MONITORING, MAPPING AND MODELLING URBAN DECLINE: A MULTI-SCALE APPROACH FOR LEIPZIG, GERMANY

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ABSTRACT

Urban remote sensing research and approaches to modelling residential mobility focus predominantly on growth patterns. In this paper, the phenomenon of extreme urban decline, named 'shrinkage', is scrutinised. The different characteristics of urban decline are illuminated using a multi-scale approach. Selected patterns of the spatial growth and shrinkage are first calculated by means of satellite imagery for the City of Leipzig, Germany. Here, Landsat data for 1994 and 2005 provide information regarding different phases of urban land use dynamics, thereby revealing a pattern of spatial expansion into the peri-urban surroundings. In addition, potential drivers of this detected pattern are investigated through analysis of municipal statistical data, at the local district level, providing evidence that urban growth in general and particularly shrinkage are results of population fluxes and migration. Because urban shrinkage can be found in both the central and peripheral parts of Leipzig City, an even more detailed scale, using a very high resolution (VHR) colour-infrared data set has then been integrated with the local district data, in order to achieve detailed information on intra-urban differentiation of both urban structure and fabric. Finally, using predictor variables such as fertility, life expectancy, migration and residential preferences, a prototype model approach is presented that analyses recent patterns of residential use and the related building vacancies that characterise the housing sector of a shrinking city.

Keywords: Urban remote sensing, urban decline, shrinking city.

INTRODUCTION

The scientific background of urban shrinkage and demographic change in former industrial regions

Tremendously high dynamics of urban change can be observed in the recent development of many Northern American and European cities: here, growth and decline processes occur simultaneously. On the one hand, in this particular case suburbanisation along with an expansion of residential and commercial areas occurs at the urban fringe. On the other hand, it simultaneously interacts with a declining population and a stagnating economy: a consequence of de-industrialisation. In the last 50 years, about 370 cities with more than 100,000 inhabitants have undergone temporary or permanent population losses of more than 10%. In extreme cases, the rate of loss reached peaks of up to 90% (Âbâdân, Iran) (1).

As a particular case, compact cities in Europe are faced with this diverging style development: in their inner parts we find a declining population (density) and, consequently an enormous increase of residential and commercial vacancy. This process stands in a fierce contrast to the continuous land at the periphery that is being built-up. As a result, such 'shrinking cities' are sprawling at their fringe and thus represent an urban form that is far from being sustainable. On the contrary, an uncontrolled perforation of the inner urban space can be observed in many recently declining cities (2). Accordingly, neither the paradigm of growth-driven development nor the related well-established planning instruments work here. However, if seen as a kind of 'counter development' this decline might be a chance to minimise the amount of future land consumption while restructuring the inner parts of a shrinking city by redeveloping areas of residential vacancy as well as increasing the settlement density and by reusing and recycling urban brownfields. Thus, new and attractive urban spaces could be created (3).

Today, the number of depopulating and shrinking cities is increasing. Moreover, this is expected to be a lasting phenomenon. Between 1950 and 2000, for example, the number of shrinking cities increased by 330 %, whereas, among cities with more than 100,000 residents, there are only 240% more as compared with 1950 (1). Thus, we find that, despite growth being held high on the political agenda, the number of shrinking cities has actually increased faster than the number of boomtowns.

Most cities declining during the last 50 years are located in western industrial countries, particularly in the US (59), the UK (27), Germany (26) and Italy (23) (4). Since 1990, shrinking cities have increasingly been found in the states of the former socialist Eastern Europe such as in Russia (13), the Ukraine (22) and Kazakhstan (13). Between 1950 and 2000, there have also been an above-average number of shrinking cities in South Africa (17) and Japan (12). But ‘hot spots’ of this phenomenon have been in Europe and in the USA. Shrinkage will also emerge in the growing conurbations of the developing world. In 35 years, less than 10% of the world's population will live in Europe or in the USA and some of the southern countries will be facing a general decrease in population, too (1).

Research objectives

The processes and pattern of decline highlighted in the introduction need to be observed and explained in terms of their spatial fingerprint, particularly in built-up structures intended to support sustainable management decisions. A methodological challenge and thus the focus of this paper is to develop an integrated multi-scale monitoring, mapping and modelling system in which remotely sensed land use information and demographic data taken from the municipal statistics (e.g. local neighbourhood, statistical district, city level) explain spatially, correspond scientifically and coincide with the development of a predictive model for the further development of residential mobility and vacancy.

The potential of a combined urban monitoring and modelling approach is analysed. This is realised using (high resolution and VHR) remote sensing data to detect land use change, social statistics, in order to prove that population change and migration have a predictable impact. Finally, an agent-based spatially explicit model is used to figure out the effects of this demographic change for residential use and building vacancy. First, using remote sensing land use information and social science data predictor variables and properties for the agents (urban residents) are identified. Second, they are integrated into a rule-based model programmed in Java. Here, it will be discussed to what extent social science knowledge can be brought together with quantitatively based remote sensing methods, to feed such a model (5). The scales of work range from the total area of the city, to the intermediate unit of the urban local district, down to urban structure types and single buildings.

In terms of the results achieved, the location of the growing and shrinking parts of the city will be shown. Moreover, the analyses presented here give an indication as to why understanding urban shrinkage requires both updated observation instruments / methodologies as well as spatial data integration procedures for model development. The paper draws on empirical evidence from eastern Germany where dramatic shrinkage processes in terms of economic decline and depopulation have been occurring since 1990. As stated before, the model approach concentrates on residential vacancy and shrinkage processes and does not, so far, touch the economic shrinkage and brownfield development.

Case Study: Leipzig, eastern Germany

The City of Leipzig provides the empirical context for our investigation, since it is an illustrative example of a city with negative demographic figures and a decrease in population, accompanied by numerous features of an economic decline. The main processes and patterns of the “shrinking”

Leipzig can be summarised in a dramatic decrease in birth rates that took place after the German reunification in 1990, an extreme loss of residents due to missing labour opportunities and high unemployment rates, and a decline of the inner urban population density due to suburbanisation processes (6).

More than a century ago the city experienced a period of vibrant growth from the 1870s to the 1930s, making it the country's fourth city when it reached its population peak with more than 700,000 inhabitants. An artificial economic push was launched right after the German reunification in 1990 with enormous institutional subsidies intended to attract capital and investments into eastern Germany (7). Combined with high unemployment and out-migration these financial incentives led to substantial misinvestments and had negative spatial development consequences, namely fostering a widespread and unbalanced urban growth or sprawl. As a consequence of expired investment promotions further residential suburbanisation is today also about to decline.

- As a result, apartments and houses fall vacant. Residential vacancy is no longer restricted to uninhabitable and dilapidating housing stocks but also to completely renovated dwellings and building complexes. The supply outweighs the demand even if, at present, household numbers still continue to rise. Some residential districts exhibit vacancy rates higher than 30%, a few even exceed 50% (own investigation).
- This severely negative und unsustainable development of the housing sector has brought up the discussion of demolition of whole housing stocks. As a new strategy, a federal program of urban restructuring and demolition was launched (8). It operates in terms of a guideline to organise and finance both, to demolish overhang of (vacant) housing stock and the revaluation of the remaining residential areas. Furthermore, the analysis of this program represents a scientific challenge, requiring techniques suitable for examining urban monitoring and modelling procedures intended to support the implementation of such a policy.

METHODS

Urban monitoring using remotely-sensed data

Remote sensing plays a valuable role in mapping and characterising urban agglomerations: their growth and decline as well as environmental effects and impacts of urbanisation phenomena (9). In this case study remote sensing is applied on two levels to give insight into the development and the structure of the City. First, Landsat TM data were used to analyse the regional urban system, to give quantitative measures and their local distribution concerning the different land uses identified for Leipzig, and to register the major changes and dynamics of growth and shrinkage patterns. Second, ColorInfraRed (CIR) images were taken because such data facilitate improved discrimination between attributes in the dense and heterogeneous milieu of the old urban cores that are characteristic of European cities. This data set helps to disentangle the urban fabric in these rapidly changing urban spaces (10).

The urban milieu poses far greater problems than the non-urban systems, in that identical spectral reflectance values can correspond to very different land uses and their functions. Hence a direct relationship between the spectral response and land cover (e.g. vegetation, water) is not prominent in this environment (11,12;13). So beyond land cover classes, which can be directly observed, land use classes are defined using expert knowledge. Mappings of land use and its changes were taken from the Landsat satellite series. For 1994 Landsat TM imagery was available (21/07/1994) and for the year 2002 a Landsat ETM scene was used dated from 20/08/2002. For the City of Leipzig these two sets of satellite images were utilised to follow the spatial development over the period of 1994 to 2002 and to observe land use changes within a very dynamic time period of spatial expansion and continuous population loss, as described above. In order to map land use a Maximum-Likelihood classification was carried out for each image. So a quantitative measure was gained for the proportion and distribution of different land use / land cover classes for two time slots. The overall accuracy of this Maximum-Likelihood classification is about 85% for the year 1994 and approximately 82% for 2002 (14).

Table 1 shows the significances of the accuracy of the different land use classes for the two time slots. The major difference between the results achieved for the two acquisition dates is that in 1994 the climate conditions showed a hot and dry summer whereas in 2002 the images were taken only two weeks after a severe inundation of rain in east Germany. So the spectral response of the soil varied immensely. In particular, either parks and grassland or bare soil were wrongly assigned as farmland. The main goal, however, was to distinguish the built-up class from pervious land use and land cover classes, and to gain information on the amount and directions in which the city was growing and shrinking.

Table 1: Accuracy assessment in 1994 and 2002.

Land use	**User's Accuracy**		**Kappa coefficient**	
	1994	2002	1994	2002
Water	98.4	100.0	0.9347	1.0000
Urban Woodland	82.7	75.4	0.8139	0.7104
Parks/ Grassland	88.3	88.5	0.8585	0.8656
Farmland	73.7	69.6	0.6998	0.6796
Impervious Surface	84.1	78.6	0.8087	0.7284
Bare Soil	84.0	80.3	0.7963	0.8004
Overall accuracy	85.2	82.1	0.8186	0.7974

Figure 1 shows the spatial distribution of the most significant changed land uses and assigning *from* and *to* which land use class the changes occur. Change detection highlights suburbanisation processes with inherent growth patterns and the expansion of impervious surface for large and adjacent areas at this spatial scale. Spatially less remarkable land use variations in more central urban districts are characterised by a high building density. Some of these areas are 'shrinking' today. However, it is problematic to detect this using the change detection methodology on the city scale. This process underlies environmental and economic impacts that take place on a larger scale and which have been detected using CIR orthophotos. So, at the city scale, the most significant changes are portrayed in a kind of belt around the central part of the urban area where the city is growing in terms of residential, commercial and transportation land uses. The share of farmland and arable land is decreasing in favour of new impervious surface for urban land.

A range of different change detection procedures comprises multispectral change detection methods, as well as change detection through spatial / textural / numerical analysis (15;16). Some of them, such as the concepts and uses of fractal dimension and spatial autocorrelation indices can be applied to change detection using uninterpreted or unclassified images. In the context of this study the quantified land use portions were of interest for each time slot so each image was classified first and then the post-classification comparison was calculated. The uncertainties of this method are that the accuracy of the change class information depends on the accuracy of the registration of multi-date images as well as on the accuracy of the separate single-date classifications (17). To achieve success two rules are paramount: First, using identical classification procedures for both dates, and second, using the same information classes for both dates (18). The remote sensing monitoring on the overall city scale gives insight regarding growth rate and growth distribution. Then, a further in-depth study is carried out in the second part of the remote sensing research concentrating on the object-oriented CIR classification on a very large scale.

The classification and change detection results were then overlaid over the socio-demographic data (see section "Mapping demographic change and de-concentration" and Figures 3 and 4). The purpose was to determine if the changes in the built-up structure of Leipzig correlated with the social, demographic, or economic indicators. These indicators are mapped on the scale of local districts which correspond well to the derived classifications. This meant that the areas of high dynamics could be discerned. This analysis revealed that growth rates in suburban impervious surface and thus in new buildings and infrastructure go along with an increase in population figures in the very same local districts but that the high inner urban imperviousness and building structure the very same local districts but that the high inner urban imperviousness and building structure did not correlate with population figures and density any more (19).

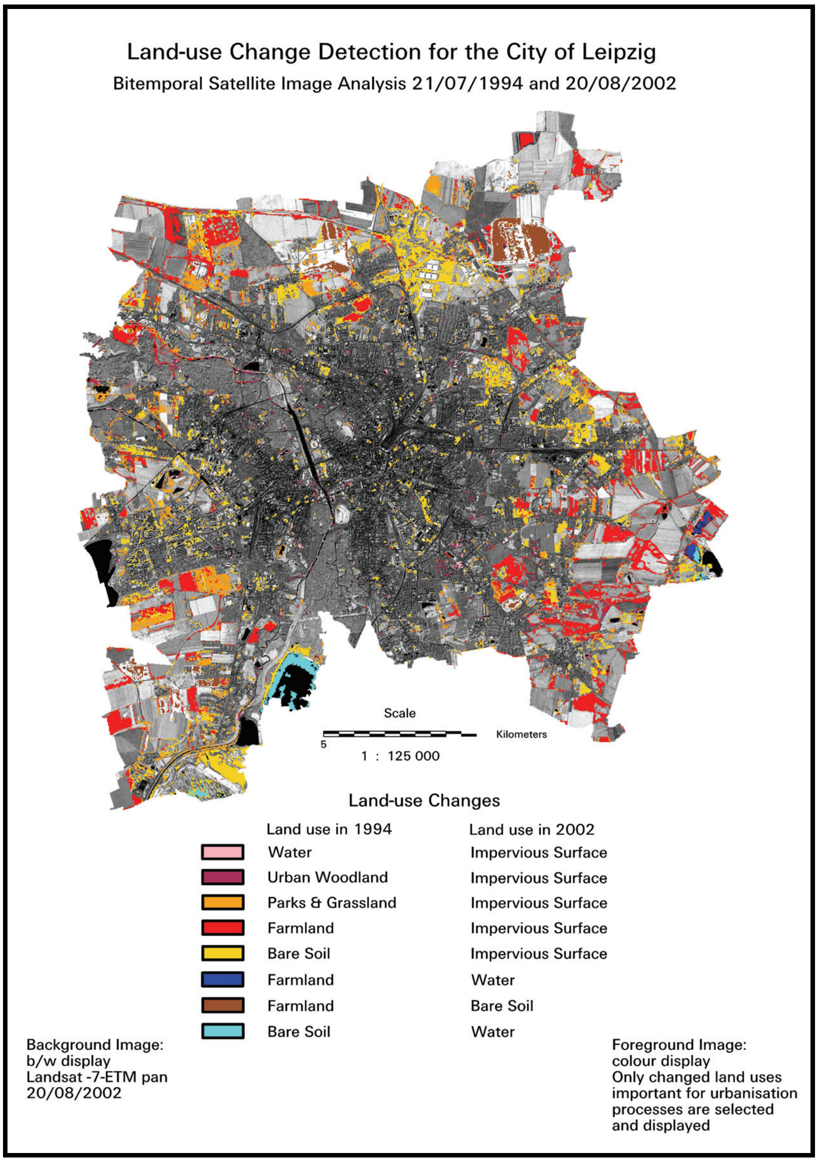


Figure 1: Change detection based on two classifications from Landsat data 21/07/1994 and 20/08/2002.

A more detailed RS data set is needed in order to monitor and analyse the land use information of the sample city, especially the information regarding the urban fabric, at the scale of each individual local district. Therefore, ColorInfraRed (CIR) imagery from the 29/07/2002 is used to calculate the different forms and structures of the built-up and natural land within the city by means of an object-based classification approach (20). The classification shows that single buildings can be extracted and that the type of the building can be assigned. The object identification procedure can also be applied for land cover types such as water bodies, natural vegetation and paved surfaces that do not belong to buildings because the imagery possesses a ground resolution of 40 cm. With variations between the different municipal districts classified, an overall accuracy rate of 82% was achieved. This classification represents the period in time before most of the demolition of vacant housing stocks started (2003/2004) (20).

This object-oriented classification was overlaid with digital ATKIS (Official Topographic-Cartographic Information System of Germany) data, updated in 2006, which served as a base for a ground-truth mapping undertaken in 2005, and was used to check the building inventory, and to quantify and localise the demolition sites for the period 2002 to 2005 (Figure 2 and Table 3).

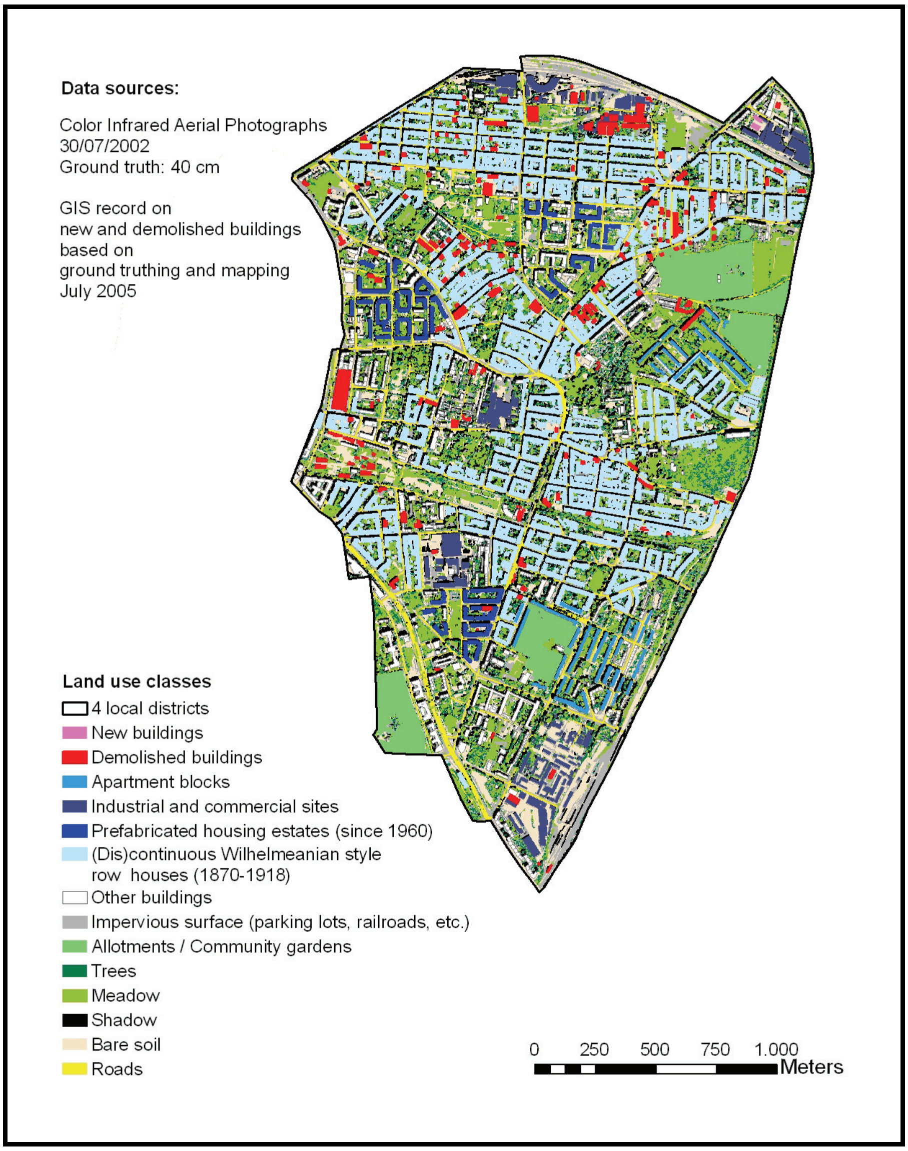


Figure 2: Classification of four local districts in the eastern part of Leipzig using digital CIR photos. Changes in the existence of buildings such as "demolished buildings" and "new buildings" are taken from GIS data sets

Regarding the challenges of urban planning and the goal of a compact urban body, the focus of the statistics is laid over the quantity and urban fabric of demolished houses. The total area of building cover is approximately 112 hectare and makes up about 20% of the total area of the four local districts. The area of impervious surface includes streets, parking lots and other paved facilities that do not belong to buildings. Together with open spaces this area covers the largest part of the test site at approximately 80 % of the total area. The largest proportion of demolished houses is taken by the Wilhelmeanian style row-to-row houses at more than 60% of these demolitions. This is due to the fact that in the eastern part of Leipzig ("east side"), which is the location of the test site, renovation of this type of building happened rather late in comparison with other parts of the city. Statistically, in the category of derelict land, this structure type is followed by industrial and commercial sites, which represent about 28% of all demolished buildings (Table 2) (20). It is hard to make these sites attractive for redevelopment because the city infrastructure now offers better access for commercial sites in suburbia than for those in the more central parts of the city. The overall result of about eight hectare of demolished houses is a high amount of rapidly created open spaces. However, hardly any demand on new buildings and new development of these open spaces has taken place. So there is now a plentiful supply of open spaces for redevelopment and a chance for a difficult area under demolition to change its face (21).

Table 2: Portion of built-up land use in 2002 (derived from CIR imagery)

Land use in 2002	**ha**	**%**
Total area of buildings	112.02	20.59
Total area of impervious surface and open spaces	432.25	79.41
Total area of 4 local districts	544.27	100.0 0

Table 3: Portion and type of demolished buildings between 2002 and 2005

Demolished buildings	**ha**	**%**	**Portion of total area of buildings in %**
(Dis)continuous Wilhelmeanian style row houses (1870-1918)	5.06	62.49	4.53
Prefabricated housing estates (since 1960)	0.06	0.71	0.05
Industrial and commercial sites	2.27	28.06	2.04
Apartment blocks	0.29	3.59	0.26
Other buildings	0.42	5.15	0.35
Total of demolished buildings	8.10	100.00	7.23

Mapping demographic change and de-concentration

When analysing and explaining the detected land use changes (as given in Figure 1) socio-demographic statistical data for the Municipality of Leipzig have been studied for 1994 and 2002. Assuming that, beside the economic variables, demography is the other main driver of urban, particularly urban residential, land use change, including changes in its spatial configuration, the demographic change between 1994 and 2002 were investigated. Based on the statistical data of the Office for Statistics and Elections of the City of Leipzig the population change between 1994 and 2002 was determined for two spatial levels: for the whole city and for each of the 63 local districts. With respect to the most important reasons for population decline, migration is one of the top-most drivers. So, migration, including its dynamics, was analysed for 1994 and 2002. Comparing both changes of population and the balance between in- and out-migration, it was possible to find out the spatial distinctions in the demographic development at the level of local districts and to study their interrelations.

Many eastern German cities have undergone a substantial land use change since 1990. This process corresponds strongly with an extreme demographic change. Based on the total population change and migration time series data provided by the Municipality of Leipzig, the overall demographic development is given in Figures 3 and 4. Having quantified the statistics and overlaid them with these spatial units it becomes obvious that the City of Leipzig is a shrinking city as the combined result of a drop in fertility and a massive out-migration since 1990 (statistically proved since 1994). The decline is accompanied by a smart growth at the urban fringe. This contrasts sharply with the total population figures: 521,539 inhabitants (with primary residence) lived in the 63 local districts in 1994, whereas in 2002 the total population of Leipzig decreased to 481,025 inhabitants. This is an overall decrease of 40,514 residents within less than ten years and corresponds to a population decline of 7.8%. The 37 inner-city districts belong to the most substantially declining districts due to a migration to the other more peripheral 26 local districts (see Figure 3). This reflects the spatial process of suburbanisation found in the change detection analysis of the satellite imagery. Until 1998, out-migration clearly exceeded in-migration.

In 1999, this trend stopped. What is more, since then, Leipzig has turned around to have a (slightly) positive migration balance. In addition to the overall migration balance an internal migration within the city, at district level occurs, and has increasing importance (22). This internal residential mobility is of great interest when explaining and modelling residential patterns and respectively, residential vacancy. Modelling these residential patterns means finding out why certain districts are preferred over others when rental costs are generally at a low level everywhere. As an overall observation suburbs today do not grow as much as in the mid 1990s. Extreme contrasts are observed in the central inner municipal districts, where residential vacancy and subsequent demolition of houses is taking place opposite vital districts undergoing considerable regeneration activity.

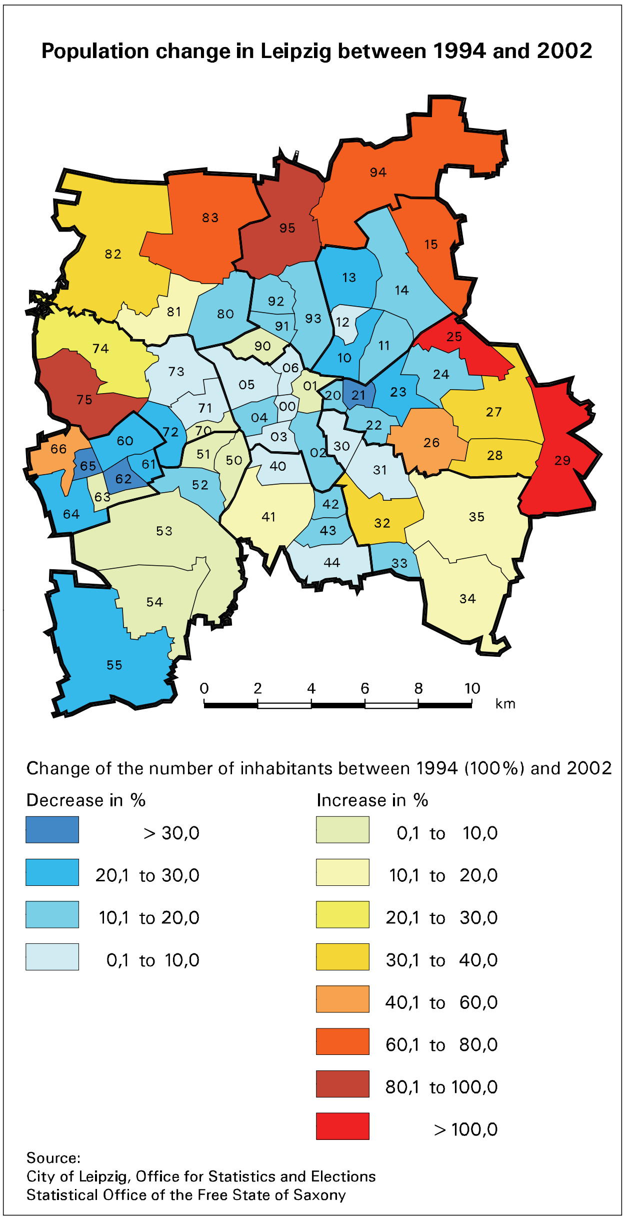


Figure 3: Population change in Leipzig between 1994 and 2002 based on municipal statistics.

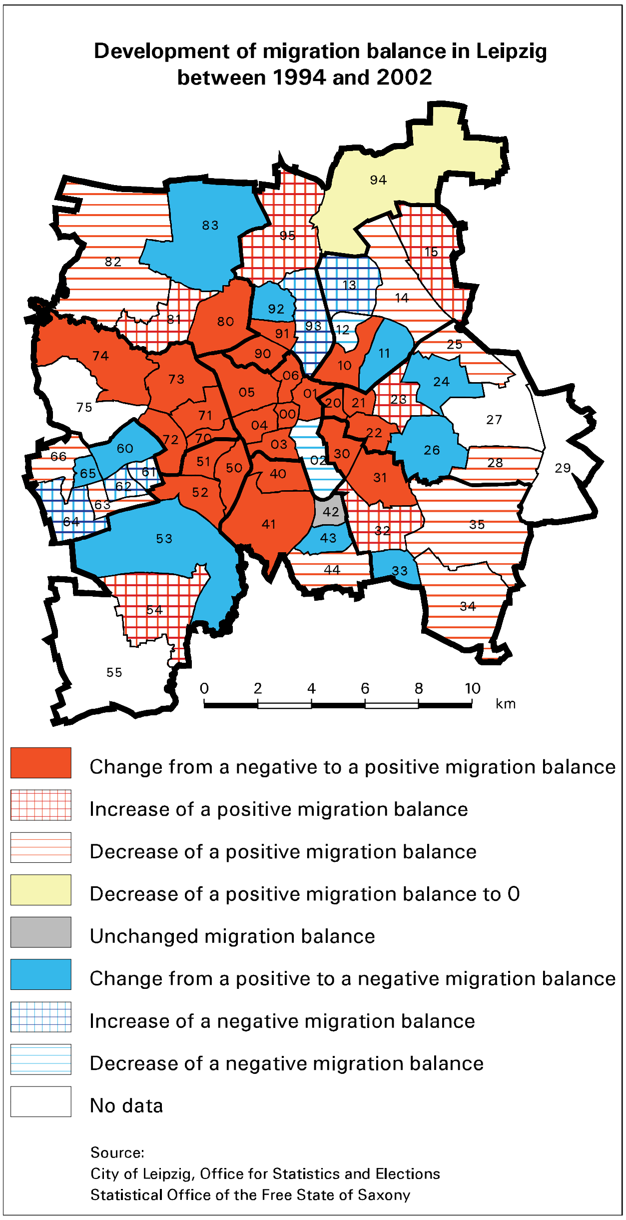


Figure 4: Migration balance in Leipzig between 1994 and 2002 based on municipal statistics.

Modelling residential mobility and residential vacancy under conditions of shrinkage using spatial and socio-demographic predictor variables

In order to analyse land use change and particularly the demolition of the urban fabric in shrinking cities, models can be used as innovative tools to support urban spatial planning, with scenarios being fed from monitoring data, which are thus based on ground truth and empirical evidence (23). Frequently used approaches in urban modelling, which deal with interactions between urban land-use changes and their socio-economic driving forces are, among others, logit models of discrete choice (24), more or less complex cellular automata (CA) models (25,26), and rule or agent-based models (ABM) (27,28,29). Most CA and ABM model-applications, however, deal with urban growth as the predominant form of urban development, whereas the process of urban shrinkage and related residential vacancy still remains outside of the focus (30).

Shrinkage, as an issue for urban modelling, requires additional agent-based, i.e. household-related knowledge and ideas about the spatial effect of migration processes in a depopulating city, if one is to explain the creation of massive stands of residential vacancy. A model approach has to focus on predicator variables and indicators that set the demands of the households into relation with the supply of housing space. Further the model needs to be calibrated with annual municipal data on population growth (fertility – mortality + migration). In doing so, such a model uses evidence provided by quantitative socio-demographic statistics as discussed in the previous section of the paper. The spatial implementation of different housing types in the model, such as apartment blocks or (dis)continous Wilhelmeanian style row houses, is based on data from time series created using the satellite imagery change detection maps presented in section 1 (Figure 2). In order to create knowledge on development and progress of residential vacancy as a function of residential mobility under conditions of excess apartment supply, an innovative ABM framework is formulated working with household types and residential choices. For these model components the above discussed spatio-temporal land use data and socio-demographic analyses are utilised (Figure 5).

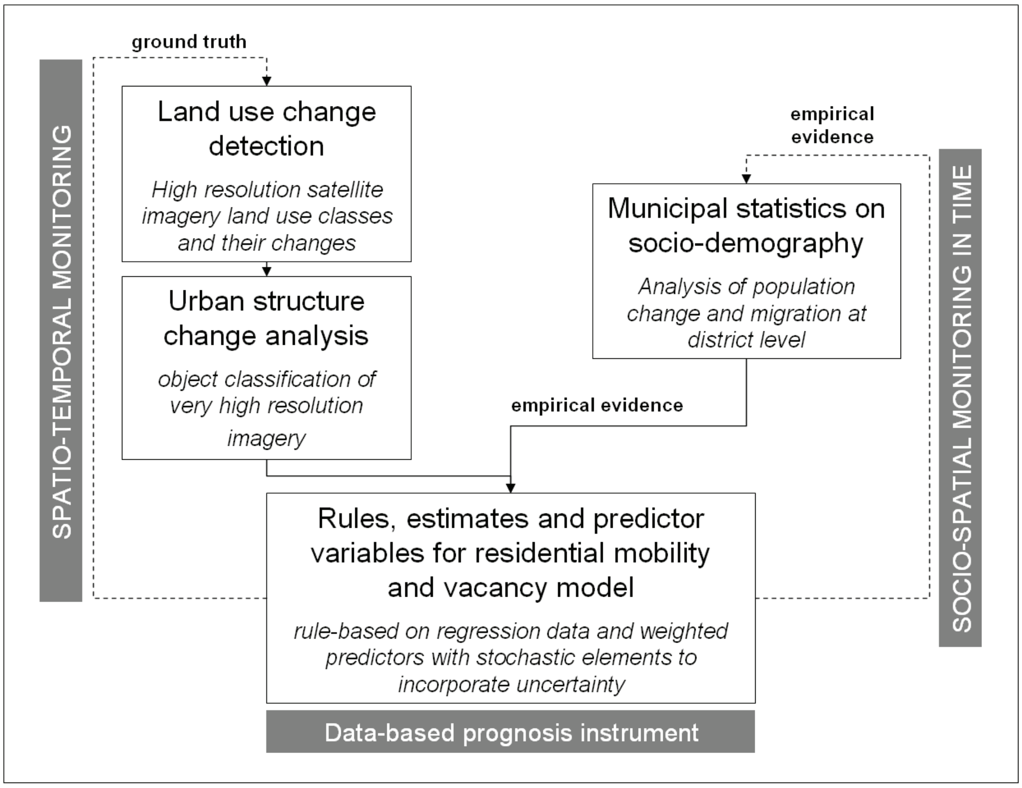


Figure 5: Model concept to operationalise residential mobility.

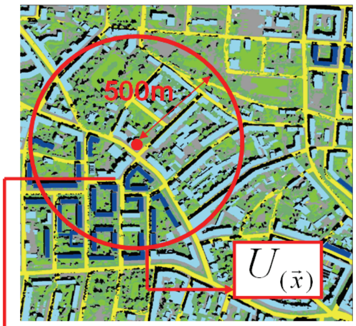
Due to empirical findings of sociological surveys (31) new age groups and household forms have been identified as crucial socio-demographic factors of residential mobility under shrinkage conditions. Furthermore, recent research has brought up the observation that households act as nexus points between changing demographics and residents' housing preferences and thus households are the agents of the housing markets (32). Therefore, they represent the agents in the model.

In a first step, a population model translates cohort-based population development into household types (singles, cohabitation "dinks", patchwork families, single-parent families, elderly cohabitation households, flat-sharers). Here, we achieve a very good accordance with municipal statistical data of Leipzig from 1994 to 2005 (33). An attractiveness indicator matrix on housing preferences for each household (social neighbourhood, housing form, prices, security, transportation, greenery, social infrastructure, shopping facilities etc.) at municipal district and building level is used to formulate a preference-restriction profile for each model agent to simulate their residential mobility (Figure 6). According to the ranking of the variables out of municipal statistics and the questionnaire survey, each indicator has been weighted randomly within a restricted range of values (Figure 6). As the main output of the model we achieve an annual household and cohort distribution for each house for the whole city of Leipzig, which gives us a number of vacant flats and, on that basis we can calculate a demolition rate for each municipal district (cf. again Figure 5).

Attractiveness (A_h) of a residential unit (house) $U_{(\vec{x})}$ for a household h:

$$A_h(\vec{x}_0) = \sum_{k=1,2,..} w_{h,k} I_k \left(U_{\vec{x}_0}(\vec{x})\right)$$

$$\sum_{k=1,2,3,...} w_{h,k} = 1$$



Object class based on CIR photos

I_1	: social milieu	(w = 0.27 … 0.32)
I_2	: urban structure type	(w = 0.18 … 0.21)
I_3	: social infrastructure (educational, shopping facilities,…)	(w = 0.08 … 0.12)
I_4	: accessibility to urban green (distance to next park,…)	(w = 0.08 … 0.12)
I_5	: security (% of crimes per land parcel)	(w = 0.04 … 0.08)
I_6	: noise, air pollution (mg/kg; dB)	(w = 0.04 … 0.06)
I_7	: travel distance to work (location of working place)	(w = 0.14 … 0.18)
I_8	: travel costs (transport means, infrastructure, …)	(w = 0.18 … 0.22)
I_9	: housing costs (rent, property estate, land market, …)	(w = 0.18 … 0.22)

Figure 6: Example taken from the classification scheme showing the building structure and building classes "apartment blocks", "detached and semi-detached houses", and "discontinuous Wilhelmeanian style multi-storey houses" as well as the vegetation structure ("parks" and "community gardens") - Spatial units of the housing sector serve as prerequisite to which a social science data based preference matrix with the indicators $I_{1...n}$ is applied.

Furthermore, a layer of residential vacancy is part of the output file of the micro-simulation with the same spatio-temporal resolution (Figure 7). It is calculated using the equation

$$M_h(\vec{x},\vec{y}) = \begin{cases} Vac(\vec{y}) & \text{if } A_h(\vec{y}) > A_h(\vec{x}) \\ & \text{and } P_h(t) > P_{\min} \\ 0 & \text{else} \end{cases}$$

where M_h is the migration choice, Vac the residential vacancy and $P_{h/min}$ the persistence of a household in a flat. The simulated vacancy has been plotted against expert estimations of current vacancies associated with the municipal districts (as done in Figure 7) and shows a very satisfying accordance. As a next step of the model analysis, the simulated vacancies are set against the classified residential vacancy of the object-oriented classification scheme (as shown in Figure 2).

In the next phase, contextual (policy, legal, planning, conceptual) constraints will be implemented using spatially implicit information such as verbal arguments and guidelines as well as spatially explicit data in form of planning maps. As one pathway of urban shrinkage the following 'compact city concept' is preferred by regional policy makers of Saxony and Leipzig: The centre of the city is foreseen to be preserved as a functional core, to maintain urban quality of life in compact structures and to avoid urban perforation. Demolition activities should be concentrated at the periphery. In fact, in many cases, those concepts of the policy makers are not in line with those of the housing enterprises who take the final decision regarding demolition of their housing stock. Despite being a problem, shrinkage and demolition of vacant housing estates also provide new place for other uses such as spacious living, less density and more greenery in neighbourhoods, which is equal to the typical suburban housing advantages.

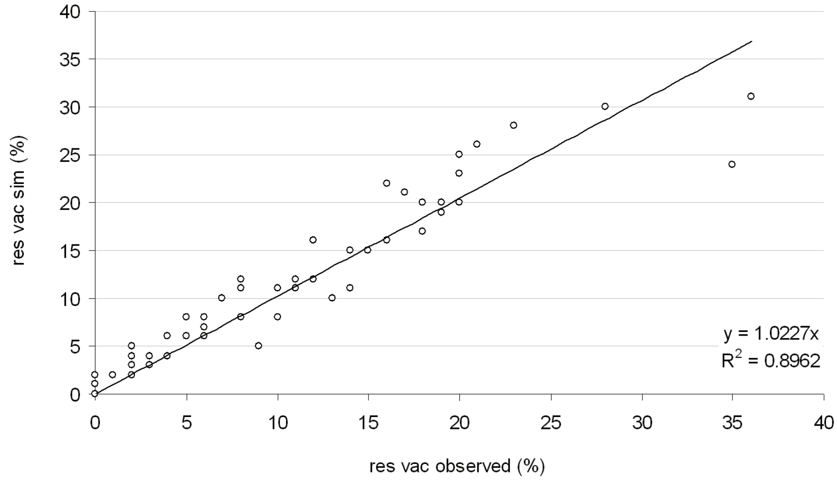
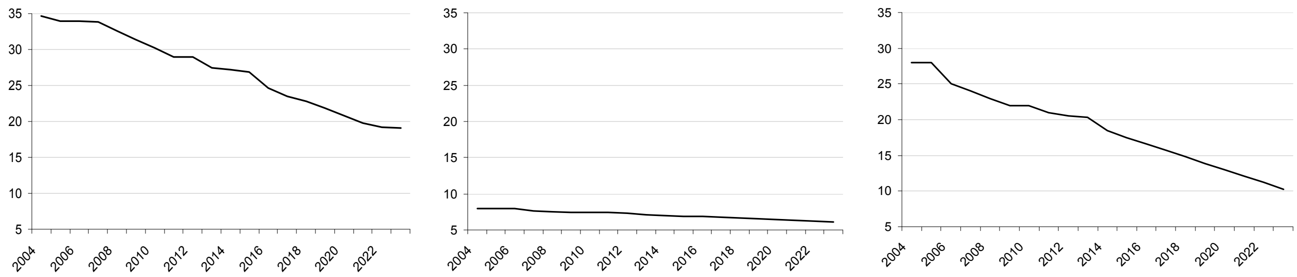


Figure 7: Simulated versus 'measured' residential vacancy in Leipzig for 2004: The first model runs show that the share of residential vacancy of the municipal districts of Leipzig (n=63) is well predicted with the model that bases on both the classes of urban land (use) structures derived from VHR imagery and the respective changes as well as on socio-demographic predictor variables derived from time series. The results are plotted for 2004, the most recent reliable estimation of residential vacancy for the city by local authorities and the Office for Statistics and Elections.



District of Neustadt-Neuschönefeld (Wilhelmeanian estates; negative image) | District of Südvorstadt (Wilhelmeanian estates; positive image) | District of Grünau-Nord (GDR-time prefabricated estates)

Figure 8: Predicted residential vacancy (%) for different old and new built-up residential housing types for Leipzig until 2025.

RESULTS & DISCUSSION

The presented study comprises monitoring of land use changes and mapping of socio-demographic dynamics right after the political transition in eastern Germany, combined with modelling of residential mobility. After having identified spatial suburbanisation processes, which were accompanied by urban growth at the urban fringe and urban shrinkage in the central part of the city, a new focus in urban land use monitoring activities was taken, deriving urban structure types from very high resolution (VHR) data. With respect to remote sensing methods two different data sets and approaches were applied: the multispectral classification and post classification comparison of TM imageries supported the monitoring of urban growth and shrinking processes in this very dynamic region. The object-oriented fuzzy classification of a VHR data set is compared with ATKIS (official topographic-cartographic information system of Germany) data in order to produce a change detection for the process of demolition of houses, which is a special feature of the massive residential vacancy typical for shrinking cities.

The assignment of demolished houses to specific urban structure types is another special contribution arising from the application of the approach presented here. Beside their obvious dependence upon economic variables, urban land use changes are mainly related to the demographic development of a city. In the integrated monitoring and model approach presented above, we assume that there is a causal relation between the built-up environment (housing and infrastructure), the configuration of urban open spaces and demographic processes (first of all migration). Initial results of this model of residential mobility in Leipzig and a respective picture of residential vacancy support the presumption that different household types prefer different housing environments and structures, and that, under a typical pattern of residential behaviour, residential vacancies are created. To validate the model results and to set a relationship between residential vacancy and demolition processes there is the need to create valid data of urban land use change at building level. This brings the model and the paper back to the VHR based object-oriented classification where next steps in the research will be focused on investigating how data sets on urban structure types can be reliably reproduced so that demolition and, respectively, new built-up areas can be monitored regularly on a local scale.

REFERENCES

1 Rieniets T, 2004. Global context. In: Shrinking Cities, edited by P. Oswalt (Hatje Cantz, Ostfildern-Ruit) Vol. 1, 20-33. A project initiated by the Kulturstiftung des Bundes (Federal Cultural Foundation, Germany) in cooperation with the Gallery for Contemporary Art Leipzig, Bauhaus Foundation Dessau and the journal Archplus. http://www.shrinkingcities.com/index.php?id=33&L=1

2 Buzar S, P Odgen & R Hall, 2005. Households matter: the quiet demography of urban transformation. Progress of Human Geography, 29(4): 413-436

3 Nuissl H & D Rink, 2005. The 'production' of urban sprawl. Urban sprawl in eastern Germany as a phenomenon of post-socialist transformation. Cities, 22 (2):123-134

4 European Environmental Agency, 2002. Towards an urban atlas. Assessment of spatial data on 25 European cities and urban areas. Environmental Issue Report No 30 (Copenhagen, Denmark) http://reports.eea.europa.eu/environmental_issue_report_2002_30/en

5 Haase D, R Seppelt & A Haase, 2007. Land use impacts of demographic change – lessons from eastern German urban regions. In: Use of Landscape Sciences for the Assessment of Environmental Security, edited by I Petrosillo, F Müller, K B Jones, G Zurlini, K Krauze, S Victorov, B-L Li & W G Kepner (Springer Netherlands) pp. 329-344

6 Couch C, J Karecha, H Nuissl & D Rink, 2005. Decline and sprawl: an evolving type of urban development - observed in Liverpool and Leipzig. European Planning Studies, 13(1): 117-126

7 Miller E J, J D Hunt, J E Abraham & P A Salvini, 2004. Microsimulating urban systems. Computers, Environment and Urban Systems, 28: 9-44

8 BMVBW – Bundesministerium für Verkehr, Bau- und Wohnungswesen (Editor), 2003. Documentation to the federal competition „Stadtumbau Ost" (Runze & Casper Werbeagentur, GmbH, Berlin, Germany) 104 pp. http://www.stadtumbau-ost.info/programm/Dokumentation-zum-Bundeswettbewerb-Stadtumbau-Ost.pdf

9 Donnay J-P, M J Barnsley & P A Longley, 2001. Remote Sensing and Urban Analysis. GISDATA 9 (Taylor & Francis, London and New York)

10 Hipple J D, T A Butchard, C Davies, T L Haithcoat, U Heiden, R R Jensen & W Song, 2006. Characterizing and mapping human settlements. In: Remote Sensing of Human Settlements, edited by M Ridd & J D Hipple. Manual of Remote Sensing, 5: 149-206 (American Society for Photogrammetry and Remote Sensing, Bethesda, Md., USA)

11 Forster B C, 1984. Combining ancillary and spectral data for urban applications. International Archives of Photogrammetry and Remote Sensing, XXV: 55-67

12 Lenco M, 1997. Étude par télédétection des écosystèmes urbains des grands agglomérations françaises à échelle du 1:25,000. In : Télédétection des Milieux Urbains et Périurbains, edited by J M Dubois, J -P Donnay, A Ozer, 361 pp. (AUPELF-UREF, Montréal, Canada) pp. 191-206

13 Baraldi A & F Parmiggiani, 1990. Urban area classification by multispectral SPOT images. IEEE Transactions on Geoscience and Remote Sensing, 28: 674-680

14 Banzhaf E, A Kindler & D Haase, 2005. Research on negative urban growth by means of remote sensing and GIS methods. In: Int. Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Vol. XXXVI-8/W27. ISSN 1682-1777. Also published in: Proc. of the ISPRS WG VII/1 "Human Settlements and Impact Analysis". 3rd Int. Symp. Remote Sensing and Data Fusion over Urban Areas (URBAN 2005). 5th Int. Symp. Remote Sensing of Urban Areas (URS 2005). March 14-16, 2005. Tempe, AZ, USA

15 Gluch R M, 2002. Urban growth detection using texture analysis on merged Landsat TM and SPOT-P data. Photogrammetric Engineering and Remote Sensing, 68(12): 1283-1288

16 Singh A, 1989. Digital change detection techniques using remotly-sensed data. International Journal of Remote Sensing, 10(5): 989-1003

17 Eastman J R & M Fulk, 1993. Long-sequence time series evaluation using standardized principle components. Photogrammetric Engineering and Remote Sensing 59, 6, 991-996

18 Congalton R G & K Green, 1999. Assessing the Accuracy of Remotely Sensed Data: Principles and Practices (CRC/Lewis Press, Boca Raton, FL.) 137 pp.

19 Clapham Jr W B, 2001. Continuum-based classification of remotely sensed imagery to describe urban sprawl on a watershed scale. Remote Sensing of Environment, 86(3): 322-340

20 Banzhaf E, V Grescho & A Kindler, 2007. Monitoring the urban to peri-urban development with integrated system from RS observation and GIS information. International Journal of Remote Sensing (submitted)

21 Banzhaf E & R Höfer, 2007. Monitoring urban structure types as spatial indicators with CIR aerial photographs for a more effective urban environmental management. IEEE Transactions on Geoscience and Remote Sensing (submitted)

22 Banzhaf E, K Hannemann, M Martini, V Grescho & M Netzband, 2007. Monitoring the urban development with integrated system from RS observation and GIS information. 4th IEEE GRSS/ ISPRS Joint Workshop on Remote Sensing and Data Fusion over Urban Areas (URBAN 2007). 6th int. Symp. Remote Sensing of Urban Areas (URS 2007). April 11-13, 2007. Paris, France. 7 pp. (IEEE Catalog Number: 07EX1577, ISBN: 1-4244-0712-5, Library of Congress: 2006934022)

23 Haase D & H Nuissl, 2007. Does urban sprawl drive changes in the water balance and policy? The case of Leipzig (Germany) 1870-2003. Landscape and Urban Planning, 80: 1-13

24 Waddell P, 2002. Urbanism: Modeling urban development for land use, transportation and environmental planning. Journal of the American Planning Association, 68(3): 297-314

25 Landis J & M Zhang, 1998. The second generation of the California urban futures model. Part 1: Model logic and theory. Environment and Planning A, 30: 657-666

26 Silva E A & K C Clarke, 2002. Calibration of the SLEUTH urban growth model for Lisbon and Porto, Portugal. Computers, Environment and Urban Systems, 26: 525-552

27 Kabisch S, A Haase & D Haase, 2006. Beyond growth – urban development in shrinking cities as a challenge for modeling approaches. Edited by A Voinov, A Jakeman & A Rizzoli, International Environmental Modelling and Software Society (iEMSs), Burlington, USA. CD ROM. ISBN 1-4243-0852-6 978-1-4243-0852-1. http://www.iemss.org/iemss2006/sessions/all.html

28 Kaa D van de, 2004. Is the Second Demographic Transition a useful research concept. In: Vienna Yearbook of Population Research 2004, edited by G Feichtinger (Austrian Academy of Sciences, Vienna, Austria) pp. 4-10. http://hw.oeaw.ac.at/0xc1aa500d_0x0006201f

29 White R, G Engelen & I Uljee, 1997. The use of constrained cellular automata for high-resolution modelling of urban land-use dynamics. Environment and Planning B: Planning and Design, 24: 323-343

30 Haase D, A Holzkämper & R Seppelt, 2006. Beyond growth? Decline of the urban fabric in Eastern Germany. A spatially explicit model approach to predict residential vacancy and demolition priorities. In: Modelling Land Use Change, edited by E Koomen, J Stillwell, A Bakema & H Scholten (Springer, Dordrecht) pp. 339-353

31 Haase D & A Haase, 2007. Do European social science data serve to feed agent-based simulation models on residential mobility in shrinking cities? In: Europe and its Regions. The Usage of European Regionalized Social Science Data, edited by W Mathiaske,G Grötzinger & K Spieß (Cambridge Scholar Press) (in press)

32 Haase, D., A. Haase, S. Kabisch & P. Bischoff, 2007. Guidelines for the 'Perfect Inner City' Discussing the Appropriateness of Monitoring Approaches for Reurbanisation. European Planning Studies (in press)

33 Haase D & R Seppelt, 2007. A household-based model to approach residential mobility and related housing vacancies in a declining city region. Environmental Modeling and Software (submitted)