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A NEW ERA FOR URBAN MODELLING?

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In the last two decades, several interesting innovations have appeared in the field of urban research. New paradigms such as the dynamics of open systems, self-organisation, synergetics, chaos, evolution, were recognised as conveying fruitful analogies for urban theory. New types of modelling were investigated, as sets of non-linear differential equations for spatial systems, cellular automata, multi-agents models, fractal growth, neural networks, evolutionary models... However, most of the new ideas have added very little to the pre-existing urban theory, and most of the models which have been built neither have been applied nor compared to other models.

Large urban models of the sixties failed mainly because of a lack of technical means for managing the huge amounts of spatially-disaggregated data that were required. Now that those problems may be solved thanks to the development of Geographical Information Systems, there is still a risk for urban modelling of an inability to meet the social demand because of an increasing trend of disconnecting "pure" "theory" and mathematical "modelling" from empirical research. It is suggested that the innovative power of the moment rests in the conjunction of new tools together with old ideas, large amounts of facts and relevant questions, and this would be a further incentive to develop a closer cooperation between the members of both Commissions.

Key Words: Urban Models, Urban Theory, Mathematical Models, Simulation Models

Introduction

Is there a real need for organizing, under the auspices of the IGU, an exchange of ideas between urban geographers and mathematical modelers? Urban geography is certainly a field where models are more frequently used than any other branch of the discipline. Most mathematical models which are developed in geography deal with urban questions or are conceived in an urban framework.

However, there is still quite a lot of serious and interesting urban geographical literature or teaching courses which ignore the issues of urban modeling. Not only qualitative studies of urban perception and collective representations or of urban hermeneutics are usually made without any help of mathematical tools, but new facts and prospective debates about urbanism or social problems are described and discussed, cross-cultural comparisons of urban systems are made without referring to the possible relevant existing models. On the other hand, how many mathematical models are built using urban objects as a pretext only and are developed only for the sake of mathematical consistency rather than any real geographical, practical or theoretical objective? How many models have appeared in one publication only, without any comparison of their properties with those of previous models, neither receiving the slightest beginning of an application to any kind of real data?

Such gaps and delays in communication are frequently observed in science, but they may be detrimental to the discipline. It seems to be a good moment for developing more interactions between the interests of urban geographers and mathematical modelers, since a series of more or less recent and promising innovations have appeared in the field of urban modeling. It is not our purpose to provide an impossibly exhaustive review of those new urban models. Several specialised reviews have already been published, about operational intra-urban models (WEGENER, 1994), or computer-oriented urban modeling (BATTY, 1992), or about models of systems of cities (MULLIGAN, 1984, PUMAIN, 1991), or urban models in general (BERTUGLIA, LA BELLA, 1991, BOURNE, 1993). After recalling the conditions under which those models could be useful and really used, we shall make some remarks about new theoretical models and modeling tools which could be of interest for urban geographers.

1. About the utility of models

Maximising utility has long been an objective, as a mathematical constraint, hypothesized by urban modelers for the behaviour of urban actors... What about the utility of urban models themselves for urban geographers? From recent reviews of urban modeling, two main broad fields of utilization may be distinguished: models as a means for the formalization and testing of urban theories, and models as pedagogical tools for teaching or for assistance to urban decision-makers.

Mathematical modeling is often referred to as an activity in theoretical research. However, perhaps under the influence of a similar trend in economics, the significance of "theory" has shifted from geography to mathematics. Is it necessary to recall that the quality of mathematical urban modeling is not only made of mathematical consistency but also its relevance and significance for the urban field? Even if theory remains a pure intellectual construction, its chances of success are linked to the number of facts that it is able to encompass and to enlighten.

A second utility of mathematical models is in their use as didactic tools, particularly when they are included in computer software packages. Mathematical models or simulation models on computers have the advantage of putting together several elements of urban theory and producing quantified tables of data or cartographic images, which are the results of a variety of sometimes rather complex interactions. The consequences of some theoretical hypotheses of spatial urban form and of its evolution may be studied and tested. The model user is also invited to do experiments by changing various parameter values and the rules of the model. Two main categories of users may be interested in such tools: first, students and young researchers may improve their knowledge of urban theory; second, urban managers and decision-makers can try to evaluate the possible consequences of some change they would like to bring into an urban situation.

Such practical urban models have met with a reasonable success, especially when they are designed as games. A software package like SIMCITY is known and used even by people who are not specialists of the urban field. There is here a challenge for urban geographers. If they want to avoid the severe regression which has been observed for instance in the average quality of the production of thematic maps with the increasing use of computer-assisted cartography and geographical information systems, specialists of the urban field should intervene personally in the process of designing those software dealing with urban problems.

2. New theories for urban modelling

Since the end of the seventies, urban models have contributed to a better integration of sometimes old ideas or empirical research findings into a more formalized urban theory. To my sense, two main improvements may be quoted in this field: bifurcation theory and self-organizing systems on the one hand (ALLEN and SANGLIER, 1979, ALLEN et al., 1981, WILSON, 1981), and individual spatial behaviour and random choice theory on the other hand (DOMENCICH and MACFADDEN, 1985).

Self-organisation theory has been useful for describing the evolution of urban systems at the level of a whole urban area (ALLEN et al., 1981, WILSON, 1981), or of a system of cities (ALLEN, SANGLIER, 1979, SANDERS, 1992). Models were transferred from physics to geography, using nonlinear differential equations for the simulation of urban change. Their novelty is not in the urban theory that they are referring to: agglomeration economies, economic base theory, distance-decay interactions and principles of central place theory are the main theoretical building blocks of those models. But for the first time those theoretical elements are integrated together in the same models; the models are both dynamic and spatial; they allow for modelling qualitative changes in urban structure from quantitative variations in the parameters. The models also try to derive in an explicit way the behaviour of a system at a higher level from the shape of the interactions between its elements observed at a lower level.

For all of those reasons, such dynamic urban models represent progress because they conciliate old ideas about urban systems and empirical observations about urban change with new mathematical and computing tools for experimenting and testing them (PUMAIN, 1989).

Major progress also has been made in the field of urban theory by developing much better insight, at a micro-level, into the behaviour of urban actors. Most operational models of today, even if referring to equilibrium theory, are far away from the concept of a perfectly informed and utility-optimizing homo economicus (MACMILLAN, 1993). Several surveys and empirical research have brought new and useful insights about the effects of a lack of information and uncertainties on spatial decisions, and to what extent differences in individual trajectories and tastes could induce a large dispersion of behaviours. Decisive advances have been made in the fields of residential mobility and housing strategies, job search behaviour and about the choice of transportation modes (CLARK, 1985, TIMMERMANS, BORGERS, 1985). The location processes of various kinds of urban industries, public facilities and retail services were investigated in the same way (BIRKIN and WILSON, 1986, WRIGLEY, 1988). Random utility or discrete choice theory and classical techniques of multinomial logit models are used for integrating such knowledge into predictive models of urban development (WEGENER, 1994).

Fractal geometry is another appealing field for urban modeling, for several reasons. First, it provides a mean for describing spatial structures where an internal order is compatible with a large part of randomness in the location and size of subsystems. Fractal structures also are revealing nested hierarchical principles and multifractals are helpful for describing systems where several levels of organisation are recognisable. Applications to urban systems, until now, have been of several kinds: the fractal structure of built-up areas has been investigated by comparing the length of the perimeter and the surface of urban areas, as well as by measuring the fractal dimension of the urban borders, or of the built-up space (FRANKHAUSER, 1994, BATTY, LONGLEY, 1994). Several attempts have been made at simulating the spatial extension of urban built-up areas with models of fractal growth (BATTY, 1991, FRANKHAUSER, 1994). However, we still lack of the means for validating the similarity between the computed and observed images. On the other hand, there is not always a clear identification of the social processes which are actually formalised by the parameters in such models. It is then interesting that for instance FRANKHAUSER (1994) identifies three kinds of urban processes which may lead to fractal structures of built-up areas, including the duality between urban extension and transportation networks ramification, polycentric growth, and the trend to preserve empty places inside urban spaces.

Fractal formalization also may lead to an improvement in the spatial theory of urban systems (ARLINGHAUS, 1985 and 1989). Such an approach invites us to integrate into models of the development of systems of cities the idea that, instead of using an Euclidean space as a backcloth, it could be more relevant to consider a fractal space, linking various speeds of movements in geographical space according to the scale under consideration.

Several other possibilities of modeling urban spatial dynamics by developing analogies with physical processes or mathematical computing have been explored, but without giving rise to enough empirical testing for validating their relevance for urban studies. This may be the case, however promising the models may appear, for instance, for equations of spatial diffusion (ZHANG, 1990), or for systems of neural networks (FISCHER, 1993, DIAPPI , OTTANA, 1994, WHITE, 1989), or for the theory of evolution applied to urban modeling (ALLEN, MACGLADE, 1987, RABINO, 1993).

Progress in theoretical urban geography may come not only from transferring and adapting ideas from other disciplines. New observations may lead to the reformulating of urban theories, leading to more general description of urban systems: for instance, the careful studies of several kinds of interactions taking place between cities help to develop a broader concept of city networks than those included in central place theory (DEMATTEIS, 1990). Progress also can emerge from the possibility of testing "old" hypotheses or models, with newly available large sets of properly prepared data. For instance, a large part of the literature on the rank-size rule and city primacy is invalidated because it uses data sets that are too limited or non comparable urban definitions (PARR, 1985, GUERIN-PACE, 1993). By using a large data base, including strictly comparable figures (MORICONI-EBRARD, 1993), deeper insights have recently been brought into questions like the domain of validity of the Paretian model for the distribution of city sizes, the generality of a stochastic model for the repartition of urban growth within an urban system, or to the justification of Jefferson's "law of primacy".

3. New tools for urban analysis and simulation

At least as significant as the new theoretical paradigms for urban research are the new modelling tools now available. M. WEGENER (1994) shows how those merely technical improvements succeeded in solving almost all theoretical difficulties which justified LEES famous "requiem for large scale models" in 1973. M. WEGENER identifies at least twenty research centres all over the world where operational integrated urban models are used and experimented. He distinguishes between "unified" models, which are tightly integrated behind a single modeling objective, and "composite" models, where models of urban subsystems (such as, for instance, population, housing, transportation, employment...) are only loosely linked within a broader framework. Whatever the chosen orientation, the existence and operationality of those models is linked to the development of large and reliable data bases, of appropriate software such as Geographical Information Systems, as well as to the above mentioned theoretical progress.

The rather good performance of henceforth "classical" modeling tools of urban geography when included in Geographical Information Systems is also evidenced for instance by the success of a programme like GMAP as developed since 1991 at the School of Geography at the University of Leeds (CLARKE, 1990, CLARKE and WILSON, 1987, BIRKIN et al., 1990). Micro-simulation procedures as well as spatial interaction models or even neural network approaches are integrated in a library of available programs working on urban or regional data bases, and used for solving problems of location or of marketing for private firms or governmental agencies. The question may be raised of the possible feedback of such applied studies on fundamental research: it may help to elaborate more operational modeling tools, but carrying out innovative research may become more difficult.

The introduction of systems for managing geographical information by computers may also change our way of constructing models. Among the first attempts at modeling the spatial evolution of urban systems are the Monte Carlo simulations by MORRILL, following a method first initiated for the simulation of the spatial diffusion of innovations by T. HÄGERSTRAND. MORRILL made simulation models at the scale of an urban area, for describing the extension of the Negro ghetto in Seattle with simple rules of social spatial segregation (MORRILL, 1965a). He also simulated the development of a system of central places according to migration flows between places (MORRILL, 1965b). In this direction of spatial simulation, progress in computer science and artificial intelligence opens new avenues for urban modeling.

A further set of models use cellular automata. A cellular automaton consists of an array of cells which may be in any one of several states. At each iteration, the state of each cell may remain the same or change to another state according to the states of neighbouring cells. Some models, like the famous "game of life", are very simple, but more complex cellular automata are useful in geography if they allow for several possible states and for sophisticated definitions of neighbourhood. W. TOBLER (1979) first mentioned cellular automata as one of the "geographical type" of models. H. COUCLELIS draw attention to their use for modeling micro-macro relationships in spatial dynamic models (1985) and for deriving complex dynamics from simple rules (1988). R. WHITE (1991) applied this formalism to simulate the evolution of land use patterns within urban areas. WHITE and ENGELEN (1993) checked the fractality of the simulated urban spatial structures.

Other simulation methods like "multi-agent systems" may allow more flexibility in spatial modeling of urban systems by generating the evolution of a global system from rules about local interactions of various types and ranges between "agents" of different kinds (BURA et al. 1993). Like all simulation models, cellular automata or multi-agent systems raise delicate problems of calibration and validation, which are not solved at the moment. However, they may be helpful tools for communicating the intuitive complexity of spatial urban dynamics to decision-makers.

The progressive inclusion of spatial analysis tools and of dynamic models within GIS may also change our way of doing research and our conception of modeling in the future. The power and speed of computing, the quasi immediacy of response between the formulation of an hypothesis and its testing, together with the instantaneous visual display of results may invite the development of a kind of "soft" modeling (MIKULA et al. 1994). The drawback of such flexibility is the development of too many "ad hoc" models with a great loss in simplicity and generality, which remain however two decisive properties of good models.

4. Urban theory without models

It should not be forgotten that a large share of interesting urban research is conducted and results are obtained without any reference to nor the help of mathematical modeling. Many of the fields where progress has recently been registered belong to that category. Among them, one could quote a few themes for which special sessions were organised at the Berlin meeting of the IGU Commission on Urban Development and Urban Life:

- counter-urbanization and metropolisation (which future for the contained urban areas and the hierarchised settlement systems?);
- social integration, spatial segregation and exclusion ("polarisation of urban space");
- city image and city marketing (connected to the questions of urban identity and of hermeneutics);
- urban poverty and the role of informal economic sectors in the urban development.

All those questions are socially important. New ideas and theories are emerging about them. They have been enlightened by significant results from empirical research and by connecting ideas coming from other fields of social sciences. Despite their social and scientific interest, they heave nor received major contributions from urban modelers. Not yet? Is the urban modeling to be conceived mainly as a formalisation process, which would come after the social, intuitive and empirical aspects of an urban question have been explored by more traditional means of investigation? Are the mathematical or the "purely theoretical" formulations real barriers to a dialogue with the empirical research and with the experimentation?

Such interrogations bring back to the question asked in the first part of this paper, about the utility of urban models.

Conclusion

So many more authorized papers already have been written on the status of modeling in urban geography and so many other deeper studies should be made about this topic that we can only consider the few remarks above as a short contribution for bringing together the work of our two Commissions and as an incentive to develop linkages through further meetings.

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