EXEMPLARY COMPUTER MODEL FOR A NATURAL HISTORY MUSEUM

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A new Fernbank Museum of Natural History, to be located in Atlanta, is in the planning stage. A major series of exhibits is entitled "A Walk Through Time." The walk culminates in exhibits which address the future. The museum planners wish to introduce the museum audience to computer modeling as an increasingly powerful tool with which to address societal problems. One exhibit is to present an exemplary computer model whose role is primarily tutorial. The model will treat limited facets of an urban system. The exhibit will present the model at two, or perhaps three, tiers of sophistication. The simplest presentation will utilize stored computer output in order to demonstrate model structure, interactions within the system, and some behavior patterns. Another presentation, also utilizing stored computer output, will allow audience participation in a restricted choice of model parameters. There may be a third exhibit tier in which less restricted parameter changes can be made in an interactive model.

INTRODUCTION

A computer model is under development as a part of a museum exhibit pertaining to the future of society. The museum planners intend that exhibits should be instructive, as distinguished from merely entertaining. The planners aim for a positive response to the question "What do you know now that you did not know before you looked at this exhibit?" Proposed exhibits are frequently structured into progressively more detailed tiers. One begins with a brief, elementary exhibit. If interested, a person may elect to proceed on to a second tier, and perhaps even to a third tier. While the initial tier is intended to be attractive to the casual museum visitor, subsequent tiers are more demanding of the visitor's attention. It is presumed that the deeper tiers will be consulted only by those who desire to learn and are prepared to put forth a reasonable intellectual effort to that purpose. Another important consideration in the tiered structure is that material of substance will be available and induce visitors to return.

Three main considerations led to the choice of an urban model. Visitors are surely concerned with the vicissitudes of urban life, so an urban model should be of intrinsic interest. Although the causal relationships between urban features are likely to be obscure, the features themselves are familiar. Finally, at the deepest exhibit level, the model might provide a tool for serious study of some urban characteristics.

THREE EXHIBIT TIERS

The preliminary plan for the urban model calls for three exhibit tiers. The first tier outlines model structure and demonstrates interactions between model elements, along with a few behavior patterns. The goal of this first tier could be achieved through a model of an inherently very simple system, as distinguished from something as complex as an urban system.

However, it is desired to maintain the urban theme at all tiers of the exhibit. At this first tier the model will not be interactive, but will utilize stored results which demonstrate the points to be stressed in the presentation.

The second tier is still intended to be primarily tutorial and will utilize a model of little more complexity than that utilized in the first tier, but limited provision for audience interaction will be provided. Stored results will be utilized again, but a variety of results corresponding to audience selection of some parameter values will be available. This does provide an opportunity to go the next step beyond instruction in general model behavior to demonstration of a variety of system reactions to the choice of control parameters. One may include both expected behavior patterns and "counterintuitive" patterns.

The third tier will incorporate those facets of an urban system already encountered in the first and second tiers into a more complete, albeit still greatly abridged, urban model. The museum visitor may interact with the model in live time. Evidently the "hardware" that must be allocated to a single user is considerably greater here; accordingly, it is anticipated that only relatively few visitors will elect to delve this far into the subject. It is at this tier that one may hope to seriously study certain urban problems. The third tier is likely to be implemented only after experience has been gained with operation of the other tiers.

URBAN MODEL

The urban model has four basic levels: labor, housing, business located in the central city, business located in peripheral areas. Only the third tier will utilize this complete model, and the complete model has not been constructed at this time. For use in the first and second tiers and for model testing purposes, three "mini-models" have been constructed, each of which includes two main levels. Model CITH emphasizes housing availability and has levels housing and labor. Model CITT emphasizes traffic congestion and has levels central business and peripheral business. Model CITP emphasizes employment and has levels business and labor; business here is an aggregate of central and peripheral business.

Guidance in this modeling effort derives from Jay Forrester's urban model (Forrester 1969). However, different facets of urban behavior receive emphasis in the two studies. In both studies, housing availability and employment opportunities are principal determinants in population migration. Forrester carefully studies the aging process in a city, which is only incidentally addressed here. Attention can be directed here to control policies, mainly through tax policies, that affect location of business in the central city vis-a-vis the peripheral area.

The present model is severely limited in its complexity in order to remain tractable within the museum use context, and rather arbitrary choices are made of facets to be emphasized and facets to be ignored or buried in some broad aggregate. For example, traffic congestion is explicitly cited. On the other hand, the impacts of policies on environmental conditions, education, crime, et al. are buried in a broad "basic urban services" aggregate. While implications about these buried categories may be inferred from model indices, it is not possible to distinguish between individual components. For example, education may be receiving favorable treatment and environmental matters poor treatment, or vice versa; but this model does not make the distinction.

MAUM

Evaluation of the condition of the urban system is treated in the model by "multiattribute utility measurement" (MAUM), as incorporated into a system dynamics model by Gardiner and Ford (1980). Three "constituencies" are defined, labor, central business, and peripheral business. Each constituency arrives at an overall "utility" for the urban condition by evaluating the status of various "attributes." Examples of attributes include housing availability and traffic congestion. The overall utility, as evaluated by a particular constituency, is obtained by combination of partial utilities associated with each of the various attributes. The combinations are made with weighting factors peculiar to a particular constituency and attribute. For example, traffic congestion is probably of more concern to central business than to peripheral business.

In the simplest implementation of MAUM, the weighting factors are constants. In the present context difficulties are encountered in model behavior when some attributes depart substantially from a reasonable range of valuations. Initially, the expedient was adopted of restricting model behavior by imposition of reasonable limits on crucial parameters. However, this does tend to dampen the richness of experience available, especially at the third, more fully interactive tier.

The MAUM implementation has been modified with the introduction of non-constant weighting factors. For example, a business constituency may be relatively oblivious to the attribute of basic urban services, as compared with a tax index attribute, under "normal" conditions. However, a severe deterioration in urban services, with concomitant dire consequences to education, crime control, garbage disposal, etc., will finally attract notice. In the model this eventuality is reflected by assignment of a weighting factor which has a normal value as long as the services remain within a reasonable range. However, the weighting factor rises rapidly, relative to weighting factors assigned to other attributes, as services drop below some assigned danger valuation. The overall effect of the MAUM modification is, of course, to improve the "robustness" of the model.

CITH

The CITH mini-model treats the impact of housing on labor migration. The structure of the equations chosen for this model facilitates study of a wide variety of behavior patterns and provides a model suitable for use at the first tier. The MAUM implementation here is trivial; there is only a single constituency, labor, and a single attribute, housing availability. However, as a first tier demonstration, this simplicity of the evaluative part of the model is preferable.

The levels are labor population and housing. A housing shortage is defined by comparison of the housing available with the demand for housing, which is dependent upon the labor population. The utility of the system to the labor constituency is evaluated in terms of the housing shortage. Migration of labor is controlled by this utility.

The housing supply responds to the housing shortage, with proportional and integral control terms in the rate equation. Provision is also made for an additional source of housing, e.g., a public housing program.

With the labor population constrained to remain constant, the mix of proportional and integral control may be varied in order to show the efficacy of integral control in alleviating a persistent tendency to a housing shortage. The constraints on the labor population may be relaxed in order to show modifications in system behavior attendant upon a rising population or upon the interplay of housing and population.

Again with the population held constant, the introduction of a delay in the response of the system may be shown to induce oscillation in the housing supply, a response characteristic of a second-order system. Then, allowing feedback between housing and population to occur may be shown to induce an oscillation superimposed on growth, a response characteristic of a third-order system.

The additional source of housing may be invoked as a periodic construction program. Sensitivity of response of the system to the periodicity of this program may be studied, and the phenomenon of a resonance response to a "forcing function" demonstrated.

CITT

The CITT mini-model emphasizes the interplay between the business population and traffic congestion. There are two levels in the model, central city business and peripheral business. Migration of business between the central city and the periphery may be studied, as well as net migration of business into or out of the urban area.

The MAUM implementation comprises two constituencies, central business and peripheral business, and three attributes, taxes, basic urban services, and traffic congestion. Migration of business into or out of the central city or the periphery responds to the corresponding utility.

A nominal tax rate is determined by decisions concerning the basic city services provided and the additional services provided specifically to alleviate residual traffic congestion. Further flexibility in the decision process is provided to admit transfer of the tax burden between the central business sector and the peripheral business sector, and it is possible to provide services without concomitant taxation. The latter possibility is intended to simulate many practical schemes for deficit financing, including passing the cost to the federal government or passing the cost on to children and grandchildren.

The population of the central city business category and, to a lesser extent, the population of the peripheral business category generate traffic congestion. Traffic congestion is affected by the level of the basic city services provided. Residual traffic congestion may be alleviated further by congestion control services. Non-linearities are incorporated into the service sectors to reflect decreasing effectiveness of services with urban growth.

Problem areas suitable for study with this model, viz. net urban growth, relative growth between the center and the periphery, and ensuing traffic congestion, are, of course, intertwined; but for tutorial purposes it is helpful to emphasize a single problem area in a particular study. The interplay between traffic congestion and central city growth tends to defeat efforts to substantially reduce traffic congestion over an extended period of time. This furnishes an opportunity to explore Professor Jay Forrester's admonition that a direct attempt to alleviate a problem is not likely to work; the direct attempt must be implemented in concert with other measures which control the feedback effects that defeat the direct action. The relative ineffectiveness of a simple, direct approach to alleviation of traffic congestion is suitable for a first tier use of the model. A combination of congestion control and growth control is appropriate in a second tier use of the model.

Shift of the tax burden between central city business and peripheral business provides a mechanism to control the relative growth in the urban area, with attendant impacts on traffic congestion and the need to provide congestion control services. Resultant behavior patterns are not likely to be surprising. However, this use of the model is of interest in suggesting that urban growth patterns may not be "natural", but may be engendered through policies dictated by influential constituencies.

CITP

The CITP mini-model emphasizes the impact of job availability on labor migration. There are two levels, labor population and business population. The business category here is an aggregate of central and peripheral business.

The MAUM implementation is the most involved of the three mini-models and comprises two constituencies, labor and business, along with four attributes, job availability, basic urban services, "amenities", and taxes. The amenities category, which is introduced in this model, is another broad aggregate of services. The distinction is made that basic urban services refer to essential services; whereas amenities refer to non-essential services, including parks, museums, and supplements to the basic services, e.g., supplements to the basic educational programs.

A surplus of jobs, compared with the labor supply, is attractive to labor and encourages inward migration of labor. Business, on the other hand, prefers a surplus of labor. Taxes are related to the basic services and amenities provided. In analogy to CITT, transfer of the tax burden between labor and business is possible; and services may be provided without concomitant taxation.

Model runs may investigate differing impacts on labor and business of various mixes of basic services and amenities. Improvement in services, with a corresponding increase in taxes, tends to cause a greater influx of labor than of business, with a net reduction in job availability. Not unexpectedly, strong growth can be promoted with a scheme that improves services but limits taxes.

Shift of the tax burden between labor and business provides an interesting control mechanism. Shift of the tax burden in the direction of labor provides an attractive atmosphere for business, which, in turn, attracts labor. The net job availability improves. In a sense, the system is improved from the point of view of labor, although the origin of this improvement seems manifestly unfair. Similar paradoxical situations often appear in model performance and are, perhaps, one trademark of system dynamics applications. As usual, the general explanation of such behavior is that the obvious, immediate tendency is overcome by ensuing feedback effects.

Of course, some behavior patterns demonstrated in this model are obvious, e.g., good services and low taxes encourage growth. However, inclusion of four attributes in the MAUM evaluation of system conditions often necessitates thoughtful interpretation of behavior patterns. The model does not seem a good choice for tier 1 of the exhibit, but should be useful at tier 2.

DECISIONS, MODELS, ABSTRACT QUALITY INDEX

The MAUM evaluative structure implemented in the three mini-models presumes that society is responsive, in the main, to the short term interests of influential constituencies. Phrases such as "fiscal responsibility" and "long term effects" often appear in pronouncements which emanate from the leadership of the public and the private sectors. However, constituencies that place such considerations ahead of their immediate interests are minuscule, and the weights that should be assigned to relevant attributes in a realistic model are nearly zero.

Public awareness of societal modeling techniques should engender more concern with the less immediate effects of policy decisions. A cynical view of decision processes assigns all the weight to self interest on the part of the decision makers. That view may not be accurate, especially in a relatively affluent society where resources may be diverted without severely compromising essential immediate requirements.

A major factor in choosing a short-sighted or poor policy may be simple misunderstanding of the intricate societal system. Unfortunately, less-than-scrupulous leaders, in the interest of attracting support for themselves, capitalize on this difficulty in understanding with deliberate deception in the advancement of policies which promise both the cake and the eating thereof. In fairness, some leaders may sincerely advance a policy because they, likewise, do not understand the system and have been captivated by "experts" dedicated to various traditional dogmas. Given the difficulty of understanding the system and the eminent stature often enjoyed by the not-so-scrupulous or misguided leader, it is easy to understand that even a conscientious citizen may support the attractive policy and reject a more onerous policy advocated by a scrupulous and well informed leader.

All of these problems associated with an incomprehensible system, acceptance on faith of leaders' or experts' views, and deceptive leadership to advance self-interest should be alleviated by more public awareness of quantitative modelling of societal systems. A central point, often cited by

Professor Forrester, is that assumptions must be laid on the table; if a neat outcome only can be achieved through absurd assumptions, that fact does not escape notice.

In order to better delineate differences between "realistic" behavior patterns and other reasonable alternatives, an idealized, hypothetical constituency may be introduced into the MAUM evaluative scheme. The associated utility has been denoted "abstract quality index." Partial utilities and weighting factors associated with this added constituency may differ significantly from those appropriate to the other constituencies; and there may be a need for additional attributes, attributes which otherwise receive zero weight. A precursor of this added constituency is incorporated in the CITP mini-model, and a more refined version will be incorporated in the full model intended for 3rd tier usage.

ACKNOWLEDGEMENTS

Inclusion in the planning for the new museum of a tutorial exhibit devoted to societal modeling was suggested by Professor A. L. Stanford, and the author is pleased to acknowledge continuing stimulating discussions with him. It is also a pleasure to acknowledge the support and interest of Dr. E. Kay Davis, Executive Director of Fernbank, Inc. This work has been supported, in part, by Fernbank, Inc.

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