Revista Internacional de Sostenibilidad, Tecnología y Humanismo
año 2009 nº 4

Computer-based methods for a socially sustainable urban and regional planning

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Abstract

Due to global restructuring and urbanization, urban and regional planning is presented with the great challenge of offering sustainable planning strategies. Through particular consideration of the interaction between spatial and social structures, this research project aims to provide a methodical instrument that helps to factor the social dimension of sustainability into planning. The project comprises three modules. In the first one, a method will be developed, which makes it possible to generate spatial structures with very different characteristics. In the framework of the second module, we first elaborate on graph-based methods for analyzing spatial structures, and secondly we develop an agent-based simulation model for residential segregation. The third module contains an empirical study of the interactions between built structures and socio-spatial organization in the partner city of Dresden. Through the comparison of simulation models and small-scale empirical data, one should be able to derive theoretical concepts which can in turn be used to evaluate specific built structures.

Keywords: Social sustainability, urban planning theory and methodology, computer-based planning systems, spatial and agent-based simulation models, graph-based analysis methods, quantitative urban milieu research

1 Introduction

In urban planning concepts of sustainability, the social dimension has until now been neglected to a great extent. Thus, the consequences that generally recognized urban planning sustainability strategies like densification, mixed use, and polycentrality (Gaebe, 2004, p. 170) have for the social structure of cities are unknown. The unintentional intensification of conflicts that arise from the spatial separation of different population groups should be avoided. There is difficulty in estimating what effects spatial restructuring measures have on the social structure of cities. In addition, suitable methods that enable the qualified evaluation of the influences of spatial structures on the social-spatial organization of the population must urgently be developed. The central question consists of examining how concepts of sustainable city and regional planning can be developed and verified, taking into account the interrelationship between spatial and social structures. On the one hand, the unintended social effects of planning conceived in terms of ecological or economic sustainability should be prevented or estimated in advance, and on the other hand, unintentional social developments should be recognized very early.

2 Sustainability

The general principle of sustainable development that maintains its effect in the long term promises to address the needs of the current world population without interfering in the possibilities of future generations (Hauff, 1987). Sustainability is generally discussed on the ecological, economic and social level, which is why there are often references to the "three E's" - environment, economy and equity - in English-language literature (Bullard, 2006). Occasionally, these three levels are supplemented by other ones - for example in Spitzner (1997), by the level of values and that of culture.

In the international professional discourse on sustainable urban planning, the social dimension of sustainability is treated peripherally at best, in that reference is made to the general influence of built space on human coexistence (Wheeler, 2004; Williams, Burton, & Jenks, 2000). "*In contrast to the ecological dimension for a socially sustainable development up to now no action principles or aims about which to a great extent agreement exist"* (Werheit, 2002, p. 94). That the problems of disadvantaged residential areas are meanwhile also perceived from the governmental side is shown by the German project "*Social City"* ("Soziale Stadt") (cf. the reports of the Bundestransferstelle Soziale Stadt (2009), which tests, in different cities, concrete measures for civil cooperation, the improvement of job market conditions, infrastructure, residences, and the living environment, as well as the design of district centers (Guidelines for the organization of the communal initiative "Social City", 2005). The CoMStaR plan approaches the question of socially sustainable urban planning strategies from another vantage point: For us, it is a matter of investigating the interaction between the built urban structure and the social organization of the inhabitants.

3 Work programm

3.1 Generation of spatial structures (Module 1)

For the creation of very detailed spatial-geometric structures that are independent of a grid, we generally rely on the shape grammar procedure (Stiny & Gips, 1971). Using a set of rules that is to be precisely defined, variations of geometric structures are created with this method. Parish & Müller have shown in the area of computer graphics that with this technology, very realistic urban structures can be generated. Duarte, Rocha and Soares (2007) have extended the shape grammar technology to an urban grammar and have demonstrated the generation of a town structure using the example of an urban quarter in Marrakesh. However, the very realistic results require the implementation of a multitude of micro-rules (controlling parameters) for all the combinations of streets and properties that occur.

In order to be able to manage the complicated interaction of micro-rules, for further development of their approach, Duarte and colleagues suggest using a genetic algorithm in the search for optimally sustainable structures. The disadvantages of the shape grammar procedure come from the fact that the rules pertain to purely geometrical circumstances and must be fixed at the beginning in great detail. Furthermore, the generative functionality of shape grammar systems is limited to certain typologies. With Duarte and colleagues (2007), this was the dense, historical built structure of an old city quarter in Marrakesh; with Parish & Müller (2001), these are modern, single buildings in "Manhattan style".

In Module 1 of the CoMStaR project, we will deal with generating typologically extensive settlement patterns, which firstly get by with few controlling parameters and secondly, can be optimized with regard to general criteria of sustainability (energy consumption, daylight exposure, ventilation). In addition, the shape grammar procedure will be combined with an evolutionary strategy, as was used, for example, by Elezkurtaj and Frank (2002) for plan generation.

3.2 Graph analysis & simulation (Module 2)

A special form of network analysis in the realm of urban research is represented by the space syntax method (Hillier, 2007; Hillier & Hanson, 1984; Hillier et al., 1976), which has become established for the analysis of urban road networks or residential plans (Fig. 1). With this investigation method, the intensity of the use of different streets is primarily calculated. After the streets are transferred into a view axis network, various centrality measures can be determined (Jansen, 2006, p. 132-138). The investigation of Omer and Gabbay (2007) is especially relevant for the present project, because it associates the calculated values of integration with the distribution of the population according to income, and shows how small-scale population data from geographic information systems (GIS) can be correlated to values of space syntax methods. A restriction of the space syntax method exists in the fact that, until now, the analyses can be

applied either to the road system of a city or the internal building circulation. There is no connection between both subsystems. To create this connection, and to illustrate and analyze the circulation structure from the apartment to the main street in a continuous graph will be an important component of Module 2 of the CoMStaR project.

Figure 1: Space syntax analysis for the city of London. Source: (Vaughan, Chatford & Ozlem, 2005)

At the interface between urban geography and urban sociology, agent-based systems are used for the simulation of segregation processes (Schelling, 1971, 1978). In the process, the organization of the population at a macro-level is explained by the behavior of individual households at the micro-level. At the same time, the individual decisions about place of residence are dependent on the overall urban population structure, which itself results from the individual decisions (Fig.2).

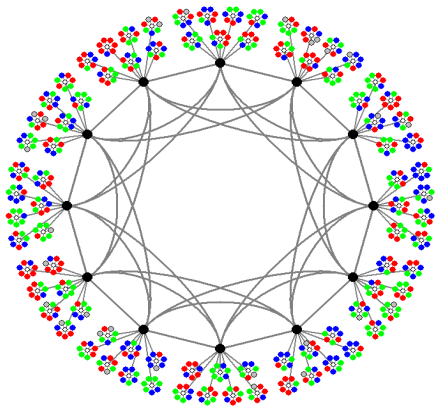

Figure 2: Households of different social groups occupying dwellings in an abstract infrastructure network graph. Source: (Koenig)

For our interests, the agent-based system for residential segregation from Benenson (1998) seems especially important, because other investigations on the dynamic behavior of the model were carried out based on it (Portugali, 2000) and qualified proofs of the validity of the simulations could be produced (Benenson, 2004; Benenson, Omer & Hatna, 2002). Another important component of Module 2 of the CoMStaR project will consist in transferring the simulation model of residential segregation onto a graph as a representation of the spatial structure of a city. In this way, using unchanged control parameters for the inhabitant's behavior, the effects of different spatial configurations can be investigated in the model. Further, Module 2 will be concerned with deriving heuristics for the perception of the townspeople amongst each other as a function of the built structure. Pointers can be found, e.g. in the study by Appleyard (1981), in which it was shown that the sum of the residents of a street who know their neighbors is inversely proportionally to the traffic volume of the street; as well as in an investigation by Hinding (2003), in which the communal sense and communication of the residents were clearly dependent on the spatial factors of individual settlement patterns.

3.3 Empirical social space analysis (Module 3)

By investigating the interaction between the built urban structure and the social organization of the inhabitants, CoMStaR concentrates upon an aspect that has been neglected until now in the discussion about sustainable urban and regional planning. In so doing, the social space analysis in Module 3 aims at the empiric investigation of these connections. Bernd Hamm has already pointed to the social importance of space: "*The social and spatial organization of a population are mutually dependent on each other and related to each other: spaces are formed and changed by social activities (...), and their design and furnishings have an impact on social relations and problems"* (Hamm, 1982, p. 28). Concerning the same circumstances, Friedrichs writes: "*Definable forms of social organization regularly lead to certain forms of spatial organization. Moreover, it remains to be investigated, what repercussions the respective spatial organization has on the social"* (Friedrichs, 1983, p. 50).

The empirical studies carried out during the last 20 years in the field of settlement sociology generally equate space with social space that distinguishes itself by the composition of the population in a certain area. How the population composition of a residential quarter affects the individuals living in it was investigated by considering, for example, the duration of poverty situations (Farwick, 2001). Thus, in the study by Friedrichs and Blasius (2000) although a precise description of the investigation areas is found, built structure no longer play a role in the actual investigation. Only the furnishings of the apartments are given attention.

Similar results are ascertained in the test of Schelling's tipping point theory by Kecskes and Knäble (1988). Here, a distinction was made between the aggregate levels of the house rows and the building block, but a further analysis of the spatial context is missing. The availability, at least fundamentally, of highly detailed spatial data, which can be collected and evaluated on the basis of GIS (Benenson & Omer, 2003), would make detailed studies about the relationship of

the spatial and social organization possible today. As part of CoMStaR Module 3, on the one hand empirical data about the spatial structure of the partner city of Dresden are processed for the graph-based analyses in Module 2, and on the other hand, thereby the (assumptions of the) simulation of residential segregation are evaluated in Module 2 on the basis of the data of a social space analysis.

3.3.1 Design of Empirical Investigation

For the reasons of data protection, the communal population data is only available on bigger official statistical areas with 200 households or more, we additionally purchased population data from the company microm. The data of the company microm, the MOSAIC Milieus, is a combination of the Sinus-Milieus of the Sinus Sociovision Institut, which are raised in all of Germany, and specific spatial projections for the city of Dresden with the help of spatial informations of commercial marketing providers (**microm Micromarketing-Systeme und Consult GmbH, 2009)**. Thus the project CoMStaR will be based on a spatial distribution of 10 Sinus-Milieus of Dresden, each point of the distribution aggregates 5 households on average (Fig. 3). In this way we are able to make statements on a small-scale level such as houses or street-segments for the years 2002, 2004, and 2008.

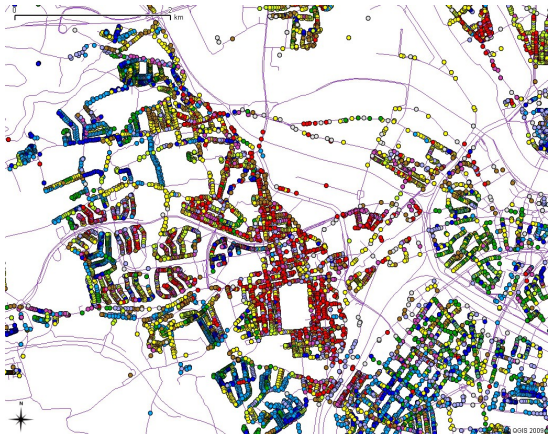

Fig. 3 Microm data points representing the dominant milieu

In order to make sure the spatial projection of the Sinus-Milieus is approximate to reality, we match this data with the official communal data of the statistical areas of Dresden. Additionally, a survey is planned in different spatial areas, which is not only for matching empirical knowledge with the spatial projection of the Sinus-Milieus, but to provide a better understanding of the interrelationship between spatial and social structure, too.

3.3.2 Milieu Approach

The milieu approach consists of not only socio-demographic variables, such as age, gender, income and education, but also of the aspects of modern, individual lifestyle such as cultural activities and preferences of residential location (Bourdieu, 1987). These two directions, vertical

(social structure) and horizontal (degree of modern lifestyle), are shown in this milieu-diagram (Fig. 4). For instance, the milieu of the conservatives on the upper left hand side, the milieu of the classical middleclass in the middle and the milieu of the hedonists on the lower right hand side.

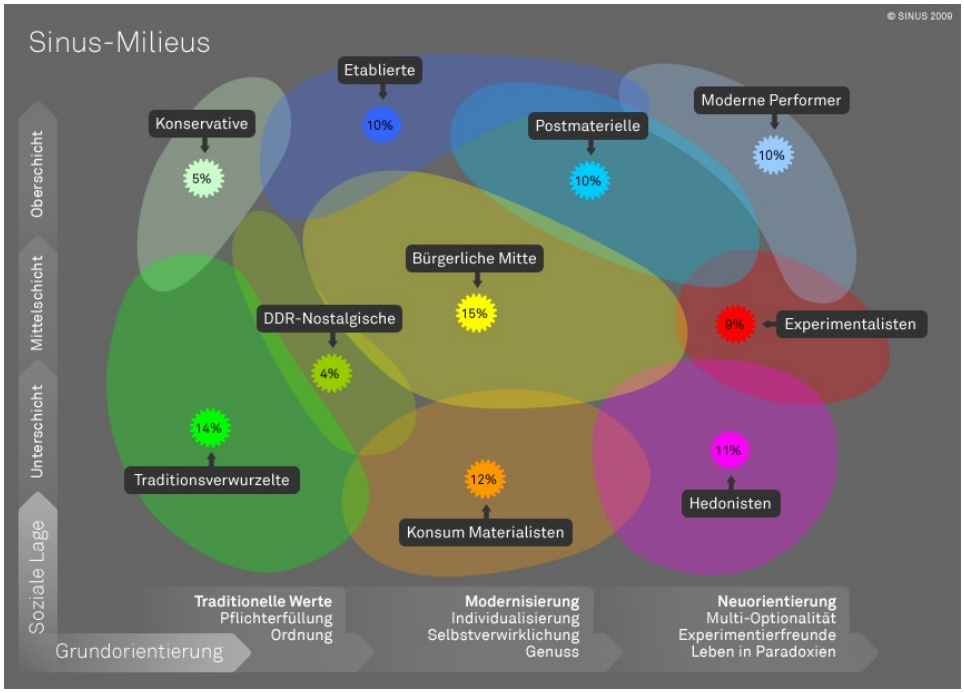

Fig. 4 Sinus-Milieus of Dresden. Source: Sinus Sociovision GmbH (2009).

Each of these various milieus has special preferences of residential location according to statistical analysis of the German Socio-Economic-Panel. These preferences are important indicators of how each household of the corresponding milieu would behave in terms of effort made for the relocation.

3.3.3 Spatial Indices of Segregation

With the help of the detailed MOSAIC Milieu data we are able to identify socio-spatial areas approximating the reality - without depending on communal statistical units. This is carried out with the aid of statistical methods such as cluster and factorial analysis.

The central question here is which level of socio-spatial areas - from building block to city level – is the decisive factor in order to claim statements of segregation and gentrification.
Therefore the proceeding of the project is first to measure segregation indices of different spatial levels and second to evaluate the results by theoretical approaches of segregation and gentrification.

Segregation is commonly measured by means of an index of dissimilarity. A “boundary modified” version of the index was formulated by Morrill (1991). It was based upon the concept

that segregation is a separation created by spatial structure imposed upon the social space and thus interaction between racial or social groups is limited. The index takes into account one of the spatial elements – contiguity – but ignores the others (Wong, 1993).

The approach of David Wong argues that the length of the common boundary between two areal units and the shape of the areal units are important spatial components in determining segregation. Thus a family of segregation indices is derived by incorporating these spatial components and can be applied to various spatial configurations. One of the indices possesses a distinctive property which is useful for comparing segregation levels in areas of various scales (Wong, 1993). Particularly the last-mentioned index represents a suitable tool to measure residential segregation for the project CoMStaR.

For the evaluation of the results by theoretical approaches of segregation authors like Häußermann/Kapphan (2002) and Dangschat (2007) will be discussed.

4 Hypotheses

The following hypotheses can be derived from these considerations:

1. Generative methods permit the automatic creation of a broad spectrum of spatial structures. In connection with graph-based analysis procedures and valid simulations of residential segregation, these offer useful support in the development of urban planning concepts. It is sensible to design a generative system in such a way that it generates the topological relations in the form of a graph in the first step, and in a second, to offer geometrical solutions therefrom.
2. Graph-based analysis procedures allow meaningful measurements of different qualities of the built structures of a city. Based on a topological-functional representation of a city, residential segregation processes can be simulated by means of an agent-based model.
3. If one looks at the built structure of a city at different levels of scale, influences on the social-spatial organization of the population can be demonstrated on every level. We assume that residential areas with comparable spatial structures exhibit similarities in social organization and vice versa. Moreover, we expect that in residential areas with homogeneous population, the use habits of the residents can be explained as a function of the spatial structure.

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