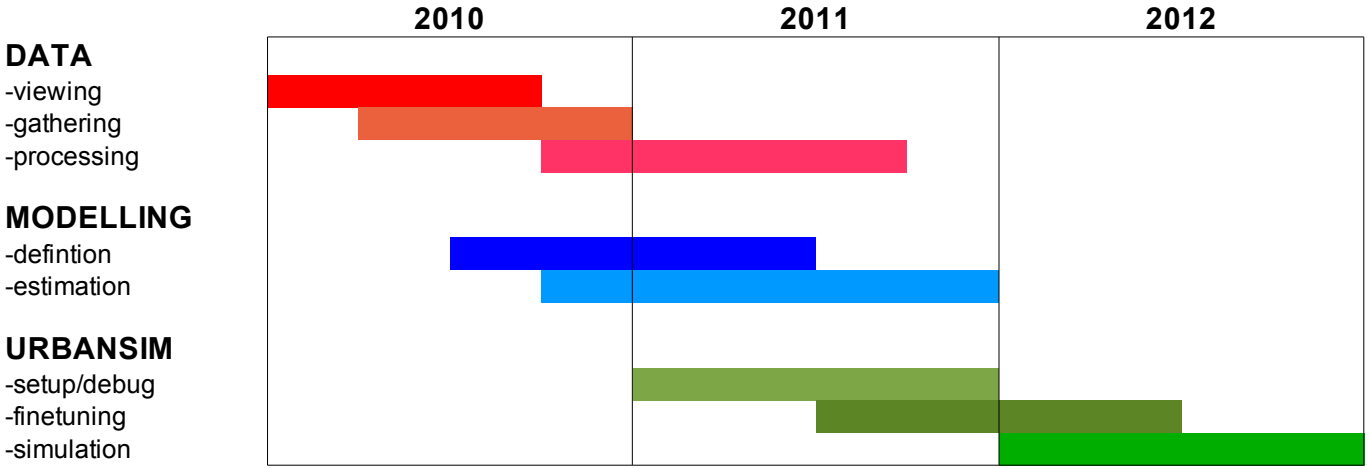


Source: Waddell, P. A. (2010) Overview of UrbanSim and the Open Platform for Urban Simulation, presentation, UrbanSim Tutorial, Zurich

Urban Simulation

Outline

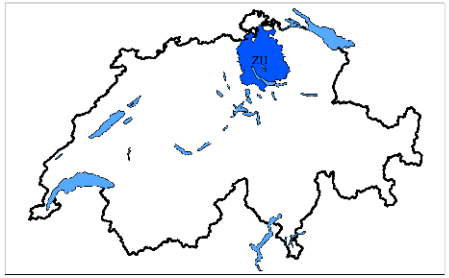
- Introduction SustainCity
- Basis data
- Data processing
- Modelling
- First UrbanSim run
- Conclusions and Outlook

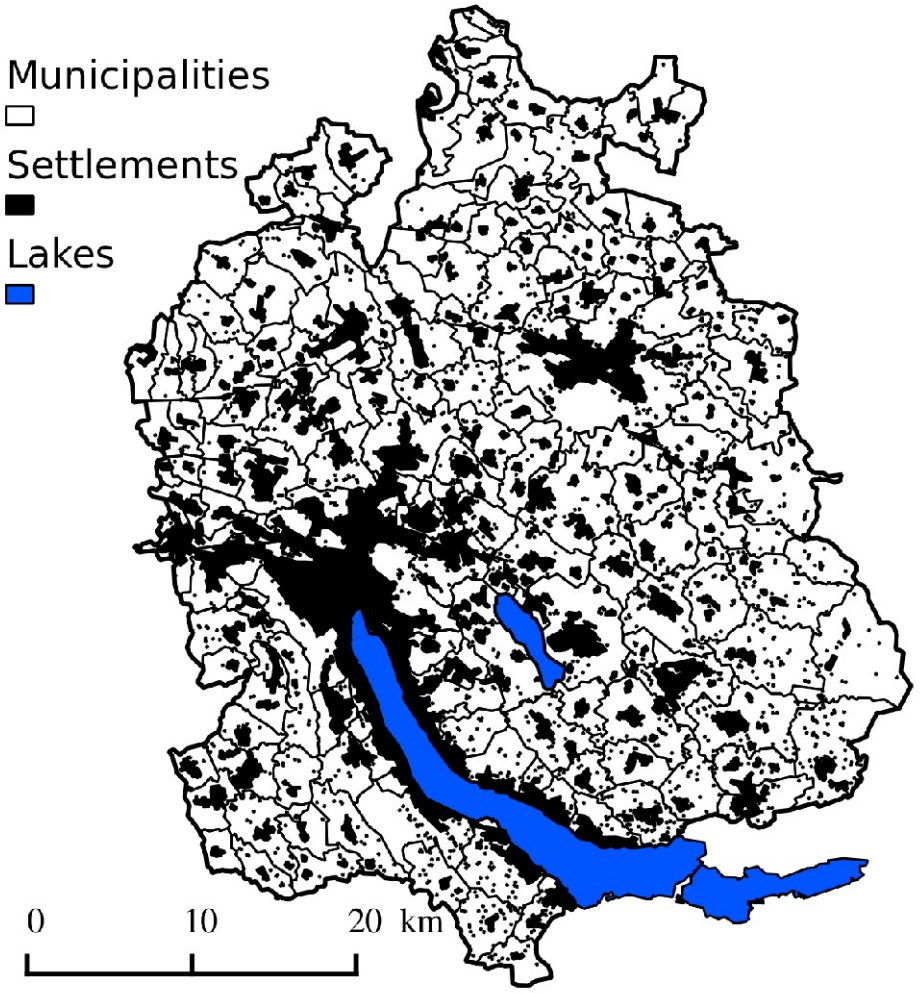


Urban Simulation

Simulation area and time period

- Simulation start: 2000
- Evaluation period: 2000-2010
- Simulation period: 2010-2030



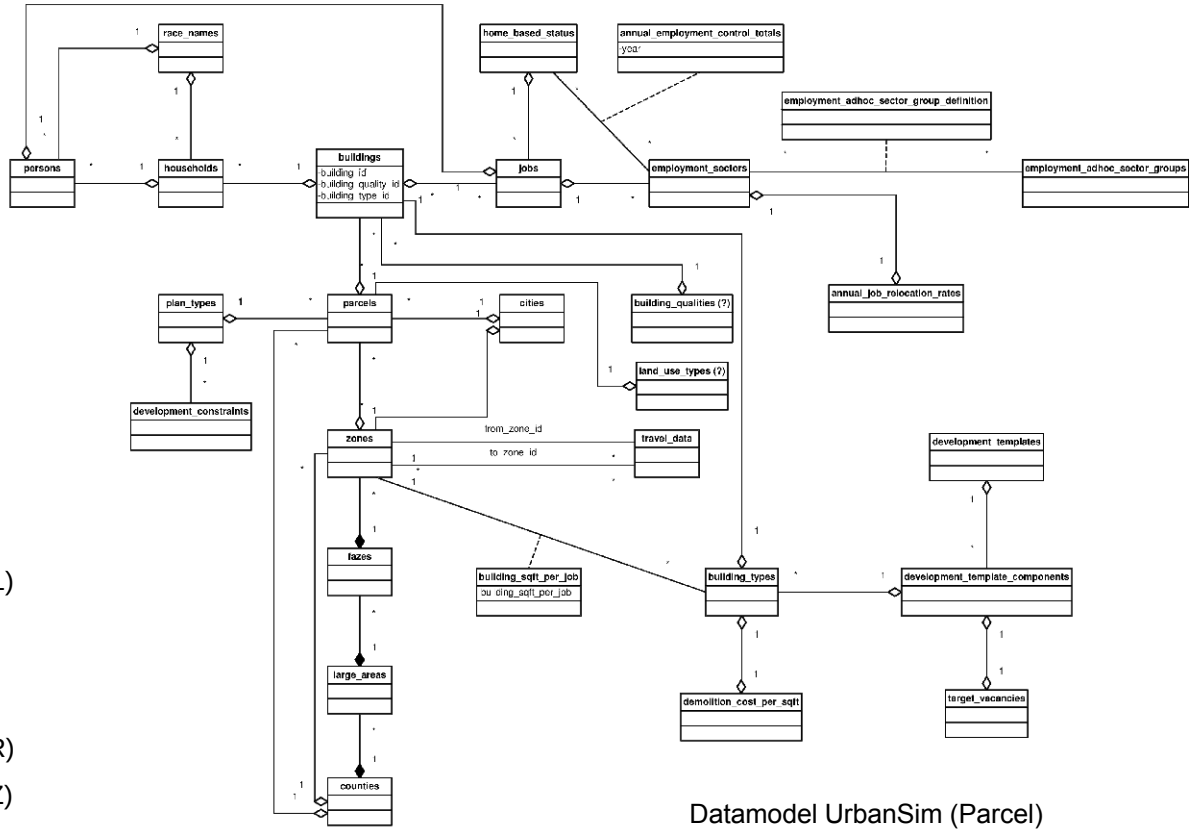


Source: Zöllig at al. (2011)

Urban Simulation

Basisdata (extract)

- Vectormaps
  - Parcels & Buildings
  - Soil coverage zones
  - Landuse zones
  - Traffic-zones (KVM & OeVM)
  - Networks & stops
  - Topography
  - Noisemaps
- Agent information
  - Population census (2000)
  - Micro census (2005)
  - Enterprise census (2001)
  - Various surveys of IVT (2000-2011)
- Object information
  - Residential building register (GWR)
  - Cantonal building assurance (GVZ)
  - Landprices (internet)



Datamodel UrbanSim (Parcel)

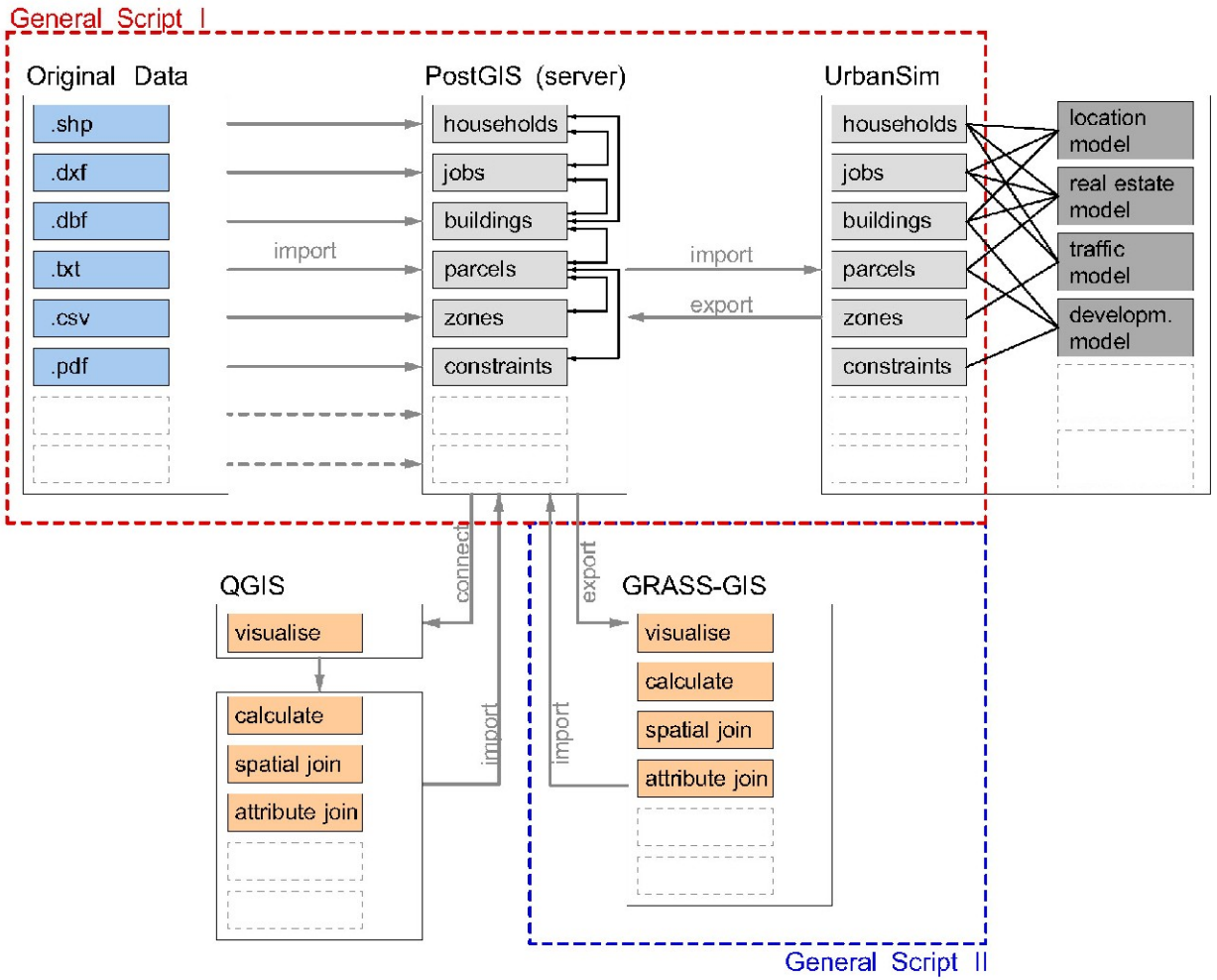
Urban Simulation

Calculation-routines: example plan_types

- **GWR/GVZ**
  - Housing units
  - Construction year
  - Value
  - …
- **Soil coverage zones (AV)**
  - surface information
  - buildings footprints
  - .....
- **Parcel**
  - size
  - FAR covered
  - ...
- **Land-use zone**
  - planning-constraints

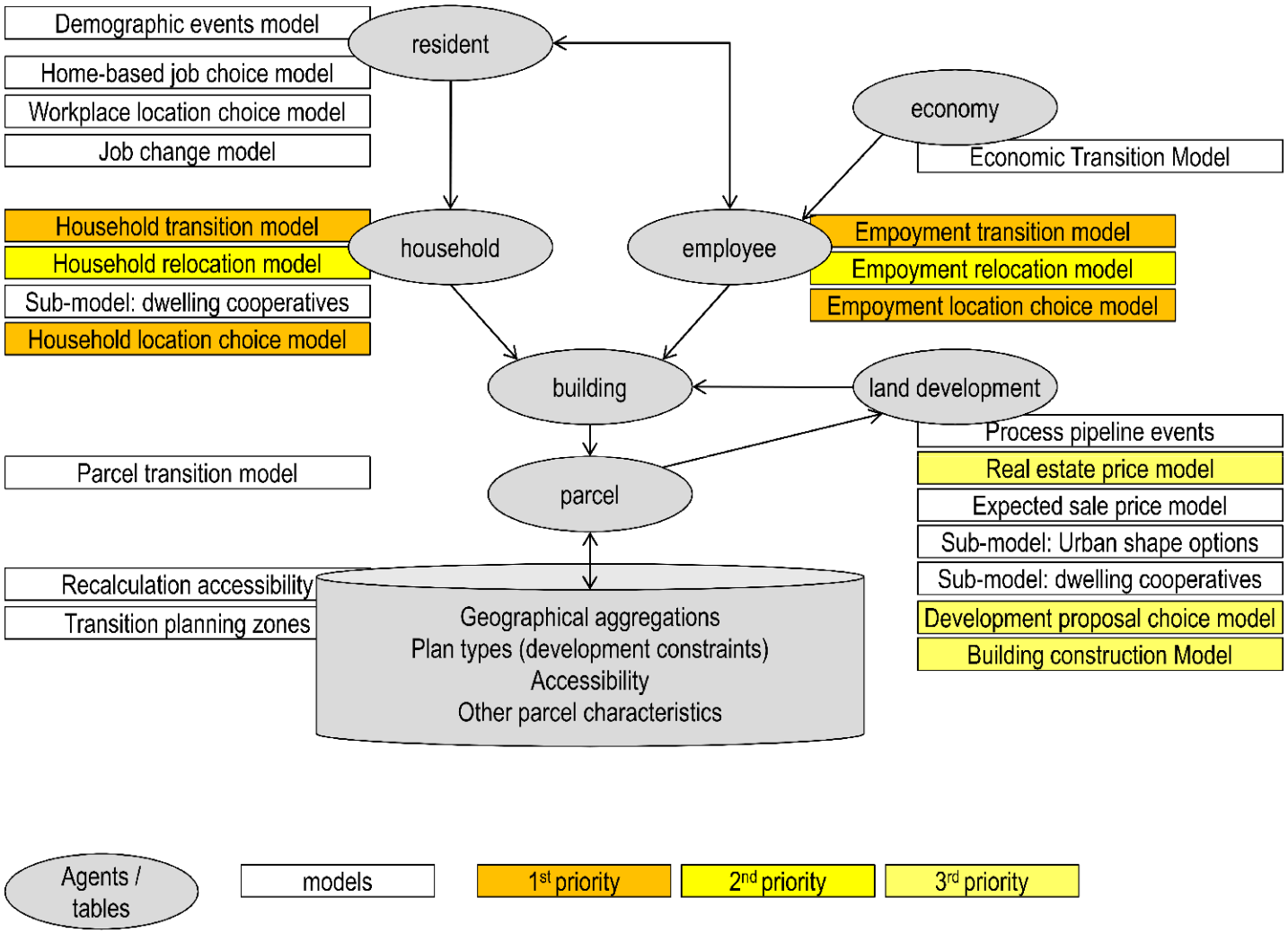
Urban Simulation

Framework SustainCity



Urban Simulation

Phase 1



Source: Bodenmann, B.R. (2011) SustainCity: Advancing land use transport interaction models in Europe, presentation at the *1st Symposium on Computation for Sustainable Architecture and Urbanism*, Zurich, July 2011.

Urban Simulation

Summary (current impression)

- Setting up
  - Basisdata (vector, agents, surveys, point in time)
  - Datamodel (dependancies, content)
  - Framework

- Working with UrbanSim
  - GUI/Python
  - Stability of software

- Simulation
  - Results ZUK very promising
  - Changes of geometry not implemented
  - Relocation of other than job/hh, e.g. public functions is missing
  - Limitations of model content through datamodel/data availability
  - Numerous variables for estimation through “database”
  - Output Indikators can be divers (population, jobs, prices, traveltime, ...)

Urban Simulation

Implementing planning projects

- Scenarios are defined through:
  - Control totals
  - Constrains/Zoning
  - Urban Layouts

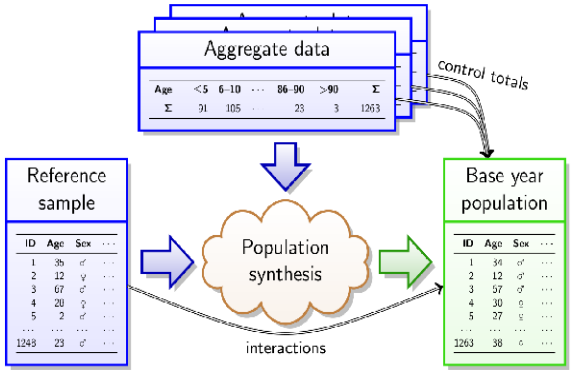
- Scenarios currently envisioned to test:
  - Stadttunnel Zürich
  - Limitation of settlement area
  - Flughafen Dübendorf
  - Rising mortages
  - Decreasing number of jobs in Zurich
    (decreasing number of immigration, smaller wages, maybe a collapsing housing bubble)

Urban Simulation

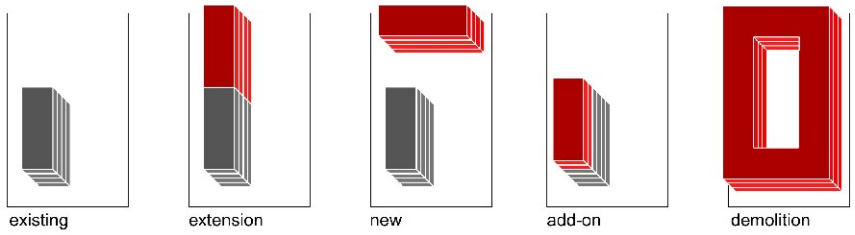
Ongoing work

- Extend models
  - Model for firmographics
  - Model for developers
  - Hedonic pricing
  - Implementing shape information
    - behaviour of agents
    - options for objects
    - visual output?

- Simplify setup
  - Population synthesis
  - Initial setup?
  - Implement Design Proposals?



Source: Müller K. and K.W.Axhausen (2011)



Location choice

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