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Retrospective on Large-Scale Urban Models

Douglass B. Lee

This commentary is by the author of "Requiem for Large Scale Models," and reflects on the original intent of that article in relation to what has occurred in the land use modeling field in the intervening twenty years.

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Urban modelers have talked a great deal about both theory and practical application, but have not seemed eager to subject their models to rigorous tests of either one. After the failures of initial attempts to address planning problems, modelers do not appear to have seriously re-evaluated their strategy or altered their approach. If, on the one hand, modelers are satisfied with adding new pieces to their models and describing the results to each other, the rest of us need not be concerned. If, on the other hand, modelers do want to demonstrate practical application, there are ways to build integrated models that are both scientifically sound and pragmatically useful.

What Spawned the Models?

Large scale urban models[1] (LSUMs) emerged in the 1960's as part of an effort to modernize planning and make the field more scientific. At the beginning of the 1960s, planning was dominated by the comprehensive land-use plan-making school, both in practice and in academia. Ferment was evident, however, in this field as well as others. Some academics viewed urban planning as archaic in its practices yet attractive in its professional scope, and ripe for the application of social science research. Planning awaited transformation from an architectonic, intuitive art into an objective, rational profession.[2] Human ecology, urban economics, operations research, and mathematical geography were probed for applicable theory and analytic methods. The field of Regional Science took shape, uniting these new interests in what was then the most active intellectual forum for planning academics.

Computers were just becoming accessible to people who were not electrical engineers. An ordinary-sized classroom was large enough to contain a machine with 5K of RAM, including tape drives the size of steamer trunks. The potential existed to specify relationships in mathematical form, and trace out the implications mechanically on a computer. It was very exciting to have so many unexplored frontiers so close at hand, and, even in hindsight, the motives were reasonable and sound, given the limited experience available.

What Happened?

By the mid-1960s, several large projects had been funded to develop complex packages of models—including land-use models—for specific urban areas, with the intent of using these analytical tools to solve urban planning problems. The first and most ambitious of these was for Pittsburgh's urban renewal program, and included TOMM (Time Oriented Metropolitan Model), based on the Lowry model. The effort collapsed around 1965; others followed in the next several years. By the early 1970s, the original promise had faded, and the remaining efforts retreated to academia.[3]

In the Fall of 1968 I started teaching at Berkeley, having written off LSUMs. My students did not necessarily disagree with my conclusions, but many were from foreign countries, and they felt they were expected to produce LSUMs so as to be "modern." They said that to be credible as critics of LSUMs, they had to be able to cite something in the literature. So with their help and encouragement I wrote "Requiem," and the *Journal of the American Institute of Planners* accepted it after the usual review and revision. Since then, urban modeling has gone through several more ups and downs, but has neither withered nor blossomed. Was I right about the flaws, and, if so, for the right reasons? What should modelers be doing now?

While Wegener and Batty offer convincing evidence that LSUMs are alive and well, they also demonstrate that modeling is mostly a cottage industry, not much different from what it was ten or twenty years ago. Despite upheavals in planning and the massive changes in computing technology, the role of LSUMs remains unresolved. That LSUMs are alive and well may be fine for the modelers, but is it of consequence to anyone else?

What Did "Requiem" Attack?

The central points of my critique can be distilled into the following three themes:

(1) *Black Box:* My contention was that not even the modelers could understand what was going on inside their models, and that consequently they could only massage them into behaving reasonably in relation to such data as they had. There was no assurance that the models did or would behave reasonably with respect to variables for which no data were available. There was no apparent understanding of what relationships caused which results.
(2) *General Purpose:* The ideal of a general purpose tool that contains a repository of knowledge relevant to problem solving, and accumulates more knowledge as it is improved and used, has a lot of appeal. This appeal is not entirely a delusion, but must be strenuously examined if the necessary discipline is to be imposed on the model construction.[4]
(3) *Command-and-Control:* This is a more recent term for tools used to support centralized planning, as well as for government dictates on behavior. The traditional land-use planning process fits this top-down approach, and many of the tools of regional science (input/output, linear programming) also derive from the command-and-control paradigm.

Some scholars were distressed by my attack. There are aspects of it for which I can apologize, one being the tone, which was argumentative, confrontational, and flamboyant. This style may be acceptable to stimulate dialectic exchange among those intent on solving problems and making progress, but it can be damaging to an infant endeavor if it amounts to airing dirty linen. It should be noted, though, that LSUMs did not come on the scene as a modest internal revision to an established profession, but as a full-fledged attack on traditional methods of land use planning.

An unfortunate effect of "Requiem" was the response by some reactionary city planners who used it to justify their resistance to learning anything new and to vindicate their current practices.[5] In this, of course, there is nothing unusual; ideas will be abused by whoever can take advantage of them to defend their own interests. This reaction did not, however, enhance the climate for honest re-evaluation of either modeling or traditional planning.

On What Grounds Should the Models Be Judged?

In my challenge to modelers, I asked them to declare whether they were advancing theory, or solving real-world problems, or doing something else. My question remains unanswered, so I will restate it with what I hope is greater clarity.

(1) *Advancing Theory:* If modelers are extending theory, then they should demonstrate their theoretical insights in the usual way—through refereed publications—or propose a more suitable forum where theoretical contributions might be assessed. Instead, defenders of models point to the long list of theories the models *consume* (e.g., multinomial logit), rather than to ones they produce. In fact, no one seems to claim that the output of LSUMs is theory. But if the input theory is so good, and has greatly improved over the years, as is the claim, then the models should be pragmatically useful.
(2) *Advancing Practice:* If models provide better ways to do planning, then either the models should be brought out into professional practice to compete against other methods for accomplishing the same purposes, or changes should be proposed to planning practice that will make it more amenable to urban models. To say that the models are not yet ready to submit to any performance evaluation, and to fail to offer any plans for when and how and on what grounds the models might be evaluated, is not acceptable even for a research effort. Modelers emphasize that the models are "operational," as if that meant the same thing as practical.

My preferences and experience lean toward the use of analytic methods in practice, so I will judge LSUMs primarily from that perspective.

The GIS Parallel

The growth in geographic information systems (GIS) is cited with more than a little envy as an example of innovation and diffusion that will, or could, propel LSUMs to success. The parallel is instructive. Both the technology and the concepts for GIS were around at the same time that urban models were being developed, but much less attention was paid to GIS.[6]

Suppose I had chosen to write a "Requiem for GIS" instead of one for land-use models. I would have pointed out data hungriness, expensiveness, and grossness (lack of detail), all of which were real obstacles at the time and prevented the development of applications for at least another fifteen or twenty years. On the other hand, hypercomprehensiveness, wrongheadedness (e.g., absence of price variables), complicatedness (lack of transparency), and mechanicalness (numerical error) would have been hard to argue. The sins of GIS were simply the cost to compute; once that cost reached a critical threshold, GIS development took off, because there were numerous practical applications.[7]

Disaggregation in GIS has never been a problem, for example, because it could be done in layers. Disaggregation in urban models, however, is another thing entirely. There is no guarantee that by moving to a finer grain, the robustness of the aggregated results will be improved. In going from total population to household types to individuals, there is no level at which behavior (e.g., location choices) is well known, and most relationships apply only at one level of aggregation. I see no more reason now to expect this problem to go away than I did twenty years ago, no matter how much theory has been developed or will be generated in the future.

What is Science?

The substitution of science for art is a good idea, and I'm pleased that Batty thinks that planning ought to be scientific, but unfortunately he doesn't say (nor can I impute) what he means by scientific. Therefore I will state what I think science is, as it applies to planning:

(1) *Transparency:* Transparency is essential for understanding how to interpret results, for communicating with other technical professionals, and for communicating with decisionmakers who must commit public agencies. It is ideas that determine public decisions, and even good ideas are insufficient grounds for making choices if buried inside a black box.

(2) *Replicability:* For policy purposes, it is important that the results obtained by one group of analysts be reproducible by another group, with or without the computer code that produced it. The virtue of replicability is that other analysts can change assumptions and parameters, rerun the analysis, and see by how much the results differ.

(3) *Pragmatic Evaluation:* There must be some pragmatic test from which it is possible to conclude that LSUMs produce results that are better than previous models and better than alternatives, either in contributing to theory or in improving planning practice.

LSUMs, as currently constituted, largely fail to meet these standards, i. e. they are not good science. The first two shortcomings are correctable, but only if addressed from a sincere willingness to learn from pragmatic testing.

A Paradigm for Analysis in Planning

As represented in Figure 1, there is a trade-off between the time horizon of the planning decision and the level of detail. Planning is broken up into three "types" here, although there is no exact number and there are no clear boundaries between the types.

(1) *Strategic Planning:* The long term is dealt with by keeping an eye on the future so that future options are not foreclosed by current actions, unless the narrowed choice is recognized and accepted. Trade-offs among goals can be evaluated, but specific outcomes or end-state objectives are effectively ruled out (examples: which corridor to improve, where to use congestion pricing, whether to use active or passive automated toll-collection technology).

(2) *Tactical Planning:* Hard decisions among alternatives are made at the tactical level, and, ideally, are formulated and studied as benefit-cost questions (examples: project evaluation, turnkey procurement, modal technology, guideway alignment).

(3) *Implementation Planning:* The execution of tactical decisions also requires considerable planning and evaluation of alternatives, but these are in the nature of problem-solving to accomplish a given result (examples: contracting, choice of equipment, installation sites).

All three types of planning should continue in parallel, with strategic planning looking ahead to check the implications of current implementation activities and of tactical alternatives under consideration. If the future appears acceptable at the point in time when something could be done to alter it, nothing further is required. If the playout of current activities could lead to undesirable choices in the future, however, then the current activities (even implementation, if need be) should be re-evaluated and adjusted. Good strategic planning is done as *early* as possible so as not to interrupt implementation or require tearing up previous work, but as *late* as possible so as to have the most information available (all planning involves learning, as in the Bayesian model).

Where Do LSUMs Fit In?

The LSUM contribution is somewhat ambiguous as to whether its aim is strategic or tactical, and that ambiguity is symptomatic of the problems with LSUMs as they are now constructed. LSUM builders do not adequately recognize the level-of-detail tradeoffs between tactical and strategic, and, as a result, strive for too much inclusiveness, more like "comprehensive" planning than is ideal for strategic planning. Modelers are caught by the everything-depends-upon-everything-else conundrum: if it is known that many things can affect many other things directly, and infinitely more things indirectly, then how is it possible to know which ones will be important without constructing an objective representation of them all? Modelers see complexity in the world, and conclude that failure to replicate known complexity is tolerating ignorance without cause. The more complexity that is modeled, the better the model.

Most formal models, including LSUMs, are too inflexible for strategic planning. They require too much information, they produce too much information that is not needed for any particular problem, and they shed too little light on the reasons for strategic choices.

At the tactical level, the prototypical application has been corridor analysis. Although LSUMs may sometimes be used for evaluating capital improvements in a transportation corridor, the land-use effects are probably not well handled. It should be possible, however, to construct a corridor-specific transportation and land-use model, which could be trans-

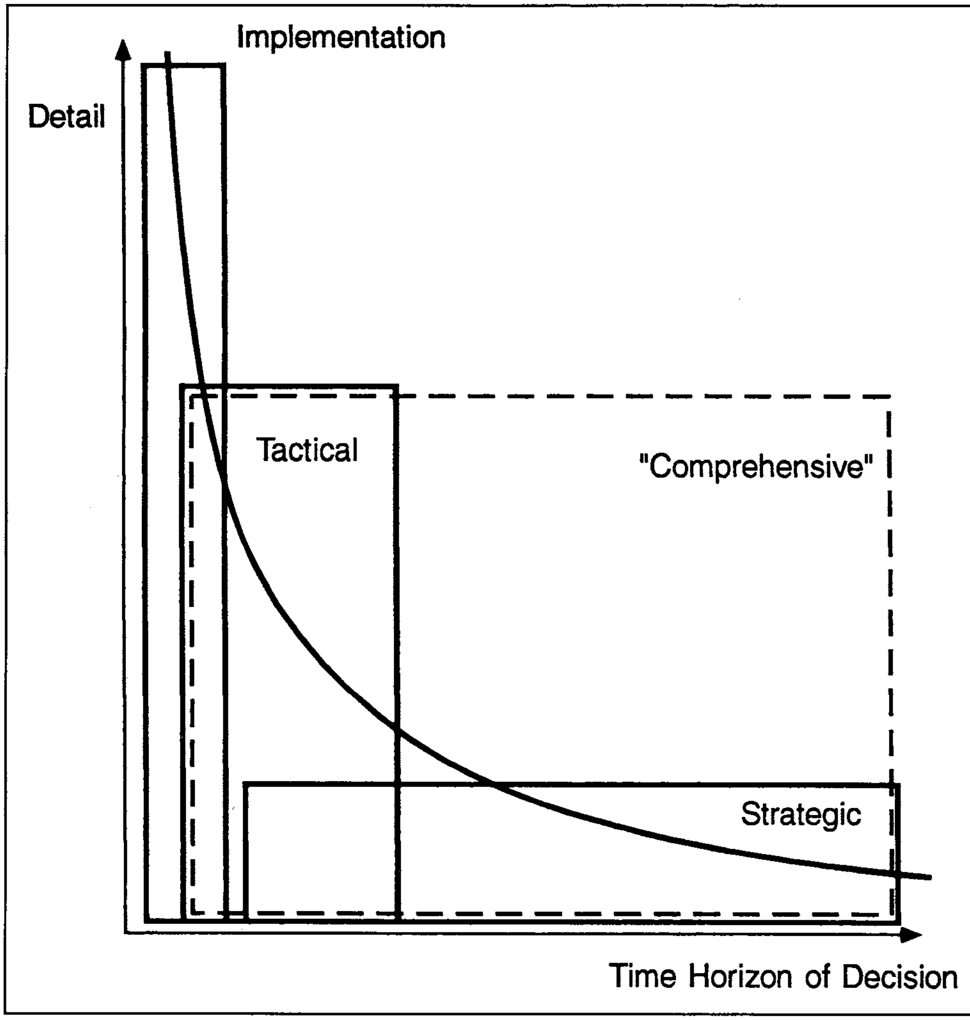

FIGURE 1: Trade-offs among strategic, tactical, and implementation planning.

ferred to other corridors with significant cost savings. Such a model would not look like current models. It could be built with rent/intensity at the macro level, access and trip generation at an intermediate level, and land-use allocation at a node-specific level. It should be noted, however, that once land-use intensity and trip generation are known, the actual land use has relatively little importance. Such variables as travel prices and parking prices would be central and explicit components of this model.

What Is the Alternative to LSUMs?

When I wrote "Requiem," I felt an obligation to offer an alternative. What I could say then was not very interesting, and became reduced to three exhortations, the main one being "work backward from the problem" to derive the methodology. When I quoted the Caterpillar as saying "It is wrong from beginning to end," it was a major paradigm shift I had in mind, but could not articulate.

Having twenty years' more experience in using analytic methods in the field of planning, I now feel greater confidence in proclaiming that a better way exists and in describing the essential features of that way. The differences are more in style than in the kit bag of tools. I do know this way works, because I practice it routinely on problems that are very similar, if not identical, to those ostensibly addressed by LSUMs.

A recent project for the U. S. Department of Transportation (DOT) that I was responsible for can be used to illustrate some of the features of useful models. We were asked to evaluate, within the space of a few months, roughly thirty options for reducing greenhouse gas emissions. The options were generated by the DOT, the Department of Energy (DOE), and the Environmental Protection Agency (EPA). Fortunately, most of the options that are good for transportation (congestion pricing) are also good for avoiding global warming, and the options that are good for avoiding global warming (a fuel tax) are not so bad for transportation.

The DOT had no previous work that was relevant, but DOE had spent several years building an integrated set of models that were intended to be applicable to many policy questions they might face. One sector—light duty vehicles—is shown in Figure 2. It is a part of the transportation sector, which in turn is one of several primary energy-consuming sectors. Each of the boxes in the light-vehicle sector is a model, or set of models. At the highest level, the sectors can be manipulated in a systems dynamics framework.

Not everything about these models is admirable, but they permitted us to carry out several valuable functions:

(1) *Replication.* The subsectors could be replicated entirely from DOE documentation, which included base data and structural relationships, in either mathematical or graph form. Spreadsheets were satisfactory for this purpose, although the DOE model is not built from spreadsheets. Dynamic analysis is easily accomplished, e. g., aging the vehicle fleet. Each sector and subsector can be independently operated, and produces results that are readily understood as to cause and effect. Each internal structural relationship is plausible and empirically verifiable.

(2) *Modification.* Relationships that DOE omitted could be added, and tested against their results. For example, the "insurance pay-at-the-pump" option called for annual auto insurance costs to be cut in half, and the gas tax raised by an equal amount. The impacts are that more cars would be registered, they would be driven fewer miles, and total VMT would be only slightly affected, but the gallons of fuel consumed would be substantially reduced. This is because the dominant effect is an improvement in fuel efficiency overall. Other effects—accelerated scrappage, a shift in the age distribution of vehicles, a shift in the weight distribution, and a shift in the emissions characteristics—are second or third order effects. DOE neglected the registration effect (making the option indistinguishable from a fuel tax), so we added it to our version.

(3) *Common Base Data.* Several of the options could utilize the same database. Thus it was worthwhile to construct some common models that could respond to various queries, i. e. a multi-purpose model. Having a standard set of data meant that differences in results among different agencies could be fully explained by differences in parameters or structural modifications, rather than different base data.

Thus it was possible to extract from the DOE model whatever pieces were useful for a particular analysis, modify them as desired, and understand the results. At all levels (other than the systems dynamics, with which we had no contact) the models were transparent, replicable, and pragmatically useful.

Other options we studied depended on data from other sources, and did not need to be conducted within a single model framework. The main effects of congestion pricing, for example, would be to shift vehicle trips out of the peak and increase vehicle occupancy. Because, however, the choices people would make as to schedule changes, carpooling, or transit ridership cannot be known from current data, the only way to test the impacts of congestion pricing is to try a range of elasticities and see what happens. Such a model can include several modes, and come at the problem from several methodological strategies. If the model also includes a detailed network for a metropolitan area (ours did

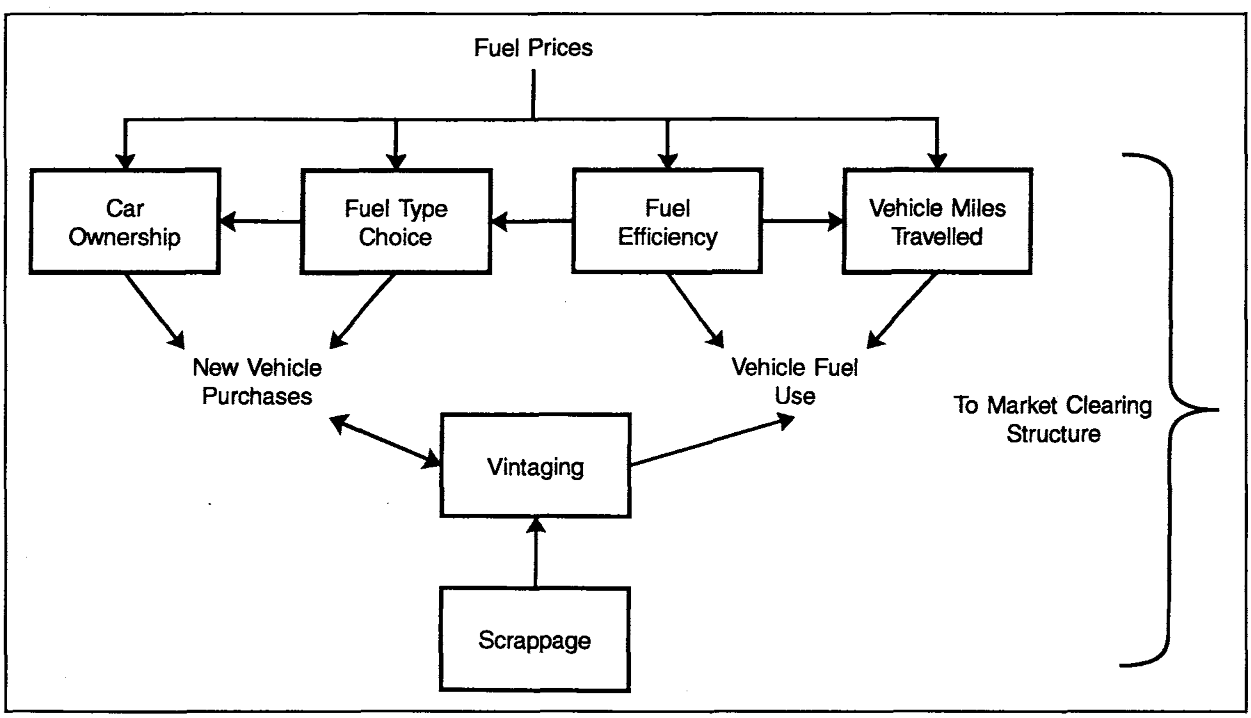

FIGURE 2: Light Duty Vehicle Sector from the DOE IDEAS model.

not), it will be quite cumbersome, not at all transparent, and not easily reproducible. At a policy level, the question is probably better dealt with through redundant approximations than through detail models; alternatively, if congestion pricing is being considered for a single expressway, then the network can be made much simpler. Having the network data available is valuable, but the utility of comprehensive models is considerably less.[8] Spatial disaggregation is rarely necessary, and can be greatly simplified (e.g., parking pricing for a dozen density classes) even if the application is metropolitan rather than national.

What Next?

The world has not been entirely inhospitable to LSUMs, and many operating government agencies have used them for various purposes. Command-and-control approaches are being developed and applied by government agencies, alongside market-oriented policy strategies. A new crowd is on the scene, and many of them seem to think that transportation models and land-use models actually work. There is a good chance that LSUMs and similar methods will be required as part of the Clean Air Act Amendments (CAAA) compliance process. Thus an opportunity exists to demonstrate the efficacy of models, and to improve them at the same time. For urban modelers, then, the question is whether they will accept the challenge, or ask for more money and time.

NOTES

1. The term "large-scale model" is not precise. "Large" is relative, changing with, among other things, the power of computers. The urban models of interest here are those that seek to describe, in a functional/structural form, an entire urban area, portrayed in spatial, land-use, demographic and economic terms. Spatial disaggregation yields zones that number at least in the hundreds, and maybe the thousands.
2. My undergraduate degree was in architecture, and I had both studied and practiced the colored-map mode of land-use planning before entering graduate school. Once I became aware of the "scientific" mode, I enthusiastically joined up.
3. I spent the summer of 1966 in Pittsburgh, to see if there was anything to salvage from TOMM. My report to the City did not offer much hope, and confirmed their previous conclusions. The following summer I went to Cornell Aeronautical Laboratory in Buffalo to write a review of models, and my conclusions were more broadly pessimistic. In 1968 I completed my dissertation, which included an effort to improve the TOMM model by disaggregating demographic groups within zones. The supposition was that more specific household characteristics could strengthen the location algorithms, but the results were again negative.
4. A cost argument for models is built on the premise that once a comprehensive general-purpose model is developed and running, additional exercises of the model have very low marginal cost. As with other claims, the idea is true enough in the abstract, but may not pertain to the LSUM context because subsequent issues are not sufficiently similar to use the same analytic structure.
5. It was never my intention to attack the use of quantitative methods, or rationality, in planning. I was and am a committed believer in society's ability to improve itself, to make use of relevant information, and to distinguish between better and worse actions on the basis of logic and empirical data and analysis.
6. In present terms, my (1966) masters' thesis would be called a GIS application. When I was a graduate student at Cornell, we had a three-foot-square flatbed plotter (with colored ink); we digitized the census tract boundaries for half a dozen moderately large metropolitan areas (each point had a number, a latitude, and a longitude, on one punched card); we calculated areas and centroids of tracts, we calculated and mapped various measures from census tract data, and we computed a number of aggregate spatial statistics.
7. For at least ten years, the annual meetings of URISA (the Urban and Regional Information Systems Association) consisted of Ken Dueker and maybe five others; now, of course, meetings draw thousands, plus equipment vendors, consultants, and the curious.
8. The EDF study of congestion pricing in LA utilizes network analysis done by Greig Harvey, working with standard traffic models, but heavily modified. Because these models were not constructed with pricing as a variable (except in mode choice), using this array for testing congestion pricing is an awkward patched-together sequence that depends on the ability of the modeler to interpret how the policy would affect particular variables in the models, and to manipulate the inputs in clever ways.

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