Geomodeling and Geovisualizations in Urban Planning und Real Estate Industry:

The Example of Office Market Research

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Abstract: Modeling, quantitative analysis, and forecasting in urban planning have a tradition since the sixties when very complex models for the whole "system of the city" were developed. After a phase of criticism about these complex black box programs in the eighties the topic got in the research focus again because of the easier possibilities for visualizing the results by the means of GIS. Subsequently, geomodeling is also interesting for more specific questions. The example shown in the paper is office market modeling – with a case study in Stuttgart. Due to higher vacancy rates and the degradation of buildings especially from the sixties and the seventies the subject is relevant for investors and real estate brokers but also for city administrations who try to avoid the degradation of whole areas. The classical time-series based office market models from urban economics describe the movement of the entire market but they do not consider local heterogeneity. Cross- sectional models like hedonic price modeling and an adaptation of the hedonic model for vacancy rates shown in the paper are difficult to couple with forecasting results. The microsimulation approach is the best way to integrate forecasting and a detailed spatial resolution. It consists in simulating movements, location choices, and vacancy at the building level. The paper presents the equations and exemplary results of the different simulation steps.

1 Geomodeling and Geovisualization in Urban Planning

Modeling in urban planning â and simulation as the most exact and methodologically complex way of modeling different future development paths â has its roots in the sixties when âlarge scale urban modelsâ were developed [For69]. Caused by the critics on lacking usability for the practice [Lee73], a general trend against quantitative methodology in urban planning became the mainstream. In the nineties modeling got again a discussed topic with the occurrence of easy to use Geographic Information Systems (GIS) [Bat92]. The easy calculation of variables describing location extended the modeling tradition to a real geomodeling. Beside the standard GIS tools a bundle of simulation tools exists today [WU04, MSW02]. However, further research has to be done: how to calculate spatially more detailed information and how to expand the modeling approach to urban themes apart from the well discussed land-use subject (e.g. for the real estate market; for the noise problem see [SR05, Rum07]) are the principal questions.

Urban planning is in the focus of politicians, the media, and the public. The lesson learned from the criticized âblack boxâ models of the sixties is the finding that visualization plays a major role in all kind of analysis and forecasting in urban planning. The typical way of visualizing zone or building related output of all kinds of urban models consists in the application of one of the standard GIS software packages. New challenges arise with integration of user generated vector data, e.g. from Google Earth, the availability of 3D-city models with mapped facades [HMM05], interactive WebGIS especially for planning process participation purposes, and the use of new augmented reality techniques for the visualization of urban future alternatives [Wie07].

2 Basics of Office Market Modeling

Office market modeling is the example chosen for the demonstration that the geomodeling and geosimulation approach can also be used for spatial questions that are not in the focus of the existing urban simulation tools.

Reference studies in office market research mainly have an economic background dealing with the cyclical movements (âhog cycleâ) of the markets. The phenomenon occurs because multiple developers start constructing without knowing from each other at a time of high space absorption. They accomplish the construction two to four years after when the market conditions often have changed fundamentally. The consequence is a high rate of vacant buildings. During a decline phase of the market the vacancy shifts from new buildings to old ones by movements. In the recent years the vacancy problem became also a discussed urban planning topic. The first reason is the existence of an increasing stock of old buildings which is left over and can not be let any more. The second reason is the technological and demographic change that will lower the total space required for office uses in most European countries. Office markets are markets with heterogeneous goods. The subsequent question for developers, investors, and urban planning authorities is where respectively in which buildings the problems of vacancy risks or low prices will occur. This requires a micro-level approach analyzing single buildings or geographically detailed zones.

The case study city for the subsequent analysis is Stuttgart in Southwestern Germany. The city with 590,000 inhabitants is mainly dominated by the headquarters of companies in the production sector (Daimler, Porsche, Bosch). It was chosen because of an actual lack of office market studies and a very stable market avoiding wrong conclusions because of short-run market movements. The data for the analysis consists in a Shapefile with all 185,000 buildings of the city, an extended attribute database for the 32,000 buildings with more than 200 mÂ of floor space, an office building inventory of the field study of the consulting company Baasner / Langwald / Mller including vacancies, and finally price

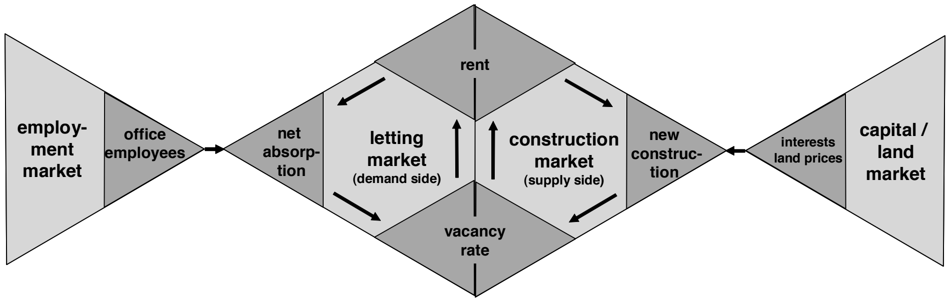

Figure 1: The interaction of the different office markets.

data of the cadastral authority and the Investment Property Databank (IPD).

3 Urban economic approaches

The classical space requirement calculation of urban planners ignores traditionally the existence of vacancy and the heterogeneity of the office space. For this reason an in- depth analysis of the local differences in office markets has to fall back on economic methods. As these are ignoring traditionally the spatial aspect, it has to be added where possible.

3.1 Longitudinal models: Simultaneous equations

The following office market model is based on works of e.g. [Ros84, DiW96, Für06]. It requires time-series data of an entire office market (in general: one city or metropolitan area). Temporal lags in the equations give the model its dynamics. The parameters of the interacting markets (the labor market on the demand side and the capital market on the supply side) are given exogenously. Figure 1 illustrates the relations between the most important variables. In the Stuttgart case the following equations were estimated as linear regression models with significant parameters (signs of the coefficients given in brackets):

(1) Rent = f(Vacancy rate of the previous period (-))

(2) Net absorption = f (number of office employees of the year before (+), rent (-))

The new vacancy rate can be calculated easily by the occupied stock and the total stock. The latter one has to be actualized periodically by the supply side development:

(3) New construction = f (Net absorption of two years before (+))

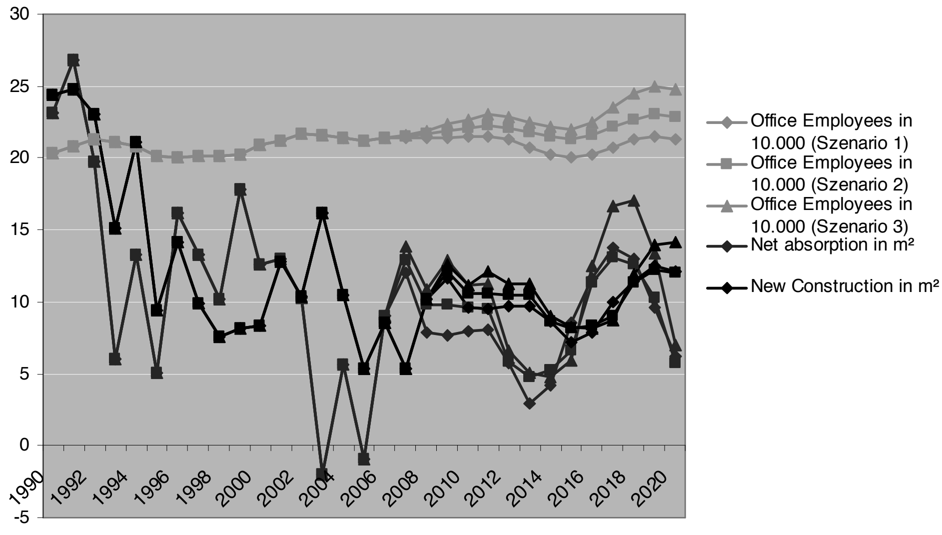

Figure 2: Forecasting changes in space demand (net absorption) and supply (new construction) for exogenously given office employment scenarios ranging from 215,000 to 250,000 employees in 2020.

The equations can then be used for the calculation of market scenarios with different values for the development of the number of employees. Figure 2 shows some results for two scenarios with a constant cycle length and a target value of 230,000 and 250,000 employees in the service sector.

The problem of the longitudinal models consists in the incapability to adapt to detailed locations. Despite the theoretical possibility of integrating flows and price elasticities between parts of a city, the approach fails due to missing long-run time-series for submarkets.

3.2 Cross-sectional models: Hedonic price modeling and the estimation of vacancy risks

One solution for analyzing market outcomes at a spatially detailed level consists in applying the hedonic price modeling approach (see [Des00, NM06]). Its general idea is the repartition of the price of a heterogeneous good on its different characteristics. Office buildings have physical characteristics (size, building quality, parking facilities etc.) and spatial characteristics (accessibility, cluster effects etc.). The spatial parameters are measured by GIS. To measure the effect of neighbouring buildings and zone characteristics each building is equipped with three buffer zones in the distance of 200, 500 and 1,000 meters (figure 4). All together, there are ca. 80 building and location variables, which are tested in all the following models. This overview paper reports only the most significant ones contributing strongly to the adjusted R^2.

An exemplary hedonic price model for office buildings in Stuttgart results in a linear regression equation with the following significant variables:

(4) *Rent = f (construction year of the building (+), number of* m^2 *of retail space in the 200-m-buffer (+), change of the number of office occupiers in the 200-m-buffer within the last 5 years in % (+))*

The function can then be used for an estimation and visualization of the rent level throughout the city. Figure 5 illustrates the outcome with a high price zone in the city center. The hedonic price modeling is a quite common approach. Despite its main use for residential appraisal in the US it can easily be adapted for office markets (with a reduction of the goodness-of-fit of the model because of the lower standardization of office buildings compared to residential ones). However, the vacancy rate is more interesting for urban planning and risk management in investment than prices. As a consequence it is useful to substitute the explained variable ârentâ by âvacancyâ. With the standard linear regression model it works only if vacancy rates for zones are explained (see [NI07]). At the building level the proposal consists in working with a binary logistic model where y=1 means the existence of vacancy in the building regardless of how many percent. In Stuttgart 15% of the buildings fit into this category of (partly) vacant buildings. The binary logistic transformation allows the calculation of probabilities for staying vacant:

(5) $$p(y_i = 1) = \left(1 + e^{-(\beta_0+\beta_1 x_1+\beta_2 x_2+\cdots+\beta_n x_n)}\right)^{-1}$$

The influence factors x_1, x_2, x_3 etc. in the Stuttgart case are:

(6) *Probability of vacancy = f (number of storeys (+), vacancy rate in the buffer zones (+), percentage of different construction periods in the 200-m-buffer zone, construction year (+), distance to the city center (-), distance to the nearest commuter rail station (-))*

Some of the estimated coefficients β_1, β_2, β_3 etc. carry an unexpected sign (e.g. the city center and the rail variable). A possible explanation is the fact that speculatively erected buildings (with higher probability of staying vacant) cluster mainly in the city center and around rail stations.

3.3 Evaluation of the approach

The combined application of longitudinal and cross-sectional models allows a forecast at the macro level and a detailed local analysis for today. Given the influence parameters of todayâs cross-sectional models the function could also be applied for future situations (e.g. new office clusters change the input parameters). In some case it might be sufficient. In others it can be quite problematic because the significance and the coefficients of the parameters can change. For this reason an alternative approach is discussed: the microsimulation.

4 Microsimulation approach

The microsimulation in urban planning reference studies is usually carried out for grid cells and for employees in different economic sectors regardless of their real estate typology they occupy. The fact that Stuttgart has a lot less office buildings than potential grid cells lets the author omit the grid cell concept and return to a building-based approach (where additional attributes from cadastral data are available). Consequently the urban microsimulation literature [MSW02, WU03] can be used as a source of ideas but the model equations have to be adapted and estimated for the specific building-based office market problems.

The first requirement for simulations is a starting stock (which is given by the cadastral data) and a starting population. The latter one comes from a business inventory of the chamber of commerce completed by an administration list of the yellow pages. The first problem consists in locating the users in the building. A simple alphanumerical join with the address field reaches a success ratio of 93.4 neighbourhood-matching in GIS (different approaches and their effectivity are discussed in [vMSH]).

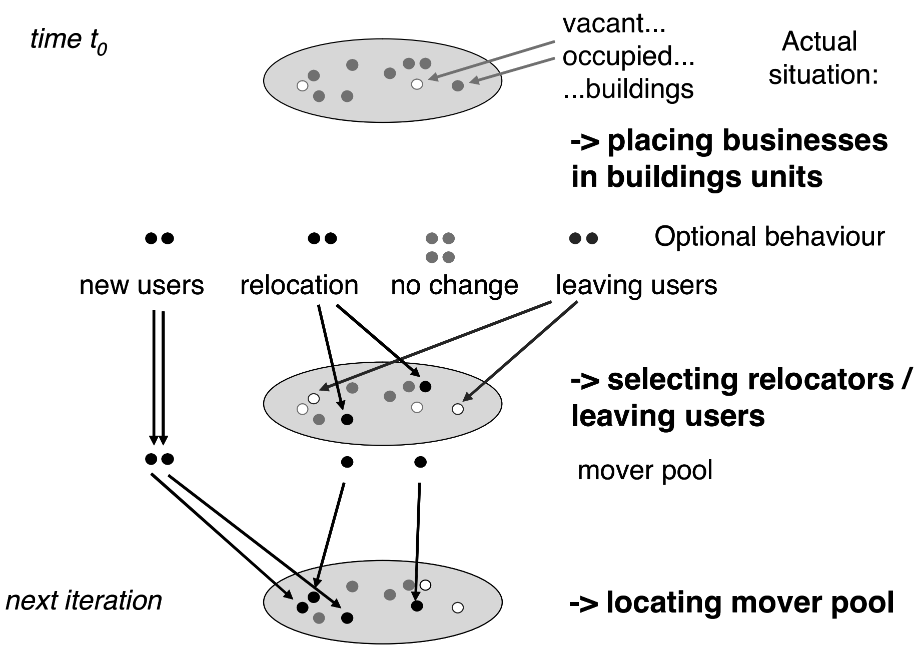

Figure 3: Microsimulation of office markets

Once the starting set of buildings and users is ready, the first iteration consists in the following steps:

1. Which user moves or leaves? To answer this question a binary logit model is estimated based on a dataset of moves collected by the chamber of commerce. The explaining variables are given by the characteristics of the user and the characteristics of the building.

   (7) p(move / leave) = f(herding behaviour: users from the same sector leaving (+), floor space ratio (+), different dummy variables for sectors and company sizes)

2. All moving users and the manually added new users are then put to a mover pool. The subsequent question is: which user chooses which location? The assignment process to the right location will be carried out in two-step-process: first, a building size restriction filters out non-suitable buildings (and the ones without vacant space). Second, different options are drawn randomly. The probability for each option is calculated by different location-choice equations which are estimated within a sample of chosen locations (drawn from the chamber of commerce mover sample) and additionally integrated non-chosen locations. As a location-choice equation can not contain user-specific and building-specific variables at the same time (due to dependence) a set of equations has to be estimated for different user types (clustered by sector and size).

The supply side will be inserted manually in a first step. For the next years the locations of assigned space for new office uses is quite determined by urban planning.

The simulation tool is actually realized in *Access* and will be migrated to *ArcView*. Figure 6 shows exemplary results with the target parameter "vacancy". It is important to remember that one simulation describes only one of millions of possible scenarios. If we are interested in forecasting e.g. the probability of vacancies multiple scenarios have to be processed and evaluated statistically. The simulation tool offers this option.

5 Outlook

The paper showed that different approaches can be used for the spatially detailed analysis of supply and demand in office markets. The microsimulation approach is not yet established in office market research. Its complexity brings with it the fact the further research has to done especially in the following fields:

- How can new construction be modeled (given the strongly regulated urban planning in Europe) and how can the refurbishment topic be integrated? How are tearing down and changing use tackled?
- The spatial autocorrelation (e.g. of the vacancy rates) and the herding behaviour have been integrated yet in a simple way. The methods of spatial econometrics could improve the models.

- How can the simulation results be visualized and communicated through an easily accessible (internet) user interface?

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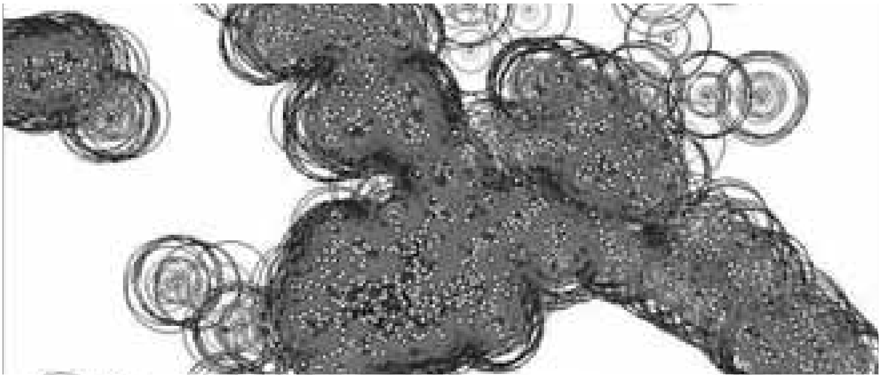

Figure 4: Methodology: The geographic influence factors are raised by influence zones around each building in the sample.

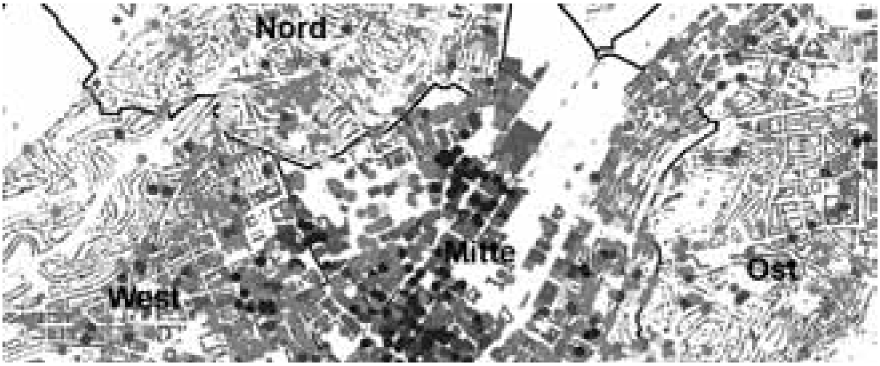

Figure 5: Forecasting price levels for all office buildings in Stuttgart (green = low price level, blue = high price level)

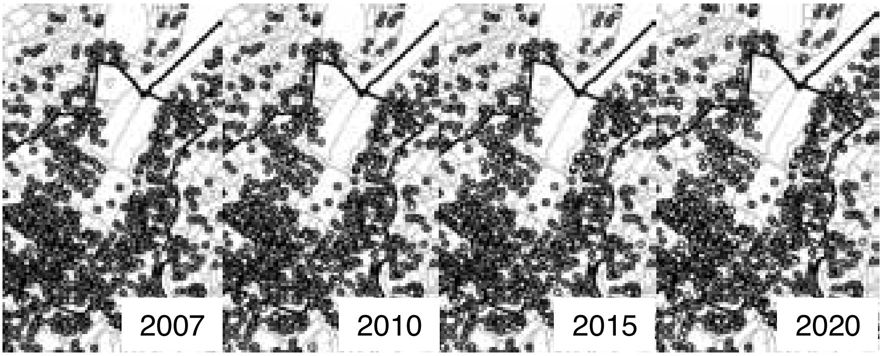

Figure 6: Exemplary simulation results for a leaving scenario. The colors indicate the vacancy rates of the buildings.