MICROSIMULATION OF FIRM LOCATION DECISIONS

Rolf MOECKEL
Institute of Spatial Planning
University of Dortmund
August-Schmidt-Str. 6
44139 Dortmund
Germany
Tel: +49 231 755 2127
Fax: +49 231 755 4788
E-mail: rolf.moeckel@uni-dortmund.de

Abstract: This paper describes a microsimulation model simulating the evolving urban spatial economy by microsimulation of businesses. Location decisions of businesses are represented by Logit models. Birth, growth, decline, and closure of businesses, also called firmography, are simulated, too. The study area for tests and application is the urban region of Dortmund, Germany. This dissertation study is integrated in the research project ILUMASS (Integrated Land-Use Modelling And Transportation System Simulation), a model simulating land use, transport and the impact on the environment.

Keywords: Microsimulation, micro data, businesses, moves, firmography

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1 Introduction

Most larger cities in Europe struggle with urban sprawl. Due to increased car availability households have started to move to the suburbs and businesses have followed. In particular, retail facilities pursue greenfield sites in order to take advantage of low land prices, accepting an increasing car dependency of their customers and their employees. According to German tax laws the financial adjustment among cities depends on population and number of businesses. Consequently, all cities strive after gaining both population and firms; because of lower land prices suburban cities usually do better. While core cities loose both population and businesses, the suburbs grow. For many core cities the impact is tremendous. As the "suburbanites" continue to use the city's amenities, such as theatres or public transport, the same capacity of public infrastructure has to be provided with less tax revenues, as the number of inhabitants and businesses in the city decreases. Figure 1 gives an overview of the change of employment by different region types. While core cities loose employment compared to the German average suburban cities develop much better.

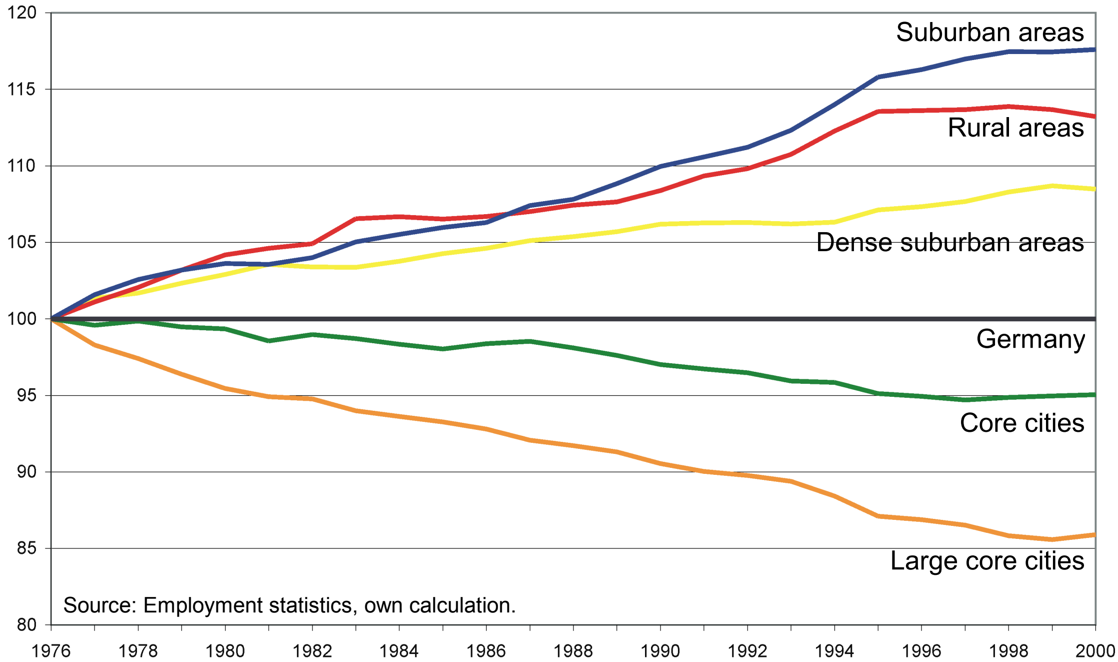

Figure 1: Employment in (West-) Germany by region type (average = 100 percent)

Urban and regional governments have trouble finding appropriate strategies to counter this loss of businesses and jobs in cities. After regional planning approaches have been weakened in most European countries alternative strategies are explored. Today, it became even common to replace government by governance, hoping that improved communication between the stakeholders of economy leads to a more sustainable development in terms of economic stability, social balance and environmental quality. This transformation from traditional planning towards cooperative planning strategies may cause problems of democratic legitimation, and recent development in many regions does not indicate that governance was able to improve sustainable development noticeable.

Today, in most German cities unemployment has become the main concern of all policy makers. Due to an ongoing loss of employment city officials tend to do everything that might keep businesses in town. Business taxes are reduced to a minimum to attract businesses from neighbouring cities. Any site a new business is interested in is offered regardless of its integrity into urban strategies. Sustainability issues are reduced to endeavour economic growth. How far these strategies are successful, in particular if all cities use similar strategies, remains unclear.

Both further instruments and smart combinations of different instruments need to be found and tested on their capability of fostering a sustainable development, including but not being limited to economic stability. Fields of relevant policies contain land use, taxation, and transport policies. The selected policies need to be tested and the most successful combinations have to be explored.

2 Method

In order to find relevant and successful policies to reduce a further loss of businesses in cities a model is developed simulating both the location decisions of businesses and the transformation of firms over time called –following demography– firmography, including birth, death, growth and decline of firms. A base scenario, or reference scenario, assumes that mayor trends and policies continue the way they developed in recent years. Then, alternative policy scenarios will be calculated taking into account the change of a single policy or a combination of selected policies. The results help to assess the usefulness of strategies aiming at reducing further loss of businesses in core cities and therefore contributing to a sustainable regional development.

The model of business behaviour described here is developed as a module of the integrated urban model called ILUMASS (Integrated Land-Use Modelling And Transportation System Simulation). The ILUMASS model simulates land use, transport and the environmental impacts (Moeckel et al. 2003a). It will be developed completely as a microsimulation, in other words every agent, such as persons or businesses whose behaviour shall be simulated, will be modelled individually. The agents represented in the ILUMASS model are persons, households, and firms.

Study area

The study area covers the city of Dortmund and 25 surrounding communities with a population of 2.6 million living in about 1.1 million households (figure 2). There are about 85,000 businesses in this area, providing roughly a million jobs. The study area is located in the eastern Ruhr area, a region that was dominated by coal, iron and steel industries for about 150 years. The Dortmund region is still marked by economic restructuring after most mining and steel industries have declined.

The study area is subdivided into 26 cities and 246 statistical zones. However, for simulating the feedback from accessibility and environmental quality on

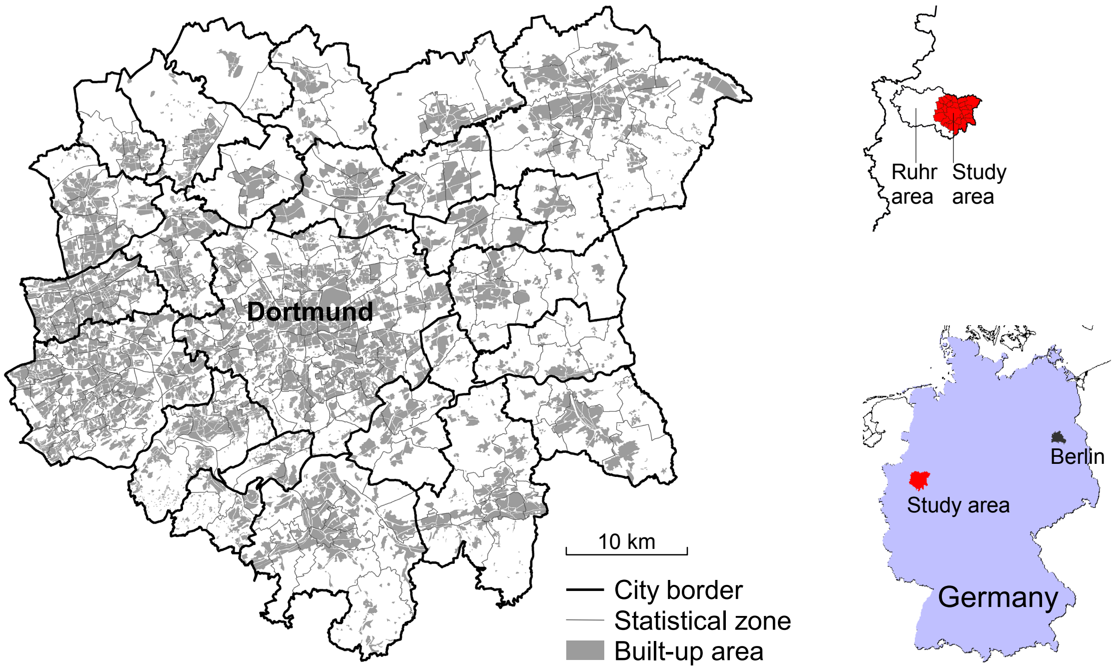

Figure 2: Study area

land use this spatial resolution is not sufficient (Spiekermann and Wegener 2000). Hence, raster cells of 100 by 100 metres are used to describe micro locations. The study area contains about 207,000 such raster cells.

State of the Art

The development of integrated urban models simulating land use, transport and partly environmental impacts has improved since several decades (Timmermans 2003,Wegener 1994). More recently these models develop toward microsimulation, simulating single agents individually. The influence of both accessibility (transport feedback) and environmental quality (environmental feedback) of micro locations on changes in land use can be represented in a few integrated models only. The most advanced models are ALBATROSS developed at the Universities of Delft, Eindhoven, and Utrecht (Arentze and Timmermans 2000), ILUTE at Universities of Canada (Miller et al. 2004), the IRPUD model developed at University of Dortmund (Wegener 1999), UrbanSim developed at University of Washington, Seattle (Waddell 2000), the 'second-generation' model of the Transport and Land Use Model Integration Program (TLUMIP) of Oregon in the United States, and ILUMASS developed at several institutes at German universities giving the framework for this paper.

So far, little focus has been spent on the development of businesses. One of the first approaches simulating urban interactions including location decisions of businesses is the Lowry model (Lowry 1964). Lowry distinguishes between firms producing export products (basic sector) whose location decisions are set exogenously and firms producing for the local market (retail sector) whose location is dependent on population density. Another important aggregated approach is the MEPLAN model (Abraham and Hunt 1999). MEPLAN simulates regional economic development focussing on the interdependence between land-use changes and transport conditions. There are only few disaggregated approaches working with microsimulation of business development. One of the most advanced microscopic firm location models is SIMFIRMS simulating the location decision of businesses within the Netherlands (van Wissen 2000), where the basic principle 'carrying capacity' determines the economic development of a region. Another important approach has been developed with UrbanSim for an application in Salt Lake City, United States (Waddell and Ulfarsson 2003). The model simulates the moves of jobs instead of firms. Within a study with the ILUTE project firm location decisions are simulated for a hypothetical study area of ten by ten raster cells by an equilibrium model (Hunt et al. 2003).

Micro data

Both the ILUMASS model and the business development model described here are developed as a microsimulation model, simulating every agent individually. Hence, micro data of agents are needed. For privacy reasons these micro data from administrative registers usually are unavailable. Therefore, synthetic micro data generated from aggregate data are used instead of real micro data. Within the ILUMASS project micro data of persons, households, dwellings, businesses, and non-residential floorspace are generated (Moeckel et al. 2003b). Basically, there are two procedures to generate micro data. First, Iterative Proportional Fitting, also called RAS-Method, is used to transform one-dimensional data into multi-dimensional data (Deming and Stephan 1940). Second, Monte Carlo Sampling is applied to select the required features of a micro data object (Wilson and Pownall 1976). Since the synthetic micro data are statistically equivalent to real data the synthetic data can be used for a microsimulation model instead of real data. However, outcomes are only published as aggregated results.

3 Power of microsimulation

The simulation of business behaviour will be represented completely by microsimulation. In a microscopic model every agent –here every firm– is simulated individually. Microsimulation was first applied in social sciences simulating the behaviour of consumers in an economic system (Orcutt et al. 1961). Following, microsimulation has been applied to a large number of fields, such as transport behaviour, demographics, information diffusion, health care, land use or housing market (Clarke and Holm 1987).

Representing life styles of different agents is one major advantage of microsimulation models. Agents need to be assigned to a certain agent group to represent their preferences, perceptions, or habits. Traditional aggregated models distinguish only few socio-economic types, and these groups have to stay the same groups for every simulation task within the model. Disaggregated models instead allow to simulate different life style groups for every simulation task. For businesses, for instance, the classification for moving behaviour can be different from the classification for growth and decline or from the classification for birth and death of firms.

Another major strength of microscopic models is to represent micro locations of activities. Usually, micro locations are described by x- and y-coordinates of a raster cell within the study area. Households life in dwellings that are located in a micro location, and businesses are placed in non-residential floorspace with a micro location. Every activity that is performed can be located microscopically. Micro locations allow to determine the location of environmental impacts more accurately. The aggrieved party of gaseous pollution or noise can be observed. The reaction of businesses and households on both the local environmental quality and the local accessibility can be simulated.

Microsimulation models allow to simulate a feedback between agents in great detail. This feedback can be transport-related, for instance if agents decide to change the route when they drive into a traffic jam. This feedback can be social, too. Thomas A. Schelling developed the 'Self-forming neighborhood model' with two homogenous groups that pursue a neighbourhood where a certain share of agents are of the same group (Schelling 1978). Although the aspiration for having neighbours that belong to the own group might be low the resulting segregation is quite high. The reason for that is a microscopic chain reaction leading agents that are unsatisfied with their neighbourhood towards clusters of one's own kind. A low individual segregation aspiration results in a rather high total segregation. Microsimulation is the only method to model this kind of individual feedback.

4 Embedding in ILUMASS

The model presented in this paper is a module of the integrated urban simulation model ILUMASS (Integrated Land-Use Model And Transportation System Simulation). The ILUMASS model simulates land use, transport and the environmental impacts. Under coordination of the German Aerospace Centre (DLR) in Berlin this project is done as a cooperation of institutes at the Universities of Aachen, Bamberg, Cologne, Dortmund, and Wuppertal. The study area is the urban region of Dortmund. Figure 3 gives an overview of the ILUMASS project. The red boxes indicate the contribution to the ILUMASS project described in this paper.

First, synthetic micro data for households, persons, dwellings, businesses, and non-residential floorspace are generated for the study area. The synthetic micro data are used to simulate changes in land use. For persons and households this includes demographic events such as aging, death, birth, cohabitation/marriage, and separation/divorce. Then, moves of households are simulated, taking into account the current satisfaction of a household with its housing location and the expected improvement in terms of the housing satisfaction at a new location. Developers decide based on the demand of dwellings by dwelling type where to invest in new apartments and houses. The development is restricted by land-use policies, prohibiting most settlement development outside urban growth boundaries. The change of businesses, called firmography, and the moves of businesses are covered in this paper.

After modelling land use the transport model can be run, simulating the transport demand of persons to accomplish activities and the transport demand of businesses for goods transport. This transport demand is assigned dynamically to the multimodal transport network taking into account the current traffic volumes on the network. Finally, the environmental impacts of transport can be calculated. Indicators such as noise and gaseous emissions are estimated.

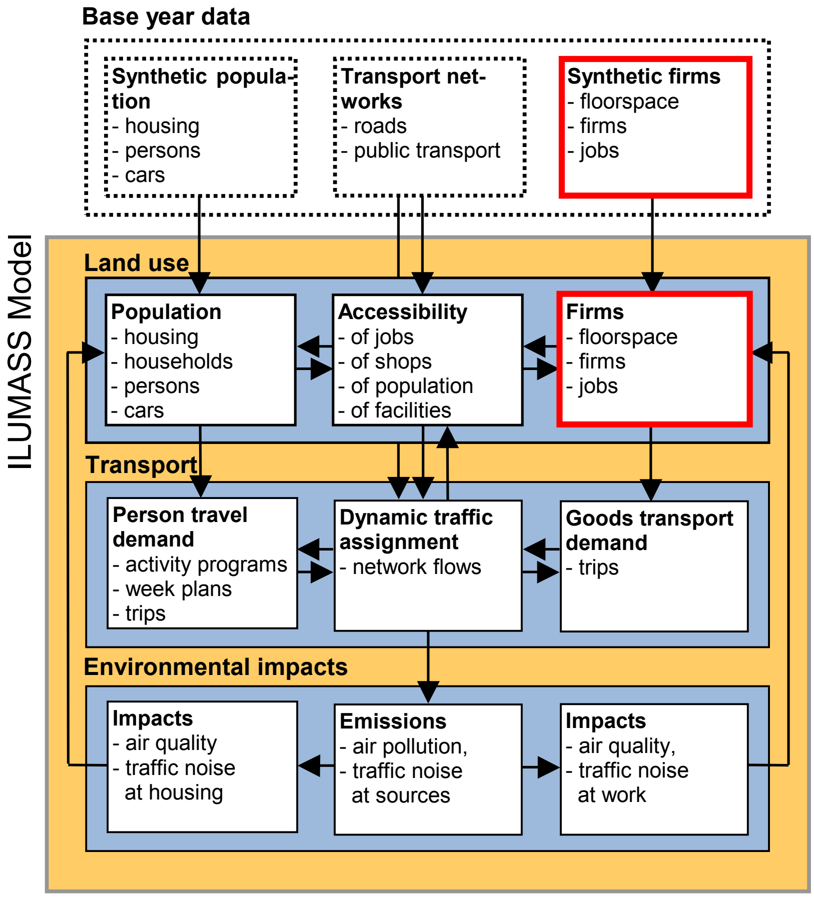

Figure 3: Overview of the ILUMASS project

The environmental impact is used as a feedback on the land-use submodel, since households and businesses adjust their location decisions among others on the environmental quality at micro locations.

5 The business simulation model

The simulation model of businesses is divided into two parts. First, the location decisions of businesses are simulated. Businesses will check their satisfaction with their current location in terms of accessibility, expansion capability, quality of non-residential floorspace, environmental quality, etc. If a business has a low satisfaction, or utility, with its location it checks alternative sites to find out whether it can improve its satisfaction with another location. If a significant improvement is possible, the business might decide to move. The second part simulates the development of the firm, called firmography. This includes the growth and decline as well as birth and death of businesses. A change simulated in the second part might induce a move of a firm in the first part of the model.

Synthetic businesses

Running a microsimulation model requires micro data. For privacy reasons the administrative registers do not provide micro data of businesses. Thus, synthetic micro data have to be generated (see section 2). The generated businesses are subdivided into 45 firm types. Furthermore, businesses are described by number of employees by qualification, capacity for customers

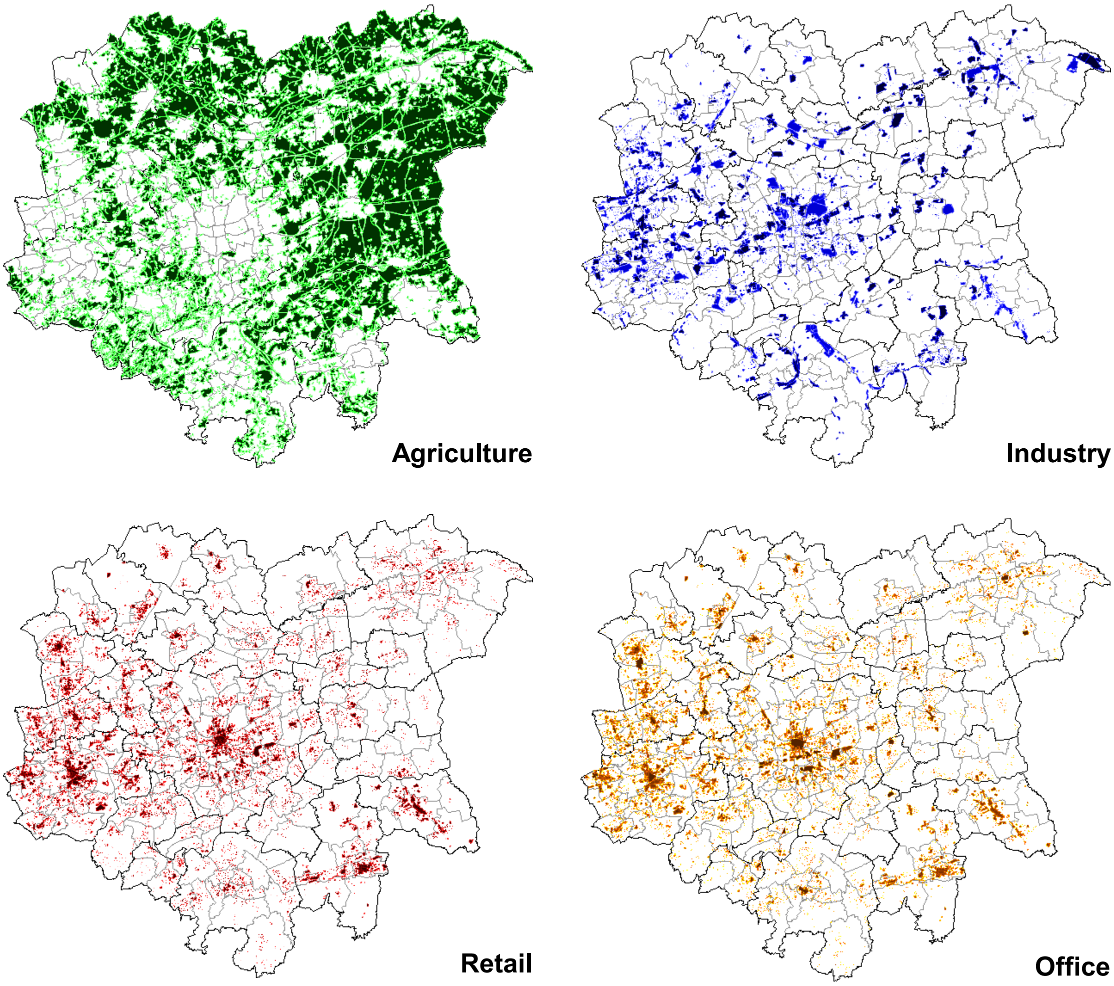

Figure 4: Synthetically generated non-residential floorspace

and rent paid monthly. These businesses are located in non-residential floorspace that is described by used and vacant agricultural, industrial, retail, and office space. Non-residential floorspace is further distinguished by quality in terms of being newly renovated or well-equipped. Figure 4 shows the non-residential floorspace that has been synthetically generated and that is available for businesses to locate in the year 2000 in the Dortmund region.

5.1 Location decisions of businesses

Most simulated location decisions refer to newly founded businesses that need a start-up location. They compare a few alternative locations and select one out of those. These new businesses need to find a location. A location is represented by a 100 x 100 meter raster cell. A couple of existing businesses might want to move and therefore search for a new location, too. If the business has grown it will check first if it can expand on the current site. If that is not possible the utility of the current site is low for the business. All location decisions are modelled by a series of Logit models (Domencich and McFadden 1975).

For simulating moves of households usually the current satisfaction of a household with its dwelling is compared with the possible satisfaction at alternative locations. If the household can improve its satisfaction significantly it probably decides to move. Simulating moves of businesses has to be done differently, since most businesses are highly lethargic in terms of moving to another site. The improvement of alternative sites alone does not motivate businesses to move. Instead, only if the business characteristics, in particular size, have altered (i.e. firmography occured) or the conditions at the current site in terms of accessibility or environmental quality have worsened significantly the businesses might decide to relocate. Thus, to simulate moves of businesses only the current satisfaction with its location is analysed. If the satisfaction is below a certain business-type-specific threshold value the business will investigate if there are other locations where the satisfaction with the location can be improved. If a business can improve its satisfaction with the location at another site a lot it might decide to move. Figure 5 shows how this model works.

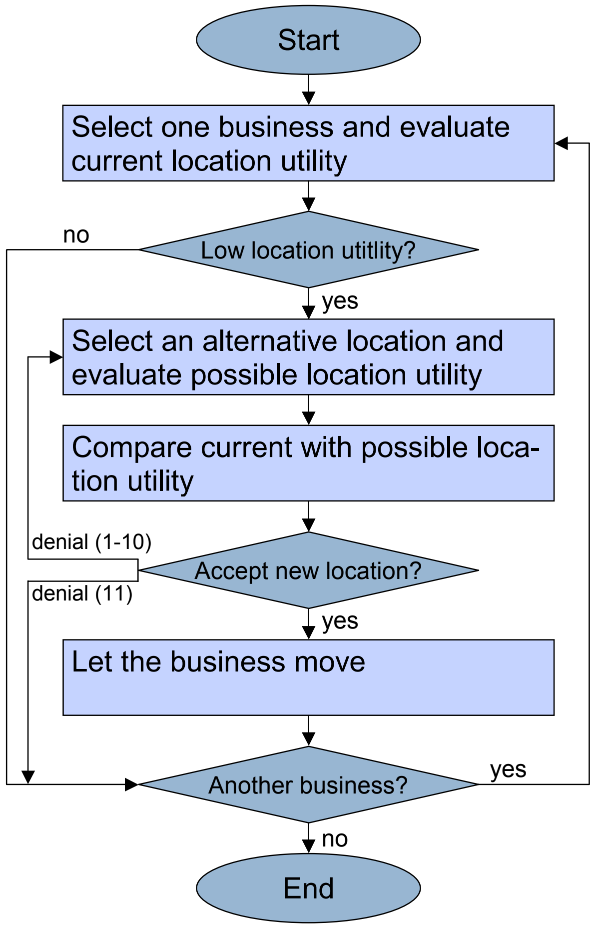

Figure 5: Procedure of simulating moves of businesses

To evaluate the location utility for a business different location factors are included for every firm type. The most common location factors include accessibility to customers, workforce and suppliers, closeness to competitors, rent, expansion capability, agglomeration effects, available floorspace, and soft location factors, such as quality of living or environmental quality. The degree of fulfilling each location factor is assessed by a value between zero and one. These values need to be aggregated to one single number representing the utility u of location i for business b. Therefore location factors are divided into essential and desirable ones. Essential location factors are aggregated by a Cobb-Douglas-Function (Equation 1). Desirable location factors are aggregated by a weighed addition (Equation 2). The two parts finally are merged by another Cobb-Douglas-Function (Equation 3) to one total utility ut. This procedure ensures that every essential location factor has to be fulfilled at least to a small extent, if one essential location factor is zero the total utility of a location is zero, too. On the opposite, single desirable location factors that are low can be compensated by others.

$$ue_{i,b} = l_{1,i}^{\alpha_b} \cdot l_{2,i}^{\beta_b} \cdot l_{3,i}^{\gamma_b} \cdot \ldots \qquad \text{(with weights } \alpha_b + \beta_b + \gamma_b + \ldots = 1\text{)} \qquad (1)$$

$$ud_{i,b} = l_{10,i} \cdot \alpha_b + l_{11,i} \cdot \beta_b + l_{12,i} \cdot \gamma_b + \ldots \qquad \text{(with weights } \alpha_b + \beta_b + \gamma_b + \ldots = 1\text{)} \qquad (2)$$

$$ut_{i,b} = ue_{i,b}^{\alpha_b} \cdot ud_{i,b}^{\beta_b} \qquad \text{(with weights } \alpha_b + \beta_b = 1\text{)} \qquad (3)$$

with $u\_{i,b}$ = utility of location i for business b (ue = utility of essential factors, ud = utility of desirable factors, ut = total utility)

$l_{k,i}$ = quality of location i in terms of location factor k

The weighting factors are set individually for every business type. For a retailer agglomeration effects might be very important, i.e. being close to other retailers where the customers are. For a health farm the environmental quality will be crucial. For certain industries being close to a motorway entrance is important. And for service industries such as banks or insurances the prestige of a location might be imperative.

Businesses that have been newly established are required to find a location. Other businesses that move into the study area from the rest of the world are treated just as newly-born businesses. The threshold values for businesses in the study area indicating if a business considers to move will be given exogenously for each business type. For farms this value will be high, since farms are not very demanding in terms of their location utility, for businesses of the service sector this value will be much lower.

If the satisfaction, or utility, of a business is below the threshold value of that business type or if the business is new in the study area a new location is looked for by a geographic-hierarchical search process (figure 6). Entrepreneurs are unable to consider thousands of different locations where they might locate their business at the same time. Therefore the geographic-

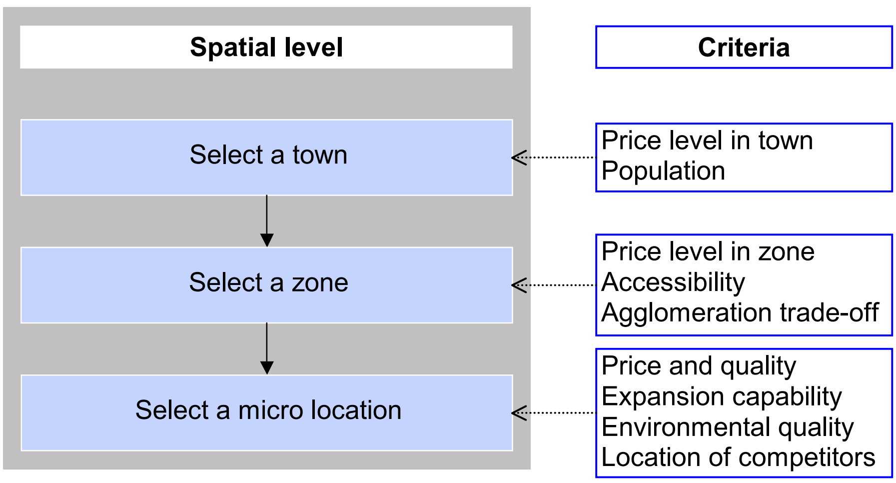

Figure 6: Geographic-hierarchical search

hierarchical procedure is applied to represent the step-wise search of a business holder. First, one out of 26 towns is selected by applying a multinomial logit model. The town's attractiveness is formed by the general price level and the number of inhabitants as indicator for customers and employees. After selecting the town a statistical zone (out of 2 to out of 62, depending on the selected city) can be selected by another multinomial logit model. The criteria to evaluate the attractiveness of a zone are general price level in that zone, accessibility to customers or transport network, and location of competing businesses to represent positive and negative agglomeration effects. Finally, a micro location described by a vacant site with x- and y-coordinates within the selected statistical zone is chosen by another multinomial logit model. Larger firms need to find a site located on several adjacent raster cells. The criteria for the attractiveness of a site are a conglomeration of price, quality, expansion capability, environmental quality, and closeness to competitors.

It is assumed that smaller businesses search for ready-to-move-in non-residential floorspace. For those businesses a micro location is a raster cell or a group of raster cells that contain at least as much of vacant non-residential floorspace as searched for by the business. Large firms are willing to construct the non-residential floorspace themselves. For those firms possible micro locations are raster cells that have the correct land use that is suited for the purpose of constructing their non-residential floorspace. After an alternative micro location has been selected the attractiveness, or utility, of that location for the business is evaluated (compare figure 5). By means of a binomial logit model the decision of the business whether it moves on that location or not is simulated.

For the first option the expectation of the entrepreneur is assumed to be rather high. If a business accepts that new location the firm moves to this site, and the next business can be selected. If the business does not accept that site another micro location is selected by the geographic-hierarchical procedure and offered to the business. Up to ten different locations are offered. With every option the aspiration level of the entrepreneur is assumed to decrease a little bit. If all ten locations are not accepted by the entrepreneur the business has to stay on its current micro location in this simulation period. It might move in the next simulation period when additional non-residential floorspace has been built or certain features of the business might have changed and therefore the evaluation of micro locations might be different. Since new businesses need to find a location they are forced to accept one out of ten offered sites.

5.2 Firmography

Every simulation period the synthetic micro data of businesses have to be updated, so-called firmography has to be modelled. Firms grow or shrink, new firms are established and other firms run out of business. Simulating firmography is highly significant for planners interested in influencing location decisions of businesses. First, firmography determines the number of businesses by representing births and closures. Secondly and likewise important, growth and decline is a major driver for businesses to seek for a new location or to establish a branch.

The development of businesses is subdivided into four different event. These include birth, growth, shrinking, and decline. All of them are modelled by Markov models, since the reasons for firmography decisions taken by entrepreneurs do not strongly depend on the local development. The reasons for businesses to emerge and to grow are much more dependent on the general and national or even global economic development, being hardly influenced by local policy makers. Since the detailed reasoning of businesses to grow or decline is not crucial in this context firmography is simulated by Markov models instead of representing single decision processes as it is done with location decisions.

All four events highly depend on the economic development of the overall economy. The economic development is given exogenously since it is assumed not to be influenced by decisions of the local government or the economic success within the study area. An external forecast of the economic restructuring giving an employment development rate for each business type is used as regional control totals, leading to a reduction of jobs in agriculture, a slight reduction in industry and a considerable growth of firms in financing.

Figure 7 shows the total employment change in percent in comparison to 1976 in Germany within the last twenty-five years. While the overall trend led to an about 15 percent increase of jobs (dashed line) the waves represent significant deviations from the average development. These waves will be extrapolated into the future in a simplified way to represent phases of prosperity and phases of recession in the model. The influence of economic waves on the development of businesses is distinguished by type of firm. While economic waves have a strong influence on banking and finance, the influence on agriculture is rather insignificant. In boom years businesses will hire additional employees and an above-average number of new firms is established. In downturn years employers reduce the number of workers or even close their business. In general, mostly small businesses will be closed. Larger business try to absorb a recession by reducing the number of employees.

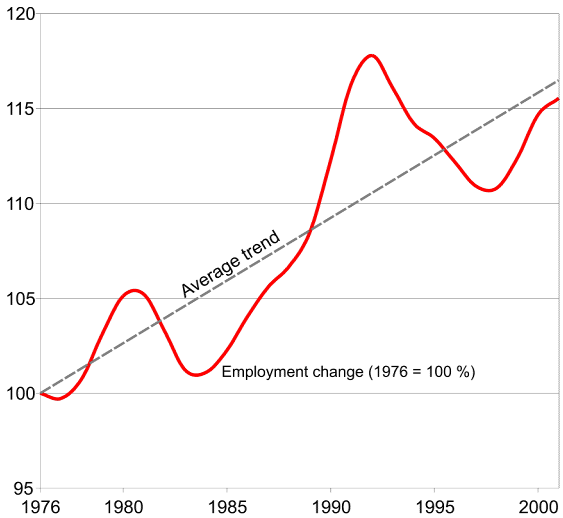

Figure 7: Employment in (West-)Germany

The empirical numbers of firms registering and deregistering serve to find the level of fluctuation. If the empirical numbers of registering and deregistering are high, many businesses will be born and many will close down, resulting in the exogenously given trend of the business type. An example shall clarify this procedure: If the trend for a certain type of business was assumed to be +1 percent, the empirical share of registered firms was 10 percent and the empirical share of deregistered firms was 7 percent, the probability for registering is reduced to 9 percent and the probability for deregistering is increased to 8 percent to lead to a resulting 1 percent increase of businesses of that type.

To simulate birth of businesses –additionally to the overall economic development– the number of highly educated persons living in a certain zone is regarded as another driving factor. Persons with a higher education are expected to be more likely to establish a business than persons with an average education. To keep to the assumed trend the number of business births is reduced in areas of lower education, accordingly.

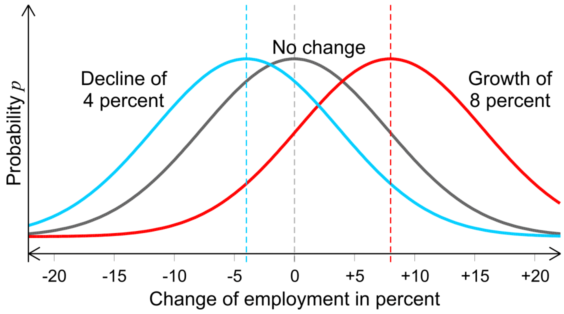

Figure 8: Probability for growth and decline

Increase and decrease of employment of one business is adjusted according to the overall economic development. If economy is growing many businesses will hire employees, but a few businesses will reduce employment regardless of the overall economic growth. To represent an appropriate distribution of businesses growing and shrinking a normal distribution is assumed (figure 8). For instance, if the overall economic development is +8% (red curve) the majority of businesses will increase employment by 8 percent, however there are some businesses that increase employment at a lower rate of even reduce employment and other businesses that hire even more than eight percent. On the average the targeted employment development is reached.

6 Outlook: Scenarios for finding new policy solutions

One major advantage of building a simulation model is the ability to run different scenarios. First, a base scenario, or reference scenario, is calculated. The base scenario represents the most likely trend of urban development. In this scenario the general conditions will change in direction of the trend they developed in recent years. This scenario represents the most likely development if no major policy strategies are changed. Then policy scenarios will be run. These scenarios calculate the likely effects of single measures or a combination of measures. The potential of simulation models is to calculate the effect of single measures while all other general settings stay the same. Then the effects of a single measure can be evaluated and compared with costs and other restrictions the measure generates.

Policy recommendations will address both local and regional authorities. Fields of policies that are addressed include but are not limited to environmental policies, land-use policies, subsidies, tax-system alterations, and transport policies. Since it is unlikely to find simply one solution impeding urban sprawl of businesses combinations of different policies will be developed. Since a simulation model is applied the interactions and synergies between different policies can be revealed. Scenarios that will be calculated cover major policy subjects such as

- change of business taxation
- improvement of street network
- restriction of any greenfield development
- increase of gas taxes
- new large-scale retail floorspace in inner-cities

- promotion of a development of decentralized concentration
- enforcement of a regionally coordinated retail concept

These scenarios can be calculated individually or as a combination of a broad policy package. The result of each model run will be compared with the result of the base scenario. The difference can be assumed to be the outcome of a single policy respectively a combination of several policies. Since jobs are distinguished in half-time and full-time jobs the job indicator will measure a full-time equivalent. The success of policies will be measured by indicators. Important indicators include number of businesses, number of jobs, ratio of jobs per inhabitant, resulting traffic flow volumes, and average commuting distance. The policy scenarios will contribute to identify feasible and successful policies for a regionally coordinated sustainable development, including economic stability, social balance, and environmental quality.

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