Editorial

B Planning and Design

Environment and Planning B:
Planning and Design
2016, Vol. 43(2) 251–256

DOI: 10.1177/0265813516630803
epb.sagepub.com
SAGE

Classifying urban models

Fifty years ago, Ira S. Lowry (1965) published his 'Short Course in Model Design' in the *Journal of the American Institute of Planners* as part of the special issue edited by Britton Harris on Urban Development Models. Lowry's paper became a classic for it provided a superb overview of the domain which we now call 'urban models', abstractions of city systems that are represented in various types of mathematical and logical formalisms that are computable; that is, systems that can be implemented on digital computers and which are capable of enabling 'scientific' prediction. The term model was rapidly becoming part of our scientific vocabulary during those years (see Batty, 2007) but Lowry's particular contribution was to sketch out a domain that could be approached through many different styles and types of model, also paying tribute to different kinds of representation of cities from various perspectives that could be articulated in computation. In this sense, he bounded the field and provided us with a map of the terrain that we could then explore. Such explorations have occupied us since that time and half a century on it is worth exploring not only how far have we come but also whether or not Lowry's classification has stood the test of time. We know there are many modelling types such as agent-based, micro-simulation and so on which did not feature as such in Lowry's classification but it is also clear that many of the origins of developments since then do appear at least implicitly in his prescient thesis.

If you examine the evolution of different models since their inception in the Chicago Area Transportation Study in 1955 (Plummer, 2003), aggregative models based on a fusion of social physics and macro-economic structures such as input-output relations and urban economics dominated the field for the first 20 years. Lowry's (1964) own model itself became the classic exemplar and there were many ways in which this model structure was thence elaborated through disaggregating its activities and adding a more explicit temporal dimension. Although dynamics provided the momentum for different model types, the notion of disaggregation to the point where individual objects comprising the aggregates could be simulated was encapsulated in the development of agent-based models and modelling (ABM). These were considerably more generic in structure than aggregate urban models in that ABM are completely general and can be applied to any kind of system whose objects can be assumed distinct, not just activities in cities. A particular form of ABM rooted in the physical domain emerged called cellular automata (CA) models which essentially articulated the 2D space as a grid of cells, regular or otherwise, and in both ABM and CA, the focus was on how the system behaves, usually in time thus embracing movement and complexity. More recently an earlier set of models called micro-simulation have begun to merge with ABM and CA although this particular usage in its strict form relates to a long-standing tradition in the economic and social sciences for simulating individual behaviour described by aggregate probability functions stemming from the work of Orcutt et al. (1961). These classes of disaggregate model are usually rule-based in that their operation depends on local rules that are used to drive the dynamics of the system.

Other model types that emerged early but have proved somewhat less popular for city systems are essentially econometric, and often linear in structure that limits their applicability in dealing with spatial and temporal change. Econometric models span the range from aggregate to disaggregate but their focus on estimation gives much greater significance to identifying the importance of individual variables than the more deductive styles of aggregate, ABM and CA types of model. In this sense, econometric urban models can be more rigorous in their validation and calibration but because they tend to focus on economic and social variables which are often not easy to represent or observe physically, they have not found as much favour in the development of urban models such as those which involve social physics, rule-based agent behaviour and processes of micro-simulation. To an extent, we might now summarise the state of the art as containing aggregate social physical models, ABM, CA and related micro-simulation, as well as urban econometric. Needless to say, there is no one single reference source which examines the range of model types and relates them one to another, and this suggests that different disciplinary perspectives and skills often characterise differences between these models types and their applications. Many of these of course do fuse into one another and it seems instructive now to examine how far we have come in terms of Lowry's initial classification.

In hindsight, it is now clear that Lowry made a key distinction between ***what*** aspects of the city were to be represented in any model and ***how*** these were to be represented. Models to Lowry and everyone else at the time were representations of activities in cities that could be related to one another mathematically and at the time, this kind of representation was quite limited to numerical quantities that could be observed, usually in the aggregate such as the amount of population in a place, the number of trips between residences and retail centres, and so on. These relationships appeared to be comparatively stable in that they were long-lasting and this tended to force the emergent field to deal with cities as static entities in some kind of equilibrium. Lowry did not in fact define different model types but at the time he was writing, the general distinction was between ***iconic models*** which were faithful but superficial representations of the phenomena in question, typically in our field, architect's models, ***analogue models*** which were relationships between aspects of the city that could be represented using mechanical and electrical forces such as wind tunnels, and ***symbolic models*** where relationships between the phenomena could be represented logically or algebraically in completely abstract terms that did not necessarily imply any alternative physical representation. This last class contained mathematical models – in fact algebraic models – which were the main focus of Lowry's article. In the intervening 50 years, what Lowry and most of us did not anticipate was the fact that symbolic models began to erode the other two classes. First analogue and mathematical models began to exist in parallel forms: wind tunnels for example could be translated into mathematical formalisms and vice versa. And then, iconic models began to be represented numerically in that the superficial but quantitative form about how the landscape and how buildings appeared were coded using digital geometries; such models then became computable in some sense, and to an extent geographic information systems technologies followed this route.

These latter developments still confuse the field. I remember some 10 years ago when someone who I did not know well approached me to set up a joint seminar on 'Advances in Urban Models'. I said that I had written a book on ***Urban Modelling*** in the 1970s (Batty 1976) and that I would be delighted to hold such a meeting. At that point we both realised that the urban models we were talking about were quite different. He was talking about geometric 3D representations of cities – iconic models in the old language – whereas

I was talking about symbolic-mathematical models. In some respects, this reflects the ever-wider usage of the word ‘model’ which I speculate on quite extensively elsewhere where I compare both types of model (Batty, 2007).

There are many other ways of classifying urban models in methodological terms. The distinctions between statics and dynamics and between aggregate and disaggregate were raised by Lowry and these continue to dominate the field. Fifty years ago, it was easier but not necessarily theoretically or practically any more desirable to represent cities as systems in equilibrium. This was despite the fact that temporal dynamics is intrinsic to city systems and the way they evolve. It still is however, despite the emergence of real-time streamed data, extremely difficult to develop temporally dynamic models which are operational. And this is despite the fact that our concern for the power of prediction has gradually lessened as we have become more conscious of the increasing complexity of cities and social affairs. Our ability to represent cities in ever more detailed form – by disaggregating aggregate activities into finer and finer classes and types – has also been limited. In fact disaggregating to the level of the individual or the building has been embraced in the development of a very different style of agent-based modelling that we will elaborate below but this has not enhanced our ability to predict or necessarily our ability to validate our models any better than before.

The last thing that Lowry talked about in his article was how models could be fitted to data. This sequence of tasks which constitute the scientific method of either inducing hypotheses from data and/or testing them against data has been elaborated quite extensively as new models have evolved. Validation, verification and calibration meaning how good the model is against data, whether the model works and how the model can be fine tuned to data are all stages that now dominate the model estimation process. These stages have become more elaborate as the separation between the raw code and the algebra of the model and the user has increased and as models have become ever bigger in terms of code (but not necessarily in their complexity). As more and more levels have been built to make models computationally feasible, the need to verify at every stage has become ever more important.

Although Lowry did sketch the main rudiments of a theory of models in his paper, and he amongst others did not anticipate the extent to which models have invaded many fields, there was some sense in his ideas that a new class of generic models in which objects and individuals called agents would emerge. In fact what he did not anticipate – none of us did – was the fact that computers would become ever more powerful and that representing things digitally in massive detail would become possible. The idea that software components called objects could be generalised was not really on the horizon in 1965 and thus the approach now called agent-based modelling was never anticipated. In fact there was some sense in which some urban models even then were veering towards agent-based representations – Chapin and Weiss’s (1968) work in Greensboro NC was a case in point but the notion that such an approach might become generic was barely discussed. Indeed, as in economic modelling most urban models were not generic – they were specific to cities – and the fact that there might be a generic approach to modelling relevant to any and every system of interest seemed impossible, at least in practice if not in theory. Whatever was generic then was at the level of mathematics and algebra, not any particular style of modelling. There were different styles but these were specific to cities.

The first urban models covered a wide variety of styles and types largely dealing with aggregate relations between land uses, activities and flows such as trips, sometimes with constraints on the location of these quantities that the predictions needed to meet. Essentially these were all algebraic specifications involving nonlinear-based social physics – potential and gravitation, econometric in terms of linear relations, urban economic nonlinearities such as relationships between utility, rent, transport cost and so on, with some models being a mix of rule-based and algebraic relations reflecting behavioural responses to a lesser or greater degree. Very quickly there was a shake out of modelling styles with aggregate cross-sectional social physics style models, henceforth called spatial interaction, Lowry's (1964) original model being the exemplar – taking pride of place. Dynamics was very largely missing and as the nature of the aggregation came under scrutiny throughout the 1970s and 1980s, excursions into making these models dynamic and disaggregate as well as interfacing them more effectively with transport models came to the fore. By the end of the century, a new class of large-scale models had emerged and these reflected many of these concerns relating to aggregation and dynamics; structures such as ***UrbanSim*** emerged which today represent the state of the art (Waddell, 2002).

In parallel, new types of model appeared from the 1980s driven largely by developments in computing. The narrower class of urban models was built around cellular dynamics – cities were divided into cells and rules formed to show how activities in cells transformed over time. These CA models were rather narrower and more visual than their large-scale predecessors and represented a very different tradition coming from remote sensing as well as computing. CA models were somewhat more generic than the initial generation of urban models for they could be applied to any system that might be partitioned into cells and to which rules of transition might be applied. To an extent, these developments were paralleled by the development of agent-based models which in a spatial context could be regarded as placing moving objects in cells and extending the rules of transition to embody how objects behave as well as change through space and time. Both types of model – CA and ABM – were considerably more generic than anything in the domain of cities hitherto but they also suffer from being too rich, too assumption driven, plausible though these assumptions might be, and too difficult to validate through data being unavailable through our inability to observe or through a lack of resources to supply the requisite data. In fact many efforts at disaggregating more aggregate static models such as ***UrbanSim*** have become orientated to styles of agent-based modelling and there has been a fusion of sorts. Micro-simulation models whose essential structure is one where agents are sampled from more aggregate distributions have also fused somewhat with ABM and many of the tools to create synthetic data sets which come from micro-simulation are rapidly finding their way into other modelling types especially where data need to be generated.

Our last class of models is econometric. In fact it is somewhat surprising that more econometric models have not been built for cities largely because econometrics involve essentially linear statistical models developed for both the macro and micro economy and there have been several variants developed for regions. To an extent, the problem in cities is that so many relations are intrinsically nonlinear that parsimonious econometric models have taken second place to gravitation and spatial interaction types. But one of the key issues that now dominates the field is that it is now possible to see any model type being generated from any other under appropriate transformations and many gravitational and transport models have been transformed to a linear structure which have drawn on the very powerful sets of techniques which exist in econometrics.

I began this editorial proposing to explore whether or not Lowry's classification of models in 1965 had withstood the test of time. In fact I believe it has except that new things have emerged that could not have been foreseen, mainly the development of generic styles of model that have been largely driven by researchers searching for communalities in modelling approaches, by similar schemes for model validation, and by dramatic developments in computing, particularly object-orientated approaches. To an extent, computers and computation rather than mathematics has been responsible for a blurring of the line between different model types – iconic, analogue and symbolic – and now a rather blunt way of distinguishing between model types in our domain is between those models that are representational and those that are functional. By representational, the key issue is that these models do not have any functional relationships within them that enable one to make predictions. Three-dimensional city models are of this kind – there is nothing in them that enables us to make predictions for these are simply basic descriptions of the city in terms of digital representation. We might be able to use them in a predictive context by changing their data but it is rare to find any relational structure within them that changes the way the world will be other than the way we say it might be. In contrast, the other class of models is essentially functional whose structure is composed of a series of relations that enable us to make predictions. In this sense, such models are mathematical. Making changes to the parameters that drive the mathematics generates new predictions, with this lying at the core of these models. Representational issues tend to be secondary.

So the first key distinction which emerged over the last 50 years is between ***representational*** models and ***functional*** models. Lowry (1965) almost made this distinction although he coined it as the difference between descriptive and predictive. Representational models do not predict whereas functional do. Within the class of functional models, mathematical models dominate although analogue models do pertain to various functions which are implemented using analogue devices. In terms of mathematical models, we can make a further distinction between logical models and algebraic models, logical being rule-based with algebraic being numerically based. Both types might be described by equations although rule-based tends to simulate behaviours in certain ways while algebraic simulate numerical changes – which of course might translate into behaviours. ABM and CA models tend to be logical and rule-based whereas econometric, social physics, urban economic etc. are algebraic and numerical. Of course there is considerable overlap between the various types and none of the classes we have defined are mutually exclusive.

We have not added Lowry's third category to this classification which he called planning models, meaning prescriptive models based on processes of optimisation. These need to be separated out from our classification much more distinctively; representational and functional models deal with the system of interest at arm's length while prescriptive models deal with how one intervenes within the system through planning, management, decision support, control, policy analysis, and so on. Such prescriptive processes might be formalised as models – that is, control and management and optimisation functions might be added to representational and/or functional models but these pertain to elements that introduce rather specialist and individualistic functions into models that usually do not match the attributes and objects that define their essence. Many who have articulated the planning process see cities as being composed of many such processes and in this sense, it might be reasonable to include the planning function as simply yet another aspect of urban models. But the urban models we are alluding to here are largely functional, mathematical models whose form and structure treat the city system as something detached and separate, rightly or wrongly, from the planning process. Indeed we might even extend our wider classification into ***representational***, ***functional*** and ***planning*** models where Lowry's main concern was with functional. Representational and planning models may well have the same degree of abstraction as functional models but the focus here and in Lowry's paper was not on these wider abstractions but on the functional relations that represented the true cement that enabled such models to be assembled for prediction.

One last point. As we have evolved urban models over the last 50 years, it is now clear that in terms of function, we can develop a generic form for a model of an urban system that if we suppress or enhance certain elements of it, we can derive any model from any other. This is not really possible for representational or planning models and although we will not pursue this here, it is worth thinking of urban models as being derivable from a generic structure so that differences in emphasis can be explored and used to determine where such models might be applied. This still remains a major challenge in thinking about how these classifications might inform our understanding of prediction.

Michael Batty

References

Batty M (1976) *Urban Modelling: Algorithms, Calibrations, Predictions*. Cambridge, UK: Cambridge University Press.

Batty M (2007) Model cities. *Town Planning Review* 78: 125–151.

Chapin SF and Weiss S (1968) A probabilistic model for residential growth. *Transportation Research* 2: 375–390.

Lowry IS, 1964, *A Model of Metropolis*, RM-4035. Santa Monica, CA: The Rand Corporation.

Lowry IS (1965) A short course in model design. *Journal of the American Institute of Planners* 31: 158–166.

Orcutt GH, Greenberger M, Korbel J, et al. (1961) *Microanalysis of Socioeconomic Systems: A Simulation Study*. New York: Harper & Row.

Plummer AV, 2003, *The Chicago Area Transportation Study: Creating The First Plan (1955–1962): A Narrative*. Available at: http://www.surveyarchive.org/Chicago/cats_1954-62.pdf

Waddell P (2002) UrbanSim: Modeling urban development for land use, transportation, and environmental planning. *Journal of the American Planning Association* 68: 297–314.