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Modelling residential mobility in a shrinking medium-sized town: Model concept and first empirical results for Delitzsch, Germany

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Abstract: Shrinking population numbers are a challenge for planning future investments into urban built structures: Declining population numbers can lead to decreasing real estate prices and can even induce vacancies, thus creating uncertainty for returns of investments into the housing stock and public infrastructure. This process is even more critical for municipalities with small budgets. Understanding and estimating future residential mobility is therefore essential for urban development in such regions. The paper provides an overview over a project that investigates the effects of population shrinkage on investments in energy-efficient heating systems and insulation of residential buildings. The paper focuses on an agent-based model for residential mobility that allows for simulating future patterns of population distribution. The agents in the model represent domestic households of different types that decide upon re-locating within the city, to leave the city or to move into the city. The agents consider their housing preferences, the availability of infrastructure as well as the behaviour of other agents in their decision. The decision algorithm will integrate empirical data on residential mobility that is being surveyed especially for this project. This empirical study follows a two-step approach of (a) qualitative, in depth interviews and (b) a quantitative, written questionnaire. The paper describes both the concept of the agent-based model as well as first empirical results. This work is accompanied by a dialogue with policy makers and residential building cooperatives about future investments into energy-efficient infrastructure in the city of Delitzsch in Saxony, Germany.

***Keywords**: urban; agent-based model; shrinkage; empirical study.*

1 INTRODUCTION

Decreasing population numbers can result from shocks in the political system such as the post-1989 post-socialist transition. They are a challenge for planning future investments into urban built structures: Declining population numbers can lead to decreasing real estate prices and can even induce vacancies, thus creating uncertainty for returns of investments into the housing stock and public infrastructure (Schwarz et al., 2010). Understanding and estimating future residential mobility is therefore essential for urban development in such regions.

Few simulation models so far have explicitly tackled urban shrinkage (e.g. Haase et al., 2010; Lauf et al., 2012, for a review see also Schwarz et al., 2010). However, to our knowledge, no simulation model exists that combines (1) vacancy and other shrinkage-related patterns and processes with (2) an individual-based approach that explicitly models the behavior of each individual household.

This paper describes the concept of an agent-based model (ABM) that aims at simulating residential mobility in a medium-sized town, focusing on the period after 1989 in Germany. The paper is related to the conceptual paper on urban shrinkage (Haase, A. et al. 2012) as well as the assessment of modeling approaches to shrinkage (Haase, D. & Schwarz, 2012). It serves as an empirical example for modeling urban shrinkage, taking the city of Delitzsch, Germany, as an example.

1.1 Shrinkage as a shock for Delitzsch

We draw upon the conceptual approach of shrinkage as a response to the shock of the post-socialist transition after 1989 in Eastern Europe given in Haase, A. et al. (2012). For the city of Delitzsch (Germany), the revolution was exogenous in the sense that the main processes of transition took place on a higher hierarchical level, although the transition itself was initiated bottom-up. The revolution originated in the human, more precisely in the political, system. First order responses such as outmigration to Western Germany, a drop of fertility rates, shut-downs of industrial estates and the like were experienced in the human system. However, second order responses emerged all over the urban system including in the environmental system. The housing market collapsed; housing and real estate prices fell. As for the environmental system, vacant land (re-)appears as houses are demolished and infrastructure is reduced. The consequences of shrinkage itself were not shocks for the environmental system, as they developed rather slowly. However, the abrupt end of environmental pollution due to GDR heavy industry could be considered a shock, but is not pursued here.

The revolution of 1989/1990 was not expected even a few months before it actually happened and clearly came as a surprise. The responses to this shock can be found in almost all areas of social and economic life. The responses to the initial shock of the post-socialist transition came abruptly, seemingly overnight. The responses developed over time in interdependencies and feedback-loops. For instance, a district of a city today might be unattractive to families with high educational background because secondary schools do no longer exist in the district. This again is the result of the demographic shock in the immediate transition years coupled with household mobility and political responses in school policies. Thus, impacts to the initial shock appear in interdependent chains of first and second-order responses. Regarding urban development, the population number of the city of Delitzsch is the most important indicator: population decreased from about 32,000 in 1989 to only 26,000 in 2010, indicating a decrease of 18% (Figure 1).

We do not model the shock – i.e. the revolution of 1989/1990 – itself, but rather the response in the residential housing sector (see also Haase D. & Schwarz, 2012). The shock is exogenous for the model; its impacts on social system are included in the simulations in terms of population losses. Within the modelled urban system, new possibilities to build single family houses create urban sprawl in the periphery. At the same time, the population in the city core decreases, leading to vacancies and thus lowering the attractiveness of the area. However, demolition of vacant buildings and the creation of new urban green might in turn increase the attractiveness again.

We build a spatially explicit ABM for two main reasons: ABMs allow for (1) the representation of individual decisions and (2) the inclusion of (spatial) interactions between agents. Simulating the dynamics of residential mobility including vacant housing due to shrinkage requires these two features of ABMs (Schwarz et al., 2010).

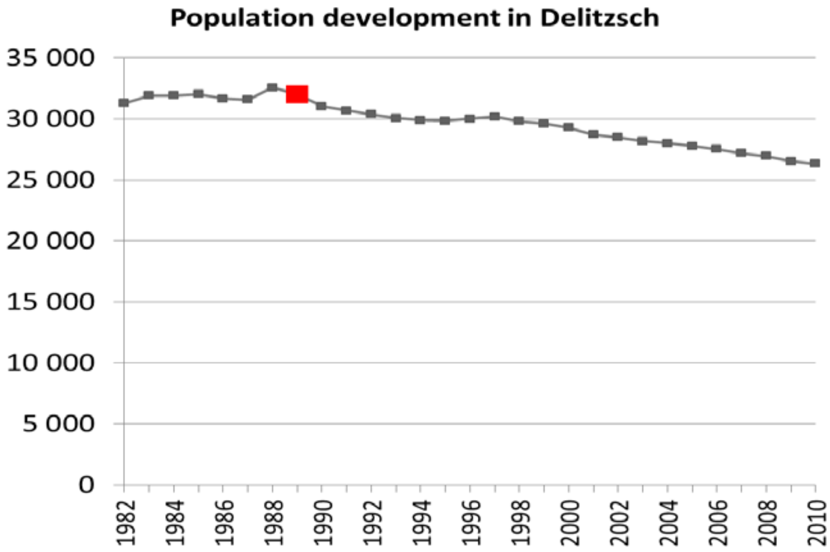

Figure 1. Population development in Delitzsch, 1982 to 2010.
Data source: Statistical Office of Saxony.

1.2 Project overview

In the project "Energy-efficient city Delitzsch" funded by the German Federal Ministry of Education and Research, the effects of population shrinkage on city-wide energy use are investigated. This includes investments in energy-efficient heating systems and insulation of residential buildings. For the city of Delitzsch in Saxony, Germany, simulation models are being built to analyze investments both by private home owners as well as owners of housing estates. For both, investments into existing or new houses are influenced by population projections and future housing demand: Only if housing stock is likely to be used in the future, investments into energy efficiency may amortize. Therefore, we will build an ABM on residential mobility within a shrinking city to allow for simulating future patterns of population distribution. The ABM will use empirical data on residential mobility that is being surveyed especially for this project. Later on, it will be coupled with a second ABM that simulates the investment decisions of private home owners. Using these ABMs, scenarios will be built that take into account future demographic trends as well as real estate development. The models will inform a dialogue ("policy exercise") with policy makers and residential building cooperatives about future investments into energy-efficient infrastructure in Delitzsch.

2 CONCEPT OF THE ABM

2.1 Model description

2.1.1 Agents

Agents in the ABM represent households. Using current population estimates, about 15,000 household agents will be represented. The model's focus is on residential mobility within the city. Therefore, two main decisions are being taken in each time step by the agents: (1) Should the household look for another house or flat within the area? (2) (Only necessary if question 1 was answered positively) Where should the household move? The latter might also imply the construction of a house. These decisions will be coded according to empirical rules that are derived from a social science survey that is especially run for the project (section

3). The total agent population in the city is determined using a simple population module that is being fed for each scenario run with assumptions regarding fertility and mortality rates as well as in- and out-migration.

Agents are characterised by two main aspects: their lifestyle as well as their life stage such as foundation of first own household or family foundation. From here household-types are distinguished, for example single households, one-parent families or empty nesters. We hypothesize that life stage is mainly determining the decision if and when to relocate according to different drivers of residential mobility (such as starting a family or retirement). The lifestyle shall account for preferences regarding housing choice as well as (environmental) attitudes and thus is more important of the second step, the location choice. The lifestyle concept used here stems from marketing research (Sinus Sociovision®, http://www.sinus-institut.de/en/) and has the advantage that spatially explicit data for the distribution of lifestyles are available (section 2.2).

2.1.2 Buildings, environment and the housing market

The building stock is simulated on a spatial grid with a cell size of 10 x 10 m². We decided against a vector-based spatial structure in order not to raise stakeholders' expectations regarding accuracy with a visually accurate representation of the case study. The grid structure might allow for an easier communication of uncertainties in the model. Residential housing is characterised by its location in the city (and thus proximity to infrastructure such as schools or medical treatment), the structure type (e.g. single family home, pre-fabricated housing estate), and the energy-efficiency in terms of insulation and heating. Furthermore, for each grid cell, housing units are differentiated by their storey, as preliminary qualitative interview results suggest that the storey is a very important characteristic for residential location choice. Thus, the ABM simulates three-dimensional housing patterns.

A simplistic approach to model the housing market is envisaged that focuses on changes in prices rather than absolute values. The housing price (or rent) on a cell is a function of the vacancy rate in the immediate surroundings and decreases with increasing vacancy. Delitzsch is not a closed system and thus is clearly influenced by the housing market in surrounding rural and urban regions. Thus, the development in the surroundings is included as external scenario assumptions in terms of in-migration rates as well as levels of housing prices in the surrounding region.

Residential mobility might influence the environment in the city in two ways: On the one hand, for instance single family homes can be build and thus induce urban sprawl. On the other hand, shrinking cities are characterised by vacancies (mostly) in pre-fabricated housing that can eventually be demolished. The construction of new homes implies urban land use change and is a decision of the household agents. The demolition of housing is part of the policy exercise being conducted with local owners of large housing estates. During a simulation run, owners will be asked if (and if yes, where) they would demolish housing or invest into the existing building stock in the current scenario. Urban sprawl as well as demolition and subsequent creation of urban green spaces in turn influence residential mobility, as they influence the attractiveness of locations in the city.

2.2 Empirical calibration and validation

For calibrating the ABM, two types of data are needed (Figure 2) on the initial localisation of the agents and on the decision rules of the agents. (1) Geomarketing data (from Microm®) on the spatial location of lifestyles are used to localise the agents for the first time step. (2) Agents' decisions are calibrated using social science surveys that are specifically carried out in the project (see section 3).

Using a simulation run of the years 1990 to 2010, the ABM will be validated in two respects: On the one hand, the results are compared to the population distribution in Delitzsch in 2010 (source: statistical data) to check if the ABM can replicate the dynamics that have taken place. On the other hand, the results are compared to "null models" to check whether it is indeed necessary to use the ABM for simulating population distribution. To test against null models, the results are compared to the initial population distribution in 1990 (source: statistical data) as well as a simple ABM that comprises of randomly moving agents. Due to data limitations, the validation is thus carried out on a more aggregated level (population dynamics including age classes) than the – independent – initialization data that also encompass information about lifestyles.

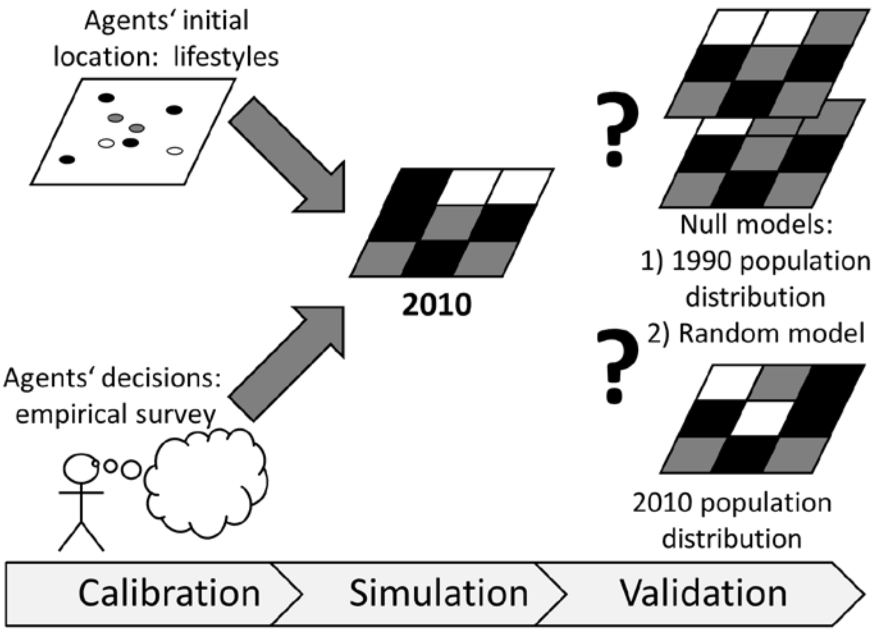

Figure 2. Empirical calibration and validation of the Delitzsch model.

3 EMPIRICAL SURVEY

To inform the behavior of the agents in the ABM, empirical data on recent housing choices and orientations of the actual population of Delitzsch are analyzed. This empirical study follows a two-step approach of (a) qualitative, in depth interviews and (b) a quantitative, written questionnaire. The interviews analyze the orientations and decision-patterns of inhabitants in the city under research. They will help to understand the local logics of the housing market and the criteria agents use to act. The topics of investigations are:

- Recent and prospective mobility of households or the level of place attachment
- Satisfaction/ dissatisfaction with the current housing situation
- Causes, inducement and motives of recent and prospective housing relocations
- Housing preferences concerning the layout, size and design of the flat
- Location preferences an selection criteria as well as selection modi for prospective housing relocations
- Orientations on the local housing market and house-hunting strategies.

3.1 Qualitative interviews

By now, 18 in depth interviews have been accomplished and further ca. 5 interviews are planned. It is a selective, non-representative sample which aims at gaining insights into the predominantly existing orientations and decisions of the residents, but not in their quantitative scope. Therefore, residents of varying characteristics were chosen, that is young and older households, employed resident, pensioners and unemployed residents or residents from different areas within the city. A focus was on households on the move that is households who recently moved house or are about to do so. To understand place attachment, also a number of interviewees represent households without the intention to move house.

The interviews are based on an open interview-guideline as it is common in qualitative social science research. The interview-guidelines support a reconstructive, inductive knowledge generation by using an open impulse-question and a series of semi-structured questions. Like this, interviewees can themselves set a focus on sub-dimensions of the topic addressed in the interviews. This helps to generate explorative knowledge about the field that cannot be anticipated by the researcher beforehand. To give an example, many interviewees explained that they do not strategically search for a new flat but rather observe housing offers over a longer period of time and wait for an appropriate offer. This is different from what mainstream literature on house-hunting strategies documents. Since this literature is usually based on experiences in growing larger cities, the behavior of Delitzsch residents might be more appropriate to smaller and to shrinking cities. These are characterized, first, by the possibility of a near to complete overview on housing offers and, second, by existing experiences with life-limited housing, so that people avoid offers in houses that are likely to be demolished further on. Instead, they wait for offers that will be stable over a required period in time. Also, by using this open interview technique, we learn better what is of high relevance to the interviewees instead of imposing our hypotheses and expectation on the field.

3.2 Implications for further empirical work and modeling concept

The data gained from the qualitative work is transcribed and coded. The codes are worked out again inductively from the data. Thus, we generate the inner structuring of the orientations and decision patterns in the form of a code-tree that classifies the answers given during the interviews in categories. For instance, location criteria are coded in categories as specified by interviewees such as “in proximity to the main station”, “physicians in the area” or “calm area”. With the help of that code-tree, a questionnaire will be designed. The codes and sub-codes are used to inform the formulation of questions and the respective closed answering categories. Like this, we can guarantee that the questionnaire does correspond to the local knowledge and orientations. With the help of the questionnaire, we gain a representative picture about the likely future acceptance of the housing market segment in the city of Delitzsch.

To correspond with the requirements with the modeling, the questionnaire will comprise indicators to analyze the life-style of respondents in order to identify the possible residential behavior of the localized agents. There is a continuous exchange between modelers and social scientists in the project concerning the interface of surveys and modeling. One important insight from the empirical work was the necessity to include the third spatial dimension into the model as elderly people often seek just ground floor flats. The Elderly are but a decisive residential group in shrinking cities. On the other hand, models made the social scientists aware of the need to gain information that can be translated to algorithms such as an algorithm of housing choice criteria.

4 CONCLUSIONS

In this paper, we focused on urban shrinkage in medium-sized cities, using the example of Delitzsch, Germany, as a case study. We conceptualized urban shrinkage as a response to the shock of the post-socialist transition after 1989 in Eastern Europe. Therefore, the model on urban shrinkage simulates the patterns resulting from the transition shock rather than the shock itself.

Simulating urban shrinkage in a medium-sized town is a challenge, as a lot of existing urban simulation models are – implicitly or explicitly – focused on larger urban areas. Our preliminary results suggest that in Delitzsch, the knowledge base of individual households differs from larger cities: Households can in principle assess the housing supply in the whole city for their location choice. Tenants have a better overview of the different housing companies, cooperatives and landlords and can therefore better assess their strategies. Furthermore, the decline of industries and the related closures of single enterprises might have a stronger impact onto a smaller city, so that the loss of jobs could be more prominent and thus responses in terms of out-migration more rapid. Simulating urban shrinkage in a medium-sized town might also be the opportunity to implement a simulation model that can explicitly model the behavior of each individual household: The population size is limited, so that agents in a simulation model for a smaller city do not have to represent all households of a single household type due to limits in computing power, as might be the case for larger cities.

The paper presents a model concept and the accompanying empirical survey that aims at eliciting data for calibrating the model. The process of conceptualizing the model on the one hand and eliciting empirical data on the other hand is a mutual relationship: The general model structure had implications for the questions being asked in the survey that thus includes questions regarding the decision to move or stay, location preferences and the like. Empirical data are not only used to calibrate the model later on, but also influence the model structure. For instance, the importance of storeys for location preferences was a preliminary result of the qualitative survey and has induced the inclusion of the third spatial dimension in the building stock of the model. Such cooperation between modelers and social scientists is essential for building empirically well-founded simulation models.

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REFERENCES

Haase, A., Rink, D., Großmann, K., Urban shrinkage as a challenge for modelling human-environmental interaction, paper presented at the 6th International Congress on Environmental Modelling and Software (iEMSs), Leipzig, Germany, July 1-5, 2012.

Haase, D., Lautenbach, S., Seppelt, R., Applying social science concepts: modeling and simulating residential mobility in a shrinking city. Environmental Modeling and Software 25, 1225-1240, 2010.

Haase, D. & Schwarz, N., So less so good - Insights from existing shrinkage models, paper presented at the 6th International Congress on Environmental Modelling and Software (iEMSs), Leipzig, Germany, July 1-5, 2012.

Lauf, S., Haase, D., Seppelt, R., Schwarz, N., Simulating demography and housing demand in an urban region under scenarios of growth and shrinkage. Environment and Planning B 39, 2012.

Schwarz, N., Haase, D. and Seppelt, R., Omnipresent sprawl? A review of urban simulation models with respect to urban shrinkage, *Environment & Planning B* 37(2), 265-283, 2010.