THE URBAN SYSTEMS MODEL

A DESIGN

JUNE 1972

DEPARTMENT OF TRANSPORTATION

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THE URBAN SYSTEMS MODEL - A DESIGN

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by
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PREFACE TO THE REPORT

This report is divided into two parts. Part I discusses the general framework in which the development of the report took place. This includes an explanation of the report's purpose; a brief discussion of the Urban Systems Model; recommendations for this model; and the background of similar modeling.

In addition, Part I discusses the objective, background, users, and modular capability of the Urban Systems Model. It also describes in some detail the transportation subsystem in the model. Two sample transportation decisions are traced through the system flowchart. Furthermore, the relation of USM to other models is described and some of the design assumptions of the model are given.

Part II discusses specifically what the model does and how it works. This includes a description of the conceptual organization of the model and a description of the system phases. The system phases discussion includes a general overview of the model from a systems perspective and a detailed explanation of data items used by the system. This includes a discussion of the data base in general and the specific component data elements of the data base.

An interim report, The State-of-the-Art in Urban Gaming Models, was produced under this study in July 1971. Copies are available from the National Technical Information Service (Order No. PB 201 944) in Springfield, Virginia. In addition, detailed information on specific design specifications, file handling routines, and data element specifications is available from the Office of Environment and Urban Systems.

PART I

TABLE OF CONTENTS

PART II

TABLE OF CONTENTS

THE URBAN SYSTEMS MODEL AND THE TRANSPORTATION SUBSYSTEM

LIST OF ILLUSTRATIONS

LIST OF TABLES

PART I

THE URBAN SYSTEMS MODEL DESIGN: BACKGROUND AND SUMMARY

INTRODUCTION

Up until the 1950's it was generally believed that America's rapid urbanization since World War I was leading to the development of vital, vibrant and efficient habitats for the delivery of the goods and services which Americans had come to accept as necessities. Sometime in the 1950's, it became clear that the cities , despite their surface glitter, were suffering from an internal decay, an atrophy of spirit and a congestion of mobility which caused the first skepticism on the part of many Americans as to the desirability of achieving the urban dream.

America's response to this urban paradox was twofold. The citizenry, as measured by the growth of suburbs surrounding the cities, opted to leave the inner core and build a new life-style beyond the central city. Public agencies, on the other hand, responded by superimposing huge and frequently self-defeating public works in the form of housing projects, highways, "renewal areas", etc. on cities ill equipped to accept projects of such scope or intent. The net result, of course, was merely a hastening or acceleration of the entire process, which when coupled with massive migrations of black and Spanish-speaking populations into the rapidly decaying urban centers resulted in the complex of issues which we currently refer to as "the urban crisis".

In short, we may conclude that America has entered the "Post-Urban Era", a period characterized by the growth of sprawling, affluent and expanding "suburbs" surrounding and radiating out from congested, decaying, tax-base reduced, service poor central cities inhabited largely by black and Spanish speaking groups. By now, it must be agreed, that the "cures" suggested in the 50's have not been effective, and in fact have been counter-productive. What then is to be done in order to prevent the total collapse of the central cities and the continued dichotomous relationship of the basically inter-dependent central and outer urban areas?

For centuries, the scientific method, employing laboratory experimentation, has been the accepted means whereby man has sought the answers to fundamental problems in the physical sciences. It is only in the last twenty years that social scientists have attempted to create laboratories in which experimentation could be conducted in areas of social concern.

The idea of building a social science laboratory, employing computer models, is essentially an attempt to conduct large-scale social experiments designed to address urban problems, without the necessity of uprooting, dislocating and inconveniencing large numbers of people and expending huge sums of money. Through computer models and other social science laboratory techniques, it may be possible still to rescue the urban environment and create a "Post-Urban Era" marked by the efficient delivery of the goods and services vital to contemporary American life.

The Urban Systems Model described in this report is an attempt to focus the attention of transportation decision-makers on the totality of the urban scene. Numerous "transportation models" have been developed which tend to isolate the transportation function from the larger framework of urban activity. Several general models exist which do allow a look at transportation problems but they do not usually allow for the richness of detail or the multi-modal capability of USM. The model provides a most comprehensive tool for the analysis of transportation problems in an urban environment.

Clearly, a single device such as the Urban Systems Model cannot alone resolve the nation's urban ills. USM can, however, have a significant impact upon the policy makers who directly effect the course our cities take. If USM serves to assist the making of policy without disrupting the lives of large numbers of people and if the model stimulates the development of similar devices for the study of urban problems, surely the project will have been worthwhile and successful.

PURPOSE

Background

It was the objective of this study to design an analytical tool in the form of a man-machine simulation model which, when developed, can be used by regional and municipal planners to assist in assessing the impact of urban transportation decisions upon socio-economic and environmental elements of the community.

The National Environmental Policy Act of 1969 directs all Federal agencies to utilize a systematic, interdisciplinary approach in planning and decision-making which may have an impact on man's environment. [This report is meant to assist in the attainment of this objective through the detailed design of a man-machine simulation model.] The design provides for the development of a mechanism for assisting the assessment of the impacts of urban transportation decisions within a comprehensive and real urban environment. The completed model will allow regional and municipal planners to test a wide range of economic, political, social and institutional decisions affecting transportation planning and implementation. The model will also be capable of assessing impacts within a central city as well as within a metropolitan and larger regional area. The major benefit of this project has been to provide the Department of Transportation with a model design which, if carried into development, will enable a full range of applications for community participation, education, planning and policy making using the man-machine simulation model for testing transportation decisions.

Technical Requirements

The original proposal desired a design of an urban systems model which would generate indicated effects of transportation and other economic, political, social and institutional decisions upon the socio-economic and environmental elements of any represented community. The model was to be modular in design to enable separable routines to be modified with minimum difficulty. Also the model had to be designed to permit geographical linkages between the Center City and surrounding suburban jurisdictions so that the output would indicate the projected socio-economic and environmental effects of transportation decisions on the broader metropolitan region.

Ideally such a model was to accept inputs reflecting the characteristics of the urban area (i.e., "the setting") and a description of the proposed transportation innovation, system or service, then produce a set of desired output measures describing the effect on the urban area. The actual interactions within the urban environment caused by the introduction of a new transportation system are so complex, however, that with today's computer simulation state-of-the-art it may be best to simply introduce human beings (acting as simulated urban decision-makers) into the model rather than attempt to mathematically simulate their behavior. Such a model is depicted in Figure 1.

Such an approach, i.e., incorporating human decision-makers in the simulation model, was also justified by another line of reasoning. That is, the effects of the introduction of a major transportation innovation to an urban area are, in fact, greatly influenced by the specifics of the implementation and reaction decisions made by local authorities and business leaders. These decisions are then most reasonably modeled by having "model" decision-makers make their best decision within the simulated social, political, and economic environment of the model.

Moreover, experience with simulation models in the planning processes has shown that the ability of the human decision-maker to maintain comprehension and control of the process has resulted in a more acceptable application of this kind of analytical tool. The decision-maker needs to have an integral involvement in the planning process such that the computer model is complementary to his own judgment and intuition. The human interaction approach; i.e., using the model in an interactive fashion until a valid assessment can be made of the overall impacts of decisions, will serve to provide this additional acceptability. Finally, the model was to be designed so that it may be programmed in one higher-level language (preferably FORTRAN) and should be kept as machine independent as possible.

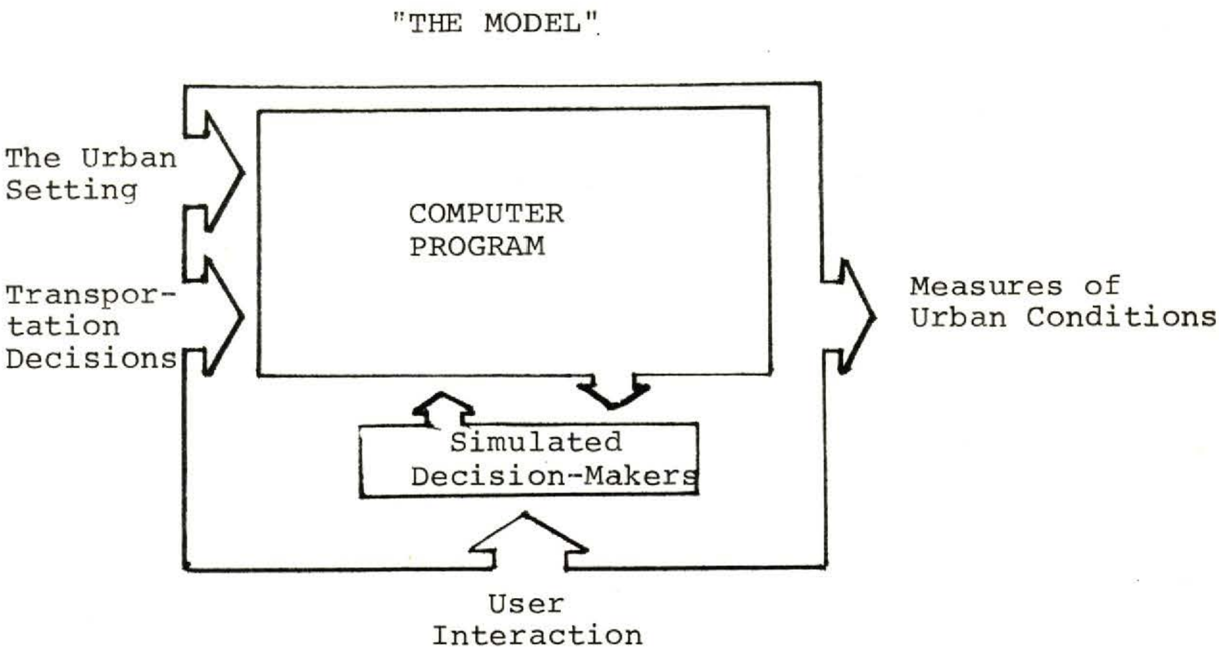


Figure 1

Man-Machine Simulation Model

MODEL EVOLUTION

Envirometrics is a non-profit research and education organization established in April of 1969 to serve the potential users of complex decision-making models: government, business and academic institutions. The staff at Envirometrics has actually had more than four years of experience working together in the design, programming, and implementation of urban and regional man-machine simulation models. The major products of this effort have been CITY I and CITY MODEL.

Envirometrics initially chose gaming as a modeling technique because it seemed that not enough was known about the social system to quantify political and social variables using standard mathematical functions. Further, the gaming models allowed a lot of experimentation outside of the existing operations research and simulation community. Following is a brief review of the existing modeling effort to present.

City Evolution

Instead of focusing on the singular aspect of transportation or land use in a simulated urban area, the CITY MODEL interrelates other variables such as the taxing, zoning and educational functions of a governmental structure. The model also adds the entrepreneurship of population groups owning property, and working in industry and businesses while living in residences according to their income level.

The CITY MODEL features man-machine simulation. In these models, players become decision-makers of "real" population groups in a simulated city while they learn about urban interrelationships.

CITY I, a well-known educational urban model, has given thousands of players a challenging experience and insight into the workings of an urban system. CITY II adds the realistic dimensions of transportation, migration and social factors. CITY III, developed for the U.S. Office of Education, furthers the simulation concept by expanding CITY II experience into a metropolitan area model. A REGIONAL MODEL design for the U.S. Department of Agriculture applies operational simulation technique on a multi-county area. A RIVER BASIN MODEL for the Environmental Protection Agency (EPA) focuses on the problems of water supply and water pollution. CITY MODEL is an advanced version of CITY III.

The CITY MODEL - Operation

In the model, participants (usually from twenty to one hundred) are decision-makers in one of three sectors: economic, social or government. The metropolitan size, geographical configuration, and political jurisdiction boundaries are chosen before play from several alternatives. See Figure 2.

Currently available are ten starting cities, ranging in population from 10,000 to 1.6 million. The simulated metropolitan area comprises 625 parcels, each representing one square mile (or one ninth of a square mile), many of which are unowned at the beginning of play.

A starting scenario may be used which briefly describes the current status of the area in terms of problems; issues; characteristics of growth, stability or decline; status of services, housing, schools, traffic, tensions, conflicts of plans.

When the model is underway, the characteristics of the city will reflect the actions and interactions of the participants.

The computer records participant decisions for each round. It indicates the effects of decisions on one another and on the metropolitan area itself. Regularly provided computer print-outs show the interaction of decisions and their influence during the run.

The CITY MODEL will respond to, and the play can be enhanced by, an almost infinite variety of player actions

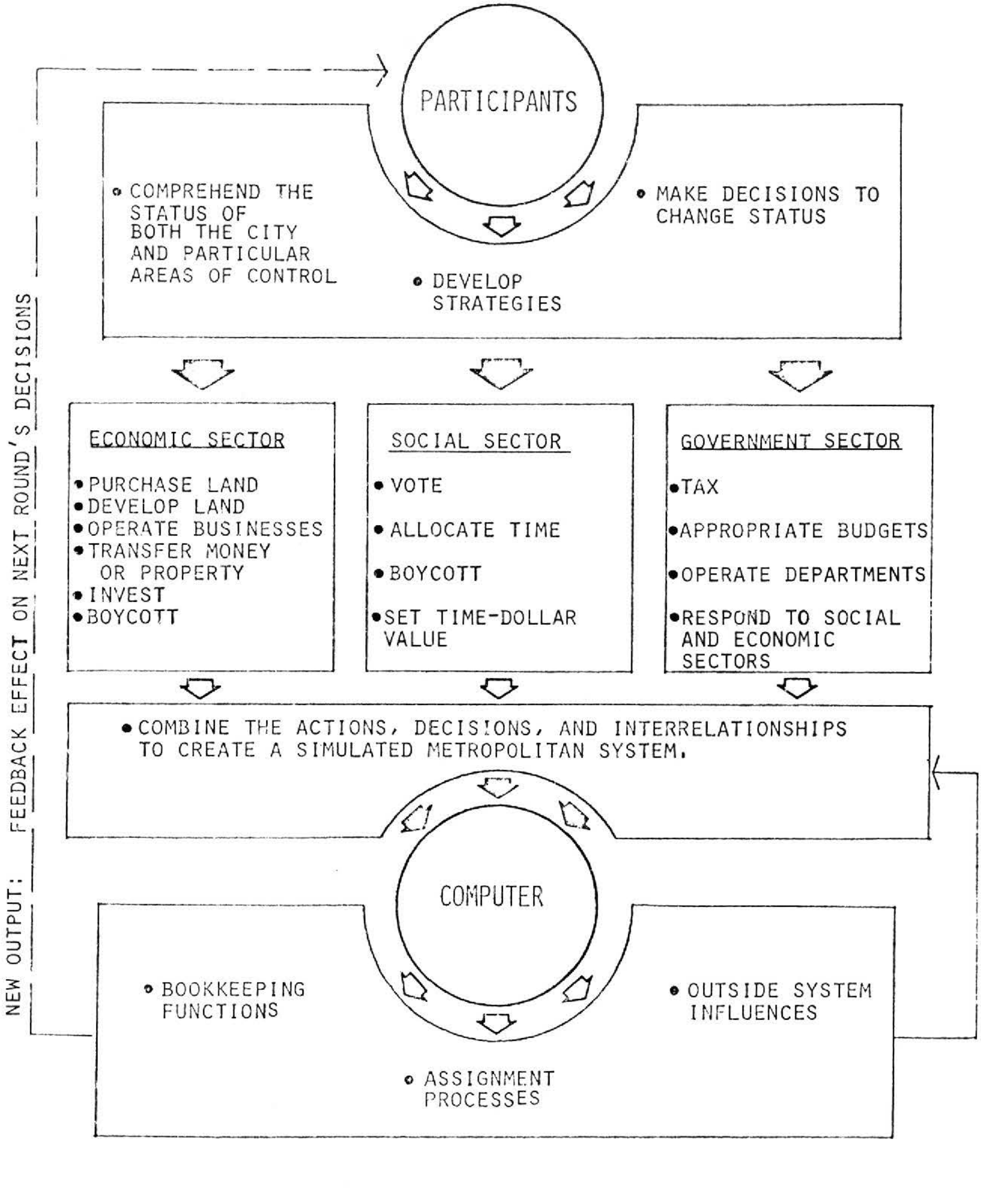


Figure 2

Interrelationships in the CITY MODEL

generated by curiosity, imagination, innovation or planning, programming, and budgeting. A general description of decision-making power of each sector follows.

The CITY MODEL - Economic Sector

Economic decision-makers have many choices of action. They are managers of their existing resources and have opportunities to expand their holdings. They may purchase and develop unowned land parcels or buy owned parcels from other economic decision-makers during a simulation run.

As managers of economic enterprises, they are faced with many decisions. Besides setting wage, price and production capacity structures for their properties, decision-makers also may decide to earn income from funds invested on cash subsidies, borrow and lend money, and, of course, have to budget for taxes.

Economic decision-makers can operate individually or in concert with other economic interests to create economic development plans, industrial parks, revitalization of a downtown area, among other things. They may also cooperate with city programs or actively oppose them.

There are four major types of economic activity in the Model:

Basic Industry

Heavy Industry (steel plants, for example), Light Industry (electronics firms) and National Service Industries (local outlets or plants of national concerns). These activities spend money for business goods, business services, utilities, maintenance services and transportation, to produce output that is sold in national markets at prices determined by the national business climate.

Commercial Establishments

Business Goods (suppliers of hardware and raw material, for example), Business Services (insurance), Personal Goods (consumer hardware) and Personal Services (supermarkets).

Construction Industry

Negotiates contracts with economic and governmental decision-makers, builds or upgrades developments with the requisite labor and material.

Residences

Single family dwellings, garden apartments (or multiple dwellings) and highrise structures. They may be developed to various densities and for three socio-economic classes. Decision-makers here are landlords, who spend money for maintenance, utilities, and taxes and earn income based on the rent charges and the number of occupants residing in the buildings.

The CITY MODEL - Social Sector

Social sector participants make decisions for population units (people) who inhabit the metropolitan area. These decision-makers allocate time for their groups (that is, to spend extra time at work, in education, politics, or recreation), boycott or strike (not to shop or work at certain businesses, or not to use certain modes of travel), and to vote (for elected officials or referenda).

Participants review their social status for the socio-economic groups they represent. They make decisions as to how they will vote, use their time and perhaps boycott so that they can improve their position. Raising the educational level, for instance, increases job opportunities and income potential.

An important part of the model's social action is the ad-hoc or special issue pressure and agitation exerted by the social sector decision-makers. Often, low socio-economic groups take concerted action to get the economic sector to create more jobs or to get the government sector to improve their schools or municipal services, or to encourage the development of education parks, for instance.

The CITY MODEL - Government Sector

Government sector positions are: Chairman or Mayor; Councilman; Assessment; School Department; Municipal Services; Highway Department; Planning and Zoning; Utility Department; Bus and Rapid Rail.

These decision-makers are elected by the social decision-makers or appointed by the already-elected officials to assume the duties of the governmental functions, which are performed simultaneously with the economic and social functions. The elected officials must satisfy voters in order to stay in office each round. The chief elected official in each jurisdiction appoints others to execute the functions of the school, municipal services, highway, planning and zoning, and assessment departments.

The government departments build schools, provide municipal services, build and upgrade roads and terminals, maintain roads, buy and develop parkland, zone land, and estimate revenues. The players decide whether or not utilities, bus and rapid rail functions may be operated publicly or privately.

Other roles which may be interjected into a run of the CITY MODEL include: Mass Media, Citizens Advisory Group, Federal-State Aid Officer; and Deputy Mayor and many others.

MODELS AND URBAN TRANSPORTATION PLANNING

Most models are built to satisfy a specific need. Often they are built as an analytical device for management and planning studies. Others are constructed by educators as teaching aids. Still others are developed out of intellectual curiosity and then built to demonstrate a theoretical construct. The Urban Systems Model (USM) and CITY are unique in this realm in that they were not restricted to satisfying any one use, but were built to serve four general purposes: education, training, research and policy making.

The models designed and built to satisfy these diverse needs were considered as part of an urban laboratory. The concept of a laboratory to teach and research the different aspects of the social system was (and still is) seen as a desirable goal and was a standard used for the USM design.

The research technique used to build USM leads to some interesting conclusions from the point of view of model building today. Both those who are attempting to construct models for policy makers and those who are evolving models toward this goal are, in effect, attempting to build the same model. The difference is that policy model builders usually proceed, not through the path of theoretical structure but by collecting data and building data banks. These models, when finally constructed, are often an attempt to relate numbers to each other in some systematic fashion. The models then become restrictive for the sake of "realistic" parameters.

On the other hand, the method of evolving a model turns the above process upside down. The principal research used is based on the structure of the social system. Little work is done with data bases. This feature, combined with the fact that the model is built independently of any specific project and not for a specific city has made the USM concept the most general model for education and policy decisions. In fact, the previous contracts from the federal government and the business community explicitly required that the model be applicable to many locales and be versatile enough for a wide variety of users. This resulted in much of the model building efforts being directed to satisfy this goal.

The final feature involved in the building of USM was a focus on the advantages of computers to the field of social science modeling.

The Urban Systems Model developed by Envirometrics is designed to allow as many theory inputs on the part of the user of the model as possible. USM is a versatile computer-assisted decision-making model. It is environmental in that it can be used to represent economic, social and governmental decision-making within regional, metropolitan, or city areas. (See Figure 3.) The model is general, in that it can be used to represent any such environmental system and can be used with a wide variety of purposes: transportation planning, education, training, research, policy information, and policy testing. With any particular run of the model as a game, there are two major users: the director and the participants. The director, the person in charge of the run of the model, may exercise various amounts of control over the starting position and/or the on-going use of the model. The participants, the people who assume control of different economic, social and government resources in the geographical area represented by the model, make decisions as to the use of these resources. That is, the participants become the decision-makers of the local system represented by the model. Used as a simulation, there is less need to divide the model into discrete decision-making areas. The concept of director and participant becomes less clear cut.

USM is also holistic in that it deals with the whole system and is not a partial model that is simply concerned with transportation, public budgeting, housing, or a number of other issues looked at in an isolated fashion.

The Need for a Transportation Planning Laboratory

The modern urban environment desperately needs solutions to its problems, and social scientists are one of the sources from which the answers will come. At present, however, they lack the comprehensive means with which to arrive at real solutions. While the natural and physical scientists have taken long strides toward examining, quantifying and analyzing the natural world, social scientists are still making the first steps toward understanding theirs.

The social scientist today appears to need some of the techniques of the natural scientist if he is to profitably study and improve man's urban environment. Until recently, such techniques were denied him, seemingly because he studies man as a social animal; which means he not only deals with a real world that apparently defies predictable physical laws, but he also faces complex dynamic variables caused by an unpredictable, if not erratic, agent -- man.

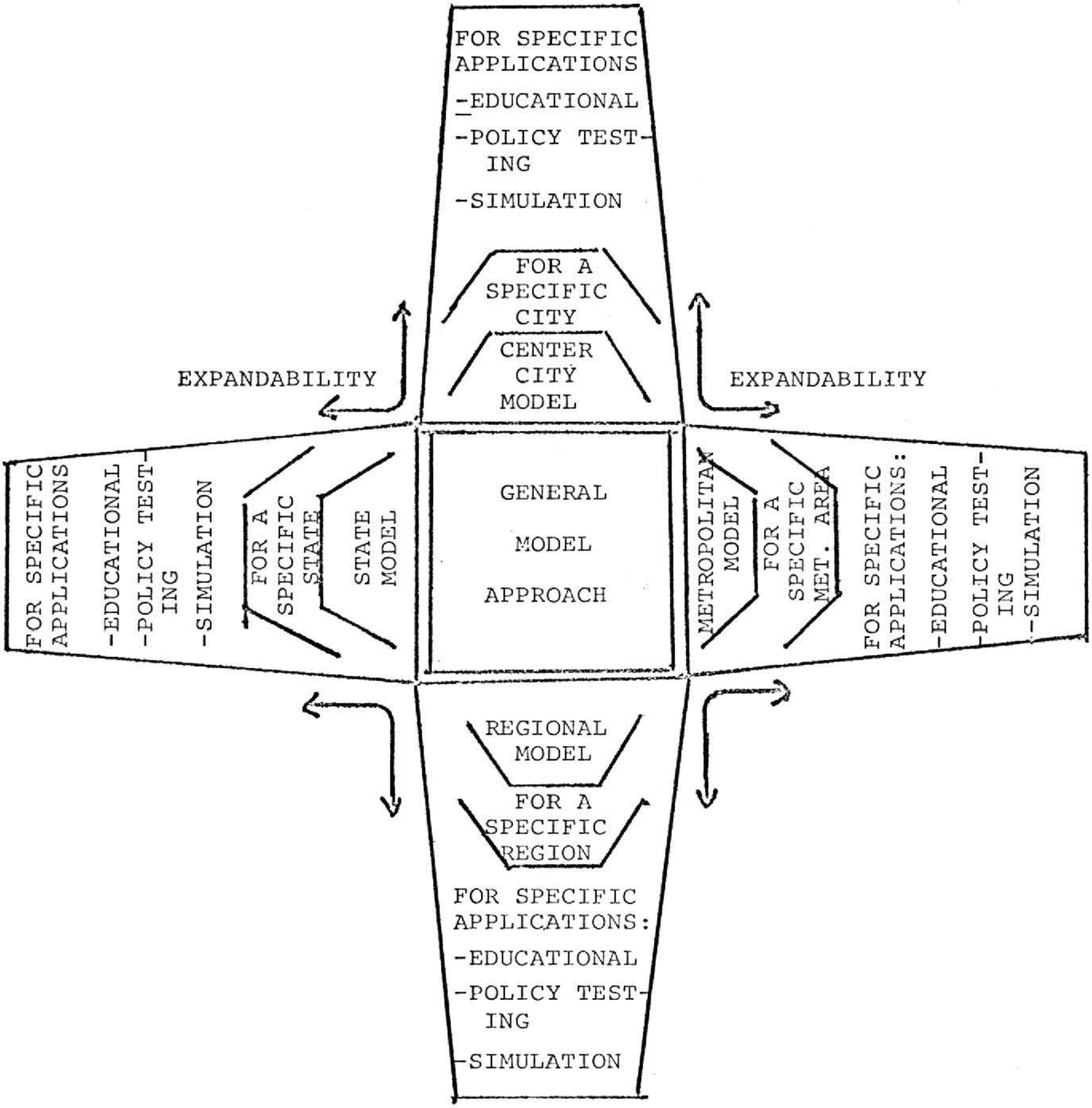


Figure 3

Expandability and Flexibility of a General Model Approach

Most of the early research in urban affairs has been undertaken from a single point of view. The economist, the sociologist, the political scientist, and the public administrator each studied one or more problems, suggested solutions, or attempted explanations. The emphasis on multidisciplinary approaches is relatively new. Although social scientists are increasingly incorporating knowledge of other disciplines into their studies to attempt an interdisciplinary approach, many have failed to do so when they examine the urban environment. They still see a particular problem as primarily economic, political, or sociological in nature. There are probably many reasons for this, but three will be focused on here. First, tradition or conservatism hinders many from changing his ways or freely embracing new ideas. Second, division of labor is as true in the social sciences as in any other marketplace; specialists profitably profer those goods and services which they produce best. And third, social scientists today lack a generally accepted urban theory within which to incorporate multidisciplinary approaches. A comprehensive theory would allow social scientists to embrace an approach large and usable enough to handle the urban problem.

Since the metropolitan area is not exclusively a social, economic or political phenomenon, full comprehension is difficult with the tools of a traditional discipline. Multidisciplinary approaches without a mutual frame of reference and common vocabulary have usually proved frustrating. Thwarted, the specialists often retreat to their particular disciplines and resume their parochial views. An ancillary problem is that many of the sub-disciplines are expanding their usual purviews to areas such as urban or environmental studies so that their traditional boundaries are becoming imprecise. This condition tends to duplicate the tendency toward segmentation.

Operational Simulation

It might appear that just when the social sciences are being challenged to surmount the pervasive national urban and environmental problems, they are without a complex tool kit with which to complete the job.

This challenge was the basis of our earlier research for an educational tool and has been carried forward in formulating an impact model for research and policy making applications.

In looking for an overall picture of urban problems, social scientists today have acknowledged the success of the technological programs fostered by space and defense industries. If a computer-aided systems orientation can work there, why can't it work in our cities.

Operational simulation offers the social scientist a laboratory tool similar to that of the natural or physical scientist for testing the results of his ideas on an urban environment. It is infiniETly more sensible than the experimentation that goes on with real cities. It is prohibitively expensive to try out new schemes on an existing city and illogical to begin programs that cannot be completed. It is wasteful to disrupt cities with unproven methods and inhuman to use segments of the urban population as guinea pigs.

In designing a simulation, however, the builders require deep understanding of the urban system. They have to think through the dynamics and interrelationships among the system components so that the simulation will work like the real urban area. Thus, in using a simulation, planners, administrators and students will be able to experience the interrelationships and dynamics among the system components.

A simulation also gives those concerned about the urban area a common language, so that they can exchange experiences, knowledge and information. It begins to hurdle the jargon problem enabling game builders and social scientists to talk to each other and work with each other.

Finally, fully realized simulations can be used to help formulate policy. As a laboratory, a simulation can let a policy-maker pretest his ideas and consider possible alternatives and their consequences before ground is broken.

The actual realization of this ambitious goal, a simulation with educational, research, and policy making applications, has been the research focus of Envirometrics. The evolution of USM is the outcome.

THE URBAN SYSTEMS MODEL

An Overview of the Urban Systems Model (USM)

The USM accomplishes two broad objectives:

- expands the scope of present transportation models by dealing with many social processes. The impacts of transportation decisions on social, economic, and government indicators is represented, as are the impacts of decisions in the social, economic, and government sector on the transportation sub-system.

- provides an instrument for intermodal planning. The modular transportation sub-system is designed in such a way that new modes can be introduced by the user of USM. The selection of modes and routes by travellers within the model are made as a result of many time, dollar, and service trade offs by travellers as a function of their economic and social class.

Capabilities of the Urban Systems Model

The USM is a framework or prototype model that can be evolved by its users to suit a large number of planning objectives.

Specifically, with regard to the transportation sub-system, model users may:

. Simulate the construction of new roads, bridges, tunnels, tracts, and special purpose rights-of-way.

. Develop and test the impact of new modes of transportation by specifying the type of link used, operating costs, user costs, user capacity, speeds, and service characteristics.

. Vary tolls and fares or tax parking.

. Test alternative assumptions about the travel preferences of population groups by income and social classes.

Flowchart Description of USM

The three phases and twelve processes of the Urban Systems Model are shown in Figure X (See Fold-out). The model user performs two types of input functions: one-time inputs that define the initial city status and model parameters and modules and annual policy and resource allocation inputs for the transportation and other subsystems.

These inputs are processed in the Pre-Model Phase. This phase checks the inputs for procedural and substantive errors and places the appropriate values into the coefficient, parameter, indicator and account files. These files are subsequently drawn upon by the modules in the Model Phase and the values are updated as a result of the task performed by these modules.

The Model Phase is composed of nine Processes each of which is, in turn, composed of several sub-processes or modules. For example, the Transportation Process is composed of four sub-processes: Network Generation, Trip Generation, Trip Distribution, and Network Use Measurement. The Network Generation sub-process contains five modules that deal with changing transportation parameters, new transportation construction, implementing transportation regulations, differentiating modal choices, and altering transportation accessibility.

An important distinction between USM and previous model designs is the number of Processes contained in the Model Phase of USM. Most previous models contained only a land use allocation and transportation process. USM is the only model that ties together detailed transportation-related processes such as those for Government and Business Policy, Population, Work, Commercial, Outside System, and Indicators.

The full 75 modules that comprise the Urban Systems Model are shown in Table 1.

I. PRE-MODEL

IA Input Data

1. Coefficient/Parameter Transactions - modifies and creates new values
2. Account Transactions - modifies and creates new values
3. Procedural Editing - interrogates inputs for procedural errors
4. Data Management - provides interface between programs and peripheral devices

IB Data Implementation

5. Coefficient/Parameter Adjustment - modifies data base
6. Accounts Adjustment - modifies and interrogates data base
7. Substantive Editing - interrogates inputs for legality and validity
8. Data Base Configuration - builds the logical data base

II. MODEL

IIA Government and Business Policy

9. Jurisdiction Modification - defines jurisdictions and districts
10. Land, Building and Corporation Purchase - enacts purchases
11. Loan, Borrow, Transfer Money - processes loans and cash transfers
12. Maintenance - calculates maintenance needs
13. Depreciation/Obsolescence - calculates annual depreciation and obsolescence
14. Computer Businesses - simulates activities of small businesses
15. Employment Requirements - calculates employees requested by employers
16. Building Rental - operates rental office space

Table 1 The Phases, Processes, and Modules of the Urban Systems Model

IIB Population Process

17. In-Migration - calculates in-migrants
18. Out-Migration - selects out-migrants
19. Pl Generator - assigns characteristics to Pl's
20. Housing Accumulator - calculates supply and demand
21. Housing Standards - lists housing supply and demand standards
22. Housing Placement - matches residents with housing
23. Housing Accountant - records rental and mortgage payments

IIC Work

24. Employment Accumulator - lists available jobs and job seekers
25. Employment Standards - develops criteria for employers and employees
26. Employment Service - matches workers with jobs
27. Employment Accountant - calculates wages earned
28. Production Function - calculates units of output produced

IID Transportation Network Generation

29. Transportation Parameter Modification - calculates effective capacity
30. Transportation Construction - constructs transportation facilities
31. Departmental Regulations - records transportation policies
32. Modal Differentiation Function - calculates dollar and time costs
33. Transportation Accessibility Basic Function - modifies costs as result of congestion and crowding

Trip Generation

34. Transportation Accessibility Parameter Function - calculates least cost route
35. Employment Trip Volume Function - assigns passenger units to work locations

Table 1 (Continued)

Trip Distribution

36. Employment Transportation Distribution - distributes passenger units to modes and routes
37. Transportation for Other Reasons - calculates cost and assignment for non-work trips

Network Use Measurement

38. Transportation Indices Maintenance - records congestion and crowding

IIE Government Services

39. Utilities Service - determines required utility service
40. Health, Schools, and Recreation Allocation - matches public school demand with supply
41. Other Government Services Demand - calculates demand for miscellaneous government services
42. Other Government Services Allocator - allocates miscellaneous government services

IIF Commercial

43. Pl Primary Demand - calculates essential consumption demand
44. Pl Commercial Price Generator - calculates local goods and services prices
45. Pl Secondary Demand - calculates common comfort consumption demand
46. Pl Tertiary Demand - calculates leisure-type demand
47. Health, Schools, and Recreation - calculates demand for special services
48. Pl Consumption - allocates shoppers to stores
49. Government Demand - calculates government demand
50. Personal Commercial Demand - calculates demand by local stores
51. Business Commercial Demand - calculates demands for manufactured goods
52. Local Business Price Generator - calculates prices for remaining MOD's
53. Business and Government Consumption - allocates local consumption among MOD's

Table 1 (Continued)

54. Consumption Accountant - records expenditures and incomes from purchases
55. Shipping-Receiving Terminal Demand - calculates imported from and exported to outside system
56. Terminal Consumption - matches terminal supply and demand

IIG Income

57. Income Taxation - calculates Pl and MOD income tax
58. Assessment Taxation - calculates property taxes
59. Sales Taxation - calculates sales taxes
60. Pl Income - calculates incomes and expenditures for Pl's
61. Government and Business Income - calculates incomes and expenditures for businesses

IIH Outside System

62. Investment Brokerage - provides rate of return for outside investments
63. Money Lending - determines loans and bonds repayment schedule
64. Building Construction - constructs all non-transportation facilities
65. Outside Personal Commercial - allocates Pl consumption to outside suppliers
66. Outside Business Commercial - allocates business consumption to outside suppliers
67. Industrial Location - simulates decisions by outside firms to invest in the local system
68. Federal Government Operation - simulates interaction with the Federal system
69. State Government Operation - simulates interaction with the State system(s)
70. Business Cycle - simulates a number of national business cycles
71. Interest Rates - calculates specific interest and bond rates

IIJ Indicators

72. Financial Accounts - calculates dollar amounts

Table 1 (Continued)

73. Statistical Accounts - calculates quantitative and qualitative status

III POST MODEL

IIIA Output

74. Data Base Interrogation - retrieves data for special and standard reports
75. Report Generation - formats and places data information on the output

Table 1 (Continued)

Comparison of USM With Other Models

It is impossible to discuss the many similarities and differences among models (in this report). Yet, some comparisons with other models is needed in order to put USM in a frame-of-reference.

Probably the most striking feature of USM from a designer's point of view is the combination of detail and scope. The detail is evident from the number of activities represented and the sophistication of the relationships that tie those activities together. The scope of the model is evident in the number of policy and resource allocation decisions that may be made by the user with regard to economic, government, social, and outside system factors.

To illustrate some of the detail included in USM, it will be compared with a number of other models in terms of the number of elements it contains. Further, to allude to the scope of the model, USM will be compared with different classes of models. For example, the land use detail in the model is compared with the land use detail in other models.

Land Use Models

Table 2 shows four characteristics of six land use models along with the same characteristics for USM. Most of these six models were developed for transportation purposes to generate travel parameters that were used in the calculation of travel demand. As is true for USM, most of these models did not have land use as their primary focus. The comparison, however, is quite illustrative. Diversity in land uses was not very important in these selected models. The specific types of manufacturing or residential development, in most cases, was not considered by these models because in the minds of the designers, the purpose for which the model was developed did not require such detail. The Urban Systems Model, on the other hand, was designed as a general purpose model in which the employment requirements, land consumption, pollution generated, transportation requirements, and local service requirements of manufacturing industries are important. Likewise, the land use characteristics and quantity and quality of housing are very important to the tax base, income mix, transportation needs, and public services associated with housing and its inhabitants.

	Other Land Use Models	Urban Systems Model
NUMBER OF TYPES OF PRIVATE LAND USES	CATS 6 EMPIRIC - 4 UNC - 1 PITTS - 5 PJ - 10 SFCRP - 27+	22 (11 manufacturing, 6 retail, 5 services)
NUMBER OF TYPES OF RESIDENTS	CATS - 1 UNC - 9 EMPIRIC - 16 PITTS - 1 PJ - 6+ SFCRP - 114	20 (5 income classes, multiplied by 4 household categories)
ELEMENTS IN ATTRACTIVENESS OF PARCEL	CATS - 2 UNC - 55 EMPIRIC - 5 PITTS - 2 SFCRP - 5	9+ (tax assessment, intraparcel and interparcel transportation indices, zoning, land code, quality of government services, etc.)
SIZE OF PARCELS	CATS - 1/4 sq mi UNC - 23 acres (2.5 acres subparcels) EMPIRIC - irregular PITTS - 1 sq mi PJ - 1/4 sq mi SFCRP - 2 acres	Variable (ranging from a portion of a census tract to an entire county)

CODE:

- CATS = Chicago Area Transportation Study
- UNC = University of North Carolina Model
- EMPIRIC = EMPIRIC Model
- PITTS = Model of a Metropolis
- PJ = Penn-Jersey Model
- SFCRP = San Francisco Community Renewal Program

TABLE 2

COMPARISON OF THE URBAN SYSTEMS MODEL WITH OTHER LAND USE MODELS

Input-Output Models

The comparison of the detail in the individual input-output studies with the detail in USM is biased in favor of USM by the fact that this model uses national parameters whereas the individual studies use local data to build their matrices. Thus, the other models may be more sophisticated in that they use locally estimated data for approximately the same number of industry groups. If, however, the USM parameters are modified to reflect actual local inter-industry relationships (as is possible), it will provide about as much detail as any of the input-output models shown which were built to represent interindustry transactions. Table 3 offers a comparison of USM with three input-output models.

The way one would operate one of the conventional input-output models to test impacts on the local area employment and income would differ considerably from how USM would normally be used. In a typical input-output model a single change would automatically cause changes in the final outputs of all other industries because of the interrelated nature of the matrix. In USM, the increase in output of one industry will not necessarily increase output of other manufacturing activities, but would cause increased sales by those local suppliers who only sell locally if they happen to have excess capacity. Thus, it will not automatically adjust supply and demand. If supply remains constant and demand increases, prices will rise in USM. Prices are not generally dealt with in input-output models. The tradeoff between labor and capital is also not considered. In USM, however, it is possible to change the capital/labor ratio by using overtime shifts or upgrading equipment.

Economic Base Models

Economic base models show in income and/or employment terms which activities are export-oriented (i.e., produce goods and services for export to markets outside of the local system) and which activities are service-oriented (i.e., produce goods or services for sale in local markets or used by local businessmen).

Economic base models are used to gain an understanding of current sources of income and/or employment in an area; to identify the importance of a single industry; as a government device, to identify expenditure needs and expected revenues; to forecast the impact from changes

	Input-Output Models	Urban Systems Model
INDUSTRY GROUPS	CenNY - 32 SD - 14 CAL - 29	22 (11 manufacturing, 6 retail, 5 services.)
NUMBER OF COUNTIES OR STATES	CenNY - 5 SD - 1 CAL - 1	Variable

Sources:

1. CenNY = Robert J. Kalter, An Interindustry Analysis of the Central New York Region, Department of Agricultural Economics, Cornell University, Ithaca, 1968.

2. SD = Tore Tjersland, Regional Inter-Industry Economics: The Economic Structure of Metropolitan San Diego - 1968, Western Behaviorial Sciences Institute, LaJolla, California, 1969.

3. CAL = W. Lee Hansen and Charles M. Tiebout, "An Intersectoral Flows Analysis of the California Economy", Review of Economics and Statistics, (XLV) November, 1963.

TABLE 3

COMPARISON OF THE URBAN SYSTEMS MODEL WITH INPUT-OUTPUT MODELS in the export sector; and in conjunction with other studies. In general, they tend to deal with fewer activities than contained in USM.

Base models deal only with the demand side of a local economy, whereas USM deals with both the demand and supply side. In USM, transportation access, labor shortages, depletion of resources, high local costs of land or other factor inputs, local financing, and available government supplied facilities are taken into account. These supply issues cannot be dealt with by a base model, which explains why the base model is most often used as a part of a larger modeling effort. Table 4 is a comparison of terms of three elements of USM with two Economic Base Models.

In many ways it is difficult to compare the scope of models. The previous comparison of several models with the Urban Systems Model merely illustrates the relative richness of the models in terms of the number of variables covered, but does little to indicate model form. The previous models were all built to simulate either a particular area or a particular problem. Usually the method of the designers of these models was to start with certain data and extrapolate it into the future. The models generally did not take into consideration all of the behavioral attributes of a system which caused a series of events to happen, but were more concerned with the magnitude and direction of a particular growth trend.

The Urban Systems Model as it Relates to Twenty Urban Planning Models

The classification scheme for urban planning models developed by Kilbridge, O'Block, and Teplitz offers a useful framework for further discussing the scope of USM.

As Table 5 shows, USM includes more subject matter than any of the twenty models surveyed by those authors. This is essential for an urban model that is holistic. A brief description of USM is provided under each of the six headings used in Table 5.

Land Use

With regard to land use, USM has three residential densities (single family, garden apartments, and high-rise) each of which may have a quality index that ranges from 0 to 100. Furthermore, the housing may be located on any of the several hundred parcels of land, each with

	Economic Base Models	Economic Base in the Urban Systems Model
NUMBER OF INDUSTRIES	LA - 25 WICH - 21	MOD - 22 (11 manufacturing, 6 retail, 5 services.)
NUMBER OF COUNTIES OR CITIES	LA - 1 WICH - 1	Variable
MEASUREMENT VARIABLE	LA - Employment WICH - Employment	Land Use, Employment, Salaries, Tax Base

Sources:

LA = Charles M. Tiebout, The Community Economic Base Study, Supplementary Paper No. 16, Committee for Economic Development, New York, 1962.

WICH = Federal Reserve Bank of Kansas City, "The Employment Multiplier in Wichita, Monthly Review, Vol. 37 (September 1952).

TABLE 4

COMPARISON OF THE URBAN SYSTEMS MODEL WITH ECONOMIC BASE MODELS

	MODEL NAME	AUTHOR(S)	CITY	APPROX. DATE
1.	How Accessibility Shapes Land Use	Hansen	(Hypothetical)	1959
2.	Activities Allocation Model	Seidman	Philadelphia	1964
3.	Chicago Area Transportation Model	C.A.T.S. Group	Chicago	1960
4.	Connecticut Land Use Model	Voorhees	State of Conn.	1966
5.	Econometric Model of Metro. Employment and Pop. Growth	Niedercorn	(Hypothetical)	1963
6.	EMPIRIC Land Use Model	Brand,Barber,Jacobs	Boston	1966
7.	Land Use Plan Design Model	Schlager	S.E. Wisconsin	1965
8.	Model of Metropolis	Lowry	Pittsburgh	1964
9.	A Model for Predicting Traffic Patterns	Bevis	Chicago	1959
10.	Opportunity-Accessibility Model for Alloc. Reg. Growth	Lathrop	Buffalo	1965
11.	Penn-Jersey Regional Growth Model	Herbert	Philadelphia	1960
12.	Pittsburgh Urban Renewal Simulation Model	Steger	Pittsburgh	1964
13.	POLIMETRIC Land Use Forecasting Model	Hill	Boston	1965
14.	Probabilistic Model for Residential Growth	Donnelly,Chapin,Weiss	Greensboro	1964
15.	Projection of a Metropolis: New York City	Berman,Chinitz,Hoover	New York City	1960
16.	RAND Model	RAND Corp.	(Hypothetical)	1962
17.	Retail Market Potential Model	Lakshmanan,Hansen	Baltimore	1964
18.	San Francisco C.R.P. Model	A. D. Little Corp.	San Francisco	1965
19.	Simulation Model for Residential Development	Graybeal	(Hypothetical)	1966
20.	Urban Detroit Area Model	Doxiadis	Detroit Area	1967
	URBAN SYSTEMS MODEL	ENVIROMETRICS	GENERAL	1971

SUBJECT

MODEL	LAND USE	a. Residential	b. Industrial (Mfg.)	c. Commercial	d. Govt. or Institutions	e. Roads,Streets,Alleys	f. Public Open Space	POPULATION	TRANSPORTATION	a. Interzonal Trips	b. Other Transp.	ECONOMIC ACTIVITY	a. Employment	1. Retail Trade	2. Manufacturing	3. Service	b. Trade	1. Retail	2. Other	c. Personal Income
1.		x						x												
2.		x	x	x		x		x					x		x					x
3.		x	x	x	x	x	x			x					x					
4.		x						x						x	x	x				x
5.								x			x			x	x	x				
6.								x						x	x	x				x
7.		x		x	x	x	x	x												
8.		x	x	x				x						x	x					
9.										x	x									
10.		x						x		x										
11.		x																		
12.		x	x	x				x						x	x				x	x
13.								x						x	x	x				x
14.		x																		
15.								x						x	x	x		x	x	x
16.		x						x					x							
17.										x								x		
18.		x						x												
19.		x											x							
20.								x		x										
URBAN SYSTEMS MODEL		X	X	X	X	X	X	X		X	X		X	X	X	X		X	X	X

FUNCTION / THEORY / METHOD

MODEL	PROJECTION	ALLOCATION	DERIVATION	BEHAVIORAL	a. Economic (Market)	b. Preference	GROWTH FORCES	a. Gravity	b. Trend	c. Growth Index	d. Input-Output	ECONOMETRIC	a. Regression	b. Input-Output	c. Markov Process	MATHEMATICAL PROGRAMMING	a. Linear Programming	b. Other Analytic Forms	SIMULATION	a. Autonomous	b. With Intervention	
1.	x							x										x				1.
2.		x	x			x				x			x							x		2.
3.	x		x						x												x	3.
4.	x		x					x		x			x							x		4.
5.	x		x							x			x									5.
6.	x		x					x		x			x									6.
7.		x	x		x	x											x			x	x	7.
8.		x	x					x													x	8.
9.	x		x					x									x					9.
10.		x	x					x												x		10.
11.	x	x	x		x												x			x		11.
12.		x	x			x		x		x	x			x						x		12.
13.	x	x	x					x		x								x		x		13.
14.		x								x			x								x	14.
15.		x	x								x			x								15.
16.		x	x		x	x				x										x		16.
17.		x	x					x										x				17.
18.	x	x	x		x	x									x					x		18.
19.	x	x	x		x	x				x								x		x		19.
20.	x	x	x					x					x					x				20.
URBAN SYSTEMS MODEL		X	X		X	X					X			X						X	X	

TABLE 5 RELATING URBAN SYSTEMS MODEL TO TWENTY URBAN PLANNING MODELS

different locational features (distance to CBD, political jurisdiction, assessed values of land, etc.) and different infra-structure (roads, utilities, public services in the form of schools and municipal services).

USM has six types of local commercial activities, eleven types of basic industries, and one type of construction industry land usage in the private sector, and several types of government buildings and land use (schools, municipal services, etc.).

Population

USM deals with population in five major income classes and four family categories as well as characteristics such as educational level, number of workers, number of students, normal number of voters, average consumption requirements, and others. The population units in the metropolitan area pass through several major operating programs of the model in order that their individual status within the local system may be determined. For example, the population units by class and category have characteristics and preferences which affect how they are handled by the processes of the model such as migration, housing, employment, transportation, commercial, and others.

Transportation

USM deals in greatest detail with the peak hour transportation issue. The model contains a sophisticated combined modal split and routing sub-model that allocates workers to auto, bus, rapid rail or other modes input by the model user and to specific routes based upon transportation capacities, dollar costs, time costs, and personal preferences.

Transportation access is also an influencing factor in the commercial process and terminal use process. In other words, the assignment of personal consumption and business consumption of goods and services to specific locations is influenced by road capacities, transit service and terminal locations.

Economic Activity

USM deals with employment in some detail insomuch as population units by class, location, and education level are employed at specific employment locations (manufacturing, retail, services, schools, municipal services, transit companies and government) that offer salaries influenced by individual considerations. Thus it is possible to have hundreds of employment locations, each offering different salaries and having different locational advantages and transportation access.

The commercial section of USM divides local purchases into several categories (business goods and services and personal goods and services). Local consumers are assigned to these establishments based upon preferences, capacity considerations, prices charged, and transportation access.

Function

USM is primarily an allocation model that matches supply and demand in the employment, transportation, commercial, time allocation, housing, and government services markets. The fact that all of these markets are interrelated through business activities, population groups, and government departments make USM a very interactive impact model.

Theory

The major theoretical assumptions in USM relate to how markets operate and how population units exert their preferences.

Method

The method used to relate inputs to outputs in USM is simulation. The components of a simulation model as defined by Kilbridge, et al. (status variables, exogenous variables, functional relations, and output) conform very closely to four of the five model elements presented in USM (data base, inputs, operating programs, and output). Human intervention is also an optimal part of USM. It is the human intervention via director and user inputs that causes most of the changes in the local area during a cycle of the model.

General Considerations

Each of the models discussed (indeed all models) improves as the data it uses gets better. In general they are more likely to be useful and valid as the data becomes more readily available and accurate. Similarly, it is quite possible for a perfectly valid model to be loaded with poor data and, because it yields ludicrous results, to be judged a poor model.

An urban model is concerned with people and activities as the ingredients in the operation of and the growth (or decay) of the system being represented. When each iteration represents a single year's activity, a highly structured model can be very useful as an explanatory tool. Real-world structures do not change very much in five to ten years, which is the usual number of cycles of such a short-term model.

Since one iteration of the model represents one year's activity in the simulated area, the specific model relationships do not change between time periods. In other words, the model itself does not recognize trends and modify its functional relationships in response to them. Some models, including a few forecast models, are loosely structured and do change in structure during successive iterations. Such models do not represent much differentiation among urban phenomena in any detail. They deal with large aggregations of people and activities over many years of real-world time.

The aim with USM was to construct a model which did allow a great deal of differentiation among and consideration of many characteristics of people and activities. The model was to be highly causal, with many interrelations among the components. USM was designed as a man-machine model. Thus structures and relationships which could not be understood, in static terms or quantified were put outside the model itself, that is, made the realm of the decision-makers.

Since the model is highly structured, components can be interrelated and interdependent. Such a structure allows more complexity than the looser structure of forecast models. More complexity and more interrelated components lead to increasingly finer degrees of resolution and allows the model user to trace the path of groups of people as they work, shop, play, go to school, etc.. Although the model has changing land use, or several forms of O-D transportation trips, these are not designed as forms of growth equations but as processes which reflect the way people and activities interact within the local system. In short, the user of the model would have to call for information contained in USM in much the same way he would call for the data in the real world; by making a study or survey. The principal difference is that the data is all available and the computer is able to make an exhaustive and rapid report of this data in a relatively short time period and for very little money.

Therefore it can be said that the format of USM replicates, in a very general way, the total change of a human system from time period to time period. To make this behavioral model a predictive one requires that the computer program be told to keep track of the data the user is interested in and perform the operations with the data in the way specified by the user. That is, the decision-makers themselves must be simulated. The advantage of the USM modeling form is that the one model can be used to test comprehensive planning strategies and their effects on the system. Since the feedbacks inherent in every real-world social system are numerous and complex, a greater degree of accuracy can be obtained with the type of methodology used in the Urban Systems Model, than with other model approaches.

RECOMMENDATIONS

The design of the Urban Systems Model was intended to be the first stage of a multi-year urban model building project. The completion of the design now allows the succeeding steps to be undertaken: evaluation, modification, programming, testing, and implementation. It is strongly recommended that these follow-on steps be undertaken as soon as possible.

The specific recommendations of this report are separated under two headings - those related to USM as an urban systems model of general utility and those related to USM as an urban systems model of use to the urban transportation planner. However, it should be clear from the final report that Envirometrics considers USM to be useful to the urban transportation planner because it was designed to also be useful to others concerned with the functioning of the complete urban system.

Looking at the Urban Systems Model as a complex man-machine simulation of the urban system, the following tasks should be undertaken:

1. Research the interaction of man with a machine. (What man-machine interface is best suited for dealing with impacts of decisions made in the future?)

2. Research the interaction of man with man in a decision-making environment that deals with the future. (How can a time collapsed decision environment best be developed so that model users perform in the simulated experience in a way similar to the way they perform in real life?)

3. Develop procedures for testing the validity of large-scale social system models. (If the model generates two million pieces of information on a city, how close do each and every one of these pieces of information have to approximate the actual value to attain various degrees of validity or reliability?)

4. Develop a means for mounting large-scale systems models on large computers and assuring that they will run within tolerable time limits. (Can these models be used practically by a wide number of users on their own facilities?)

5. Distribute this final report on a widespread scale. This document presents a model structure that is useful as a theoretical construct for the understanding of and study of the urban system and the environment in general. Further, the framework is a useful guide for those who would gather data for the large-scale management information systems currently under consideration. Thus, the present document should receive wide distribution among persons concerned with the urban system generally and the transportation subsystem specifically.

Looking at the Urban Systems Model as an urban transportation planning device, the following tasks should be undertaken:

1. Commit further support to the programming of part or all of the USM design. If only part of the design is implemented, the Transportation Process could be done first and grafted on to the existing CITY MODEL. Alternatively, the processes other than transportation could be implemented and linked to an existing transportation model. A number of other implementation phases or strategies could be developed. In any event, the funding for a more holistic urban transportation planning model should be made available.

2. Promotion of the USM design and operating program as a supplement to the tools already available to the urban transportation planner. The USM is not a panacea. It does many things that no other urban transportation model has attempted to do, but it will not suffice as the only device used by a transportation planner. It will be best utilized in concert with present models and with models still to be developed. This however is not to minimize the evolutionary capability of USM. As a result of its modular design, it may be easily modified and additions to it may be made with relative ease.

In sum, the Urban Systems Model design is a major contribution to the effort to develop planning models that are more responsive to the economic and social implications of various policy alternatives on the urban system. Since it is a major departure from past model building efforts directed toward the planner, it deserves a wide reading by interested persons. Furthermore, since it has evolved from a series of operational models that proved to be successful for the purposes to which they were directed, it is a model structure that is operational despite its comprehensiveness. Therefore, the Urban Systems Model should receive further support for its implementation.

PART II

THE URBAN SYSTEMS MODEL AND THE TRANSPORTATION SUBSYSTEM

INTRODUCTION

Urban transportation planners have been accustomed to developing and using computer models that focus to a large extent on the transportation subsystem of the entire urban system. This focus has been so strong that the models have not been able to deal simultaneously with a wide number of urban concerns that are directly or indirectly related to urban transportation planning, such as the effect of transportation accessibility on employment rates by different segments of the labor force, percent of incomes spent for various types of transportation, externalities (air pollution, noise, assessed value of land, etc.) of transportation networks and use, and financing of alternative transportation plans. In short, the urban transportation models have not been models of the entire urban system with the transportation subsystem realistically interacting with all the other major subsystems.

USM is a transportation model, but it is also a labor market model, a commercial allocation model, a migration-housing model, a land use and assessment model, a government operations model, and several more. In short, USM is an urban systems model. It deals with a full range of factors that impact on the transportation subsystem and a wide range of factors that are in turn affected by transportation planning decisions.

USM deals with groups of people, corporations, and government departments as they interact with one another within a spatially constrained environment. One of the means of communication for these activities is the transportation subsystem. USM differs from other urban models in that it generates much of the data used as inputs to transportation models as a result of complementary processes that are a part of the urban system. For example, a typical transportation model might need inputs as to where people live, how much they earn, and where their jobs are located. USM has a migration-housing process that moves people into, out of, and within the local system based upon a large number of factors (transportation access being one). Processes within the USM also hire people as workers at specific locations based upon salary levels, educational levels, accessibility, boycotts, etc. and thereby determine in a competitive labor market what the people will earn and where they will work.

USM recognizes that many concerns of the urban transportation planner may be handled only within the confines of a holistic model of the urban system.

To deal with the economic, social, and governmental impacts of transportation planning calls for a model that incorporates and simulates the interaction of many subsystems other than transportation. Some of these subsystems are directly related to the transportation subsystem while others are related in only an indirect way. The USM design is an attempt to represent in an operational model all of these major urban subsystems, and thereby place transportation planning within its realistic perspective.

Overview

The objective of the Urban Systems Model Design Project was to develop the design specifications for a computer-based urban simulation model (called the Urban Systems Model) that can be used for the following purposes:

- representation of any small or large metropolitan area (that is, it is a general model in so far as the model relationships - but not coefficients - hold true from one area to another)

- as a flexible man-machine model in an experimental-simulation format or in a gaming format (that is, the evaluation of the urban status, the setting of goals and objectives, the implementation of strategies, and the input of decisions may be made by a single individual or by a group of people representing various system decision-makers.)

- to assess the impact of transportation decisions on a wide range of social, economic, and environmental indicators (that is, the model will be holistic in so far as the transportation subsystem will be linked to the other major urban subsystems)

- to assess the impact of many urban decisions on the transportation subsystem (that is, the effects on transportation generated by a wide range of economic, social and governmental decisions will be represented by the model)

Background

The Urban Systems Model utilizes a systematic and interdisciplinary approach in its design, which users of the model may then build upon as they plan and experiment with decision-making through the use of the model. Such a systematic and interdisciplinary approach was called for by the National Environmental Policy Act of 1969.

The Urban Systems Model design represents the culmination of over four years of model building design and implementation which produced a number of operative decision-making models for various federal agencies. The Urban Systems Model, when programmed and implemented, will provide the Department of Transportation with a full range of applications for education, indicative planning, testing of transportation alternatives, and citizen participation.

Model Users

User interaction in the Urban Systems Model

- requires fewer model assumptions on the part of the designer than most previous models
- allows realistic human interaction and reaction
- allows political repercussions associated with transportation decisions, reversal of policy, etc.
- allows human involvement in the decision process

The Urban Systems Model deals with:

- External Inputs - area characteristics, including the present transportation subsystem and service levels

- Internal Inputs - wide range of transportation; economic, social, and government decisions

- Internal Outputs - changes in the resources of the individual decision-makers

- External Outputs - changes in the area characteristics, allocations, assignments, matching of supply and demand, insufficiency of government services, and complete status of the transportation subsystem

The completed Urban Systems Model will be useful to citizens as well as planners because the model output is designed in such a way that it is comprehensive, easy to understand, and quick to retrieve. Thus, regardless of the sophistication of the user, the model will provide the necessary level of information upon which evaluations can be made and decisions can be generated.

Modular Capability

The Urban Systems Model has been designed in a modular fashion, so that new modules may be added or existing ones replaced or modified at minimal expense. Separation of model parameters from the programs means that it is:

Easy to redefine the model
Easy to load various cities
Easy to dynamically define new modes of transportation by specifying capacities, times, speeds, costs to user, operating costs, etc.

This modular feature of the USM design allows the model to be truly evolutionary, thus making it a framework that can continually be improved and modified for specific uses.

PHASES AND PROCESSES

The Urban Systems Model is a general man-machine simulation model that can be used to represent the economic, social, governmental, spatial, and transportation subsystems of any size urban system.

The cycles of the model (each set of computer output) represent one fiscal year in the life of the urban area simulated by the model. Users provide the evaluation of the current status of the urban area (in its economic, social, governmental, spatial, and transportation dimensions). Through a wide range of decision alternatives, they are able to devise strategies and implement policies in an attempt to achieve any set of goals or objectives they devise.

These decision inputs may be generated in a simulation environment (in which a single user or group of users such as transportation planners are given control over all the resources of the local system) or in a game environment (in which individual users such as transportation students and citizens are given control over various resources in the local system).

Model Phases and Parts

The computer model consists of three phases: Pre-Model, Model, and Post-Model (which corresponds to input, processing, and output). The three phases are comprised of twelve processes, which are, in turn, comprised of 75 modules. Modules are specific functional operations (such as in-migration, the production function, and transportation network use measurement) which are comprised of components (equations).

The model user may change a large percentage of the model components as part of the Pre-Model phase. Figure 4 shows the hierarchy of parts of the Urban Systems Model. Figure X (the foldout) shows flowchart of the processes of the Urban Systems Model.

Figure 4

URBAN SYSTEMS MODEL:
MODEL PARTS OR SYSTEM

Phases (3)

Processes (12) - broad functional Operations

Modules - specific functional operations

Components - relates data elements (constants and variables) to one another through a logical mathematical expression

TABLE 6

THE PHASES, PROCESSES, AND MODULES OF THE URBAN SYSTEM MODEL

PRE-MODEL PHASE (I)

Input Data Process (IA)
- Coefficient/Parameter Transactions (1)
- Account Transactions (2)
- Procedural Editing (3)
- Data Management (4)

Data Implementation (IB)
- Coefficient/Parameter Adjustment (5)
- Accounts Adjustment (6)
- Substantive Editing (7)
- Data Base Configuration (8)

MODEL (II)

Government and Business Policy (IIA)
- Jurisdiction Modification (9)
- Land, Building and Corporation Purchase (10)
- Loan, Borrow, Transfer Money (11)
- Maintenance (12)
- Depreciation/Obsolescence (13)
- Computer Businesses (14)
- Employment Requirements (15)
- Building Rental (16)

Population Process (IIB)
- In-Migration (17)
- Out-Migration (18)
- Pl Generator (19)
- Housing Accumulator (20)
- Housing Standards (21)
- Housing Placement (22)
- Housing Accountant (23)

Work (IIC)
- Employment Accumulator (24)
- Employment Standards (25)
- Employment Service (26)
- Employment Accountant (27)
- Production Function (28)

Transportation-Network Generation (IID)
- Transportation Parameter Modification (29)
- Transportation Construction (30)
- Departmental Regulations (31)

TABLE 6 (cont.)

- Modal Differentiation Function (32)
- Transportation Accessibility Basic Function (33)

Trip Generation
- Transportation Accessibility Parameter (34)
- Employment Trip Volume Function (35)

Trip Distribution
- Employment Transportation Distribution (36)
- Transportation for Other Reasons (37)

Network Use Measurement
- Transportation Indices Maintenance (38)

Government Services (IIE)
- Utilities Service (39)
- Health, Schools, and Recreation Allocation (40)
- Other Government Services Demand (41)
- Other Government Services Allocator (42)

Commercial (IIF)
- Pl Primary Demand (43)
- Pl Commercial Price Generator (44)
- Pl Secondary Demand (45)
- Pl Tertiary Demand (46)
- Health, Schools, and Recreation (47)
- Pl Consumption (48)
- Government Demand (49)
- Personal Commercial Demand (50)
- Business Commercial Demand (51)
- Local Business Price Generator (52)
- Business and Government Consumption (53)
- Consumption Accountant (54)
- Shipping-Receiving Terminal Demand (55)
- Terminal Consumption (56)

Income (IIG)
- Income Taxation (57)
- Assessment Taxation (58)
- Sales Taxation (59)
- Pl Income (60)
- Government and Business Income (61)

Outside System (IIH)
- Investment Brokerage (62)
- Money Lending (63)
- Building Construction (64)
- Outside Personal Commercial (65)
- Outside Business Commercial (66)
- Industrial Location (67)

TABLE 6 (cont.)

Federal Government Operation (68)
State Government Operation (69)
Business Cycle (70)
Interest Rates (71)

Indicators (IIJ)
Financial Accounts (72)
Statistical Accounts (73)

POST MODEL (III)

Output (IIIA)
Data Base Interrogation (74)
Report Generation (75)

The model parts are comprised of Form, Functions, and Structure. In USM, Form is comprised of the building blocks that make up the model. The Forms are expressed in terms of Parameters. The model assumes that urban Forms as measured by groups of people (population units), business activities, and government activities are located in space and interact with one another. One of the major means of interaction is via the transportation modes or forms which are defined by the transportation Parameters such as the types of links and vehicles.

The urban forms encounter one another through the major urban Functions. These include such operations as migration of population into, out of, within the local area, housing selection by income class for various housing types, etc. The results of the functional operations are expressed as Accounts, which may include economic and/or social indicators.

The Structure of the model is the particular way in which the forms interact. For example, the forms of population units and business activities meet in the function of employment. The structure of employment is such that population units of various skill classifications compete with one another to be hired by the various employers in each of the skill categories. The number of workers required for each level of business activity from each of the skill classes is part of the structure of the model. Structure is expressed in terms of Coefficients. Other employment related coefficients are the maximum travel distances allowed by the gross transportation check associated with workers as they search for jobs within a reasonable travel distance of their place of residence. Table 7 shows some examples of form, functions, and structure in the Urban Systems Model.

TABLE 7

URBAN SYSTEMS MODEL:
CONSTRUCTION FORMAT

		Expressed in Terms Of:
		Parameters
Form	Population Units	People Per Pl
	Land Parcels	Acres Per Tract
	Business Categories	MOD Activities
	Government Activities	Government Departments
	Transportation Modes	Auto, Bus, Rapid Rail, and Others
		Accounts
Functions	Migration	Movers
	Housing Selection	Occupancy Rates
	Employment	Unemployment Rate
	Production	Output Index
	Transportation	Utility of Service
	Etc.	Etc.
		Coefficients
Structure	For Example, within Transportation:	
	Gross Transportation Check	Maximum Commuter Miles to Work
	Modal Preference by Income Class	Percent Preferring Auto by Class
	Etc.	Etc.

The Transportation Process

All of the processes of the Urban Systems Model are interrelated. To illustrate these interrelationships, attention will be focused on the Transportation Process. Table 8 shows the Transportation Process in outline form.

The model user is able to make a wide number of decisions to affect network generation (introduce new modes, change costs, build links, set fares, etc.), trip generation (change assumptions about employment and housing choices), trip distribution (selection of mode groups, assignment of travel preferences to classes of travelers, etc.) and network use (changing coefficient assumptions for crowding, congestion, and constraints).

The Urban Systems Model has been designed to be a very flexible decision tool for experimentation with changes in transportation and transportation-related phenomena and policy.

TABLE 8

THE TRANSPORTATION PROCESS OF THE URBAN SYSTEMS MODEL

1. Network Generation - the development and maintenance of links and vehicles and their associated costs.

    a. Modes - comprised of links (roads and rail rights-of-way) and vehicles (autos, buses, rail cars, and new means of transportation).
    b. Use Costs - function of distance, speed, urbanization, crowding, congestion, normal cost and toll cost.
    c. Decisions - concerning links and capacities, lines and capacities, fares, employment and contracts.

2. Trip Generation - the identification of origins and destinations and the associated volumes of travel.

    a. Peak-Hour Trips - for workers to places of employment
    b. Other Trips

3. Trip Distribution - the selection of modes and combinations of modes for all trips.

    a. Mode Groups
    b. Classes of Travelers

4. Network Use - comparison of used capacity to design capacity.

    a. Crowding - overuse of vehicles
    b. Congestion - overuse of links
    c. Constraints

Network Generation

Links may exist or be constructed between the nodes of adjacent parcels. Parcels of land are areal units which have locational characteristics. They may be comprised of from one to fifteen tracts. Figure 5 shows a portion of a sample urban area represented by the model. Six types of links may be represented by the model (these are roads or tracks that are below, on, or above the ground), and each link may be at one of several possible capacity levels. These links consume land and may be constructed by local or national construction firms.

There are seven types of vehicles (two forms of auto, trucks, two forms of bus, and two types of rail cars) which may traverse the links. They also have specified capacities in terms of the number of people or goods that can be carried. The combination of a vehicle and a link produces a mode of transportation. Each mode of transportation may have a base and per unit distance cost of use which is a function of speed, urbanization, fares, tolls, and operating expenditures.

Trip Generation

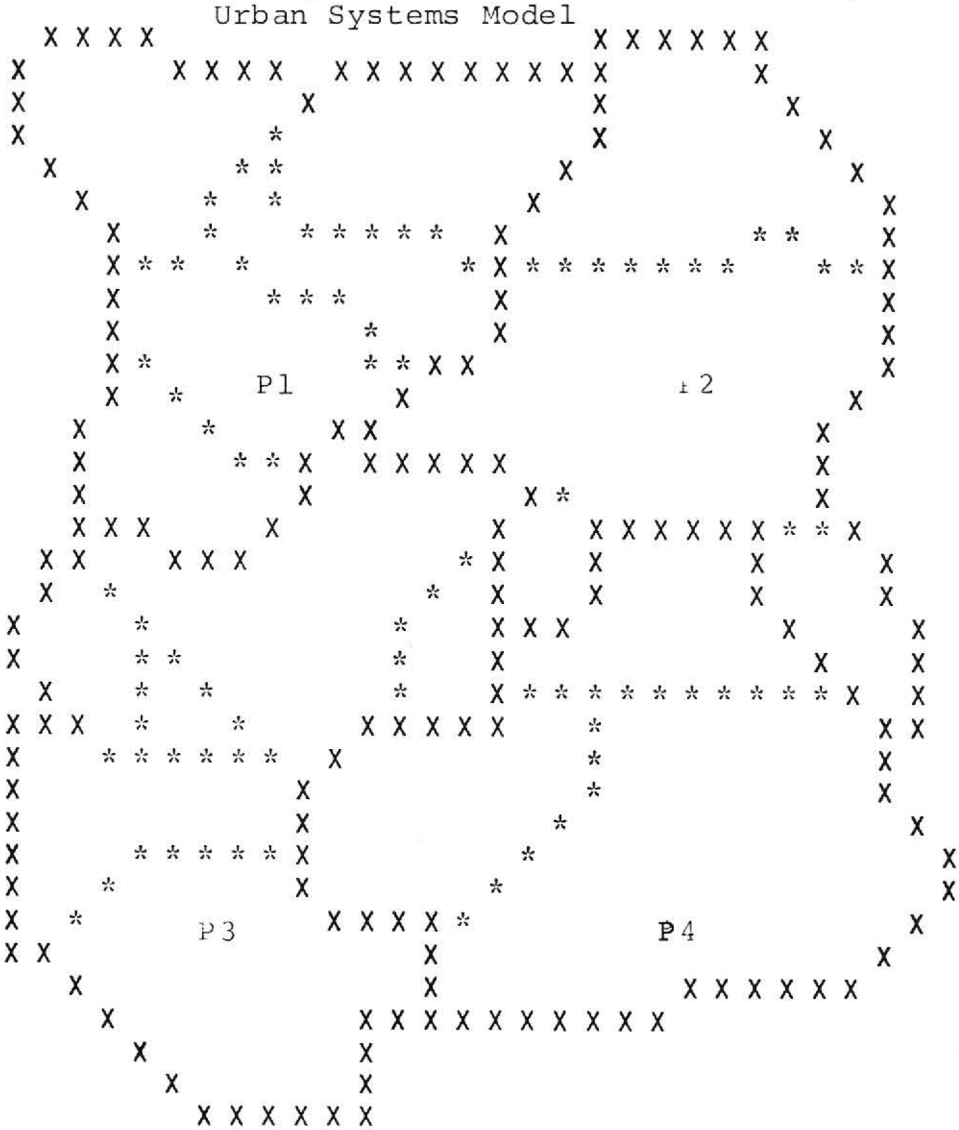
A trip is a journey from an origin to a destination for a specific purpose. The model deals with six personal trip purposes: work, shopping, school, health, recreation, and all others. Origins and destinations are provided by the other major functional processes (employment, commercial, and government services) which, in turn, use as input transportation results from the previous cycle in making allocations that involve spatial considerations. Thus, there is a very crucial feedback between the transportation process and these other important processes that provide the major structure for an urban system.

Trip Distribution

Three things affect the choice of a mode of transportation for a traveler going from a known origin to a known destination: the real time and dollar cost of each mode, the traveler's perceived cost, and the availability of the modes. The model user is able to experiment with different cost functions and different dollar value of time estimates to generate different sets of real time and dollar cost values. The traveler's perceived cost is a value that varies by income class. It may also be changed by the model user. The availability of means of transportation may be affected

Figure 5

Portion of Sample Urban Area Represented By
Urban Systems Model



XXXX Parcel Boundaries (parcel no.)
**** Tract Boundaries

by public policy choices in the transportation sector. It is also affected by input statistics on automobile ownership which will more than likely vary by income class and by geographical location within the urban area.

Network Use

Network Use is the calculation of the utilized capacity of both transportation links and vehicles. Overcrowding of links is called congestion, and overcrowding of vehicles is called crowding.

Execution of the Four Modules

The transportation process just described is run ten times in a single cycle for personal trips to work. First, the workers without automobiles are processed for each of the five classes with the low class going first. Then, five more runs are made for the workers who have an option to use their automobile. The cost and capacity factors calculated in the Network Generation Module are changed at the end of each of these ten runs. Thus the use of the transportation system is dynamically calculated using a prespecified sequence in which users of the system are assigned.

A less elaborate procedure is used to calculate the routes, modal choices, and costs for personal commercial trips, trips to government services, and trucking trips. Personal trips and costs, however, are partially based upon results derived from the peak hour transportation process.

Referring again to Figure X (the overall flowchart), note that the Transportation Process takes place approximately in the middle of the operating programs for the Urban Systems Model. Twenty-eight modules are usually operated before the ten transportation modules function. After they function in the iterative fashion described above, another 37 modules are operated before a complete cycle of USM is finished. The fact that most of these other modules contain the same level of detail and scope as the transportation modules allows the Urban Systems Model to show the many interrelationships between the transportation subsystem and the economic, social, and government status of the urban area being represented.

SAMPLES OF THE TRANSPORTATION PROCESS

To illustrate some of the interaction among the processes and modules in USM, two transportation decisions will be traced through the model. First, a decision to implement a new public transit mode, and second, a decision to build a new highway link.

New Public Transit Mode

A financial account must be identified as being responsible for the bills and income (if any) from this new mode. The account may be one that is already operative (the local public transit authority) or it may be a newly created account.

The inputs for the new mode design would be:

General Information
- Account Number
- Type of link(s) used - highway, rail
- Cost of Vehicle
- Capacity of Vehicle
- Normal Speed of Vehicle
- Manpower Required per Vehicle (including support personnel)
- Other Operating Cost per Vehicle
- Fixed Overhead per Vehicle
- Congestion Factor for Vehicle

Specific Information
- Routes
- Fares
- Service Levels
- Salary Levels
- Employment Standards

The general information defines the mode and its characteristics. That is, it represents the technology embodied in that particular mode of public transit. If a new technological breakthrough occurs (such as automating a previously manual operation) the requirements (manpower reductions) and costs (increased cost per vehicle) are changed accordingly.

The specific information describes how that particular mode will be operated within the local system on a year to year basis. Thus, these are the policy variables as opposed to the technical variables.

To simplify the illustration, both the general information inputs and the specific information inputs will be treated as a single decision. This decision will be traced through the flowchart for the Urban Systems Model. (Figure 6)

All inputs go to the Input Data Process (IA) and the Procedural Editing (3) module first checks for format and other procedural-type errors. For example, if the account number was placed in the wrong card column or information slot this would cause the input to be rejected. Since this decision contains accounts, coefficients, and parameters, modules (1) and (2) would be employed next. Then Data Management (4) would receive the inputs and send it to the Data Implementation Process (IB).

Substantive Editing (7) checks the input for substantive errors. For example, the account number given in the decision might not have the power to operate this public transit mode. The two parameter adjustment modules (5 and 6) receive the edited inputs and make the appropriate adjustments.

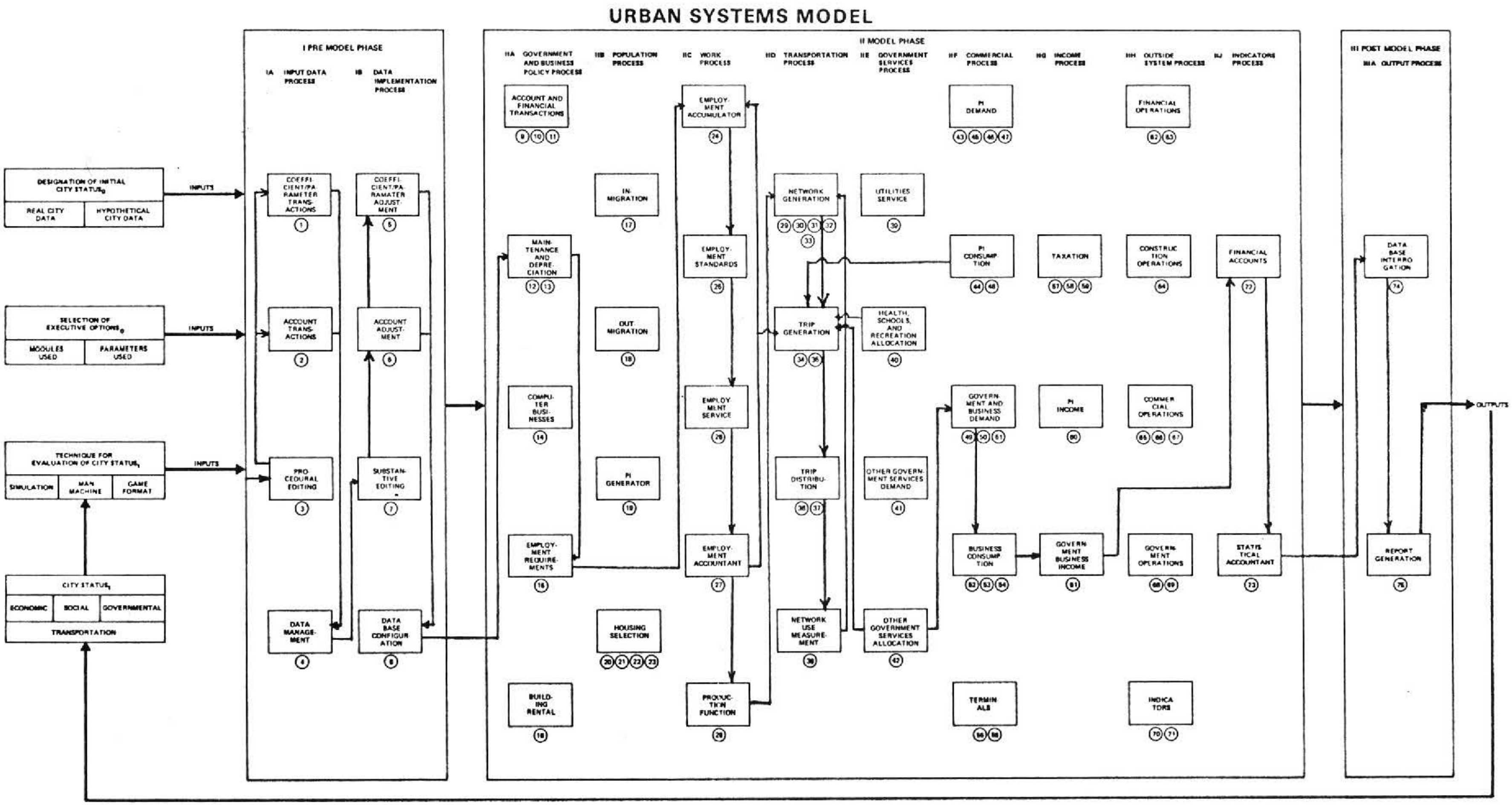
A number of modules in the Government and Business Policy Process might be used depending upon the full details of the new public mode input. For example, if zone fares were desired, the Jurisdiction Modification (9) module would be called into play. If a transfer of money was required, module (11) would be used. The maintenance level applied to the vehicles required by the new mode is handled by module (12) and future depreciation and obsolescence (as the result of time, uses, and maintenance) would be calculated by module (13). The employment required by the new mode to operate at the desired level would be calculated by Employment Requirements (15) for use in the Work Process.

No direct feed to the Population Process is generated by this decision to input a new public transit mode, but the changes that take place in accessibility in the future years will have an indirect impact on future migration patterns. Likewise, the increase in jobs caused by the new mode will have an effect that may attract in-migrants who see a rise in employment opportunities (all other things remaining equal, that is).

The Work Process (IIC) receives the employment requests for a specific number of workers from each of the classes. The modules comprising the Work Process are iterated several times to derive the actual full time and part time workers hired. The Employment Accumulator (24) puts the new mode's employment requests in a list with the requests

FIGURE 6

SAMPLE OF THE FLOW OF IMPACTS FROM A DECISION
TO IMPLEMENT A NEW MODE OF PUBLIC TRANSIT



of all other employers. The Employment Standards Module (25) develops an employer index for the new public mode based upon the salary offered, central employment location, skill level desired, and work conditions for the new mode. The Employment Service (26) matches workers with jobs. If all the full time jobs are not filled, the employment standards are changed (for both workers and employers in 25) and this module is run again. Likewise the part time employment process is run. The Employment Accountant (27) calculates the wages paid by the account responsible for the new mode.

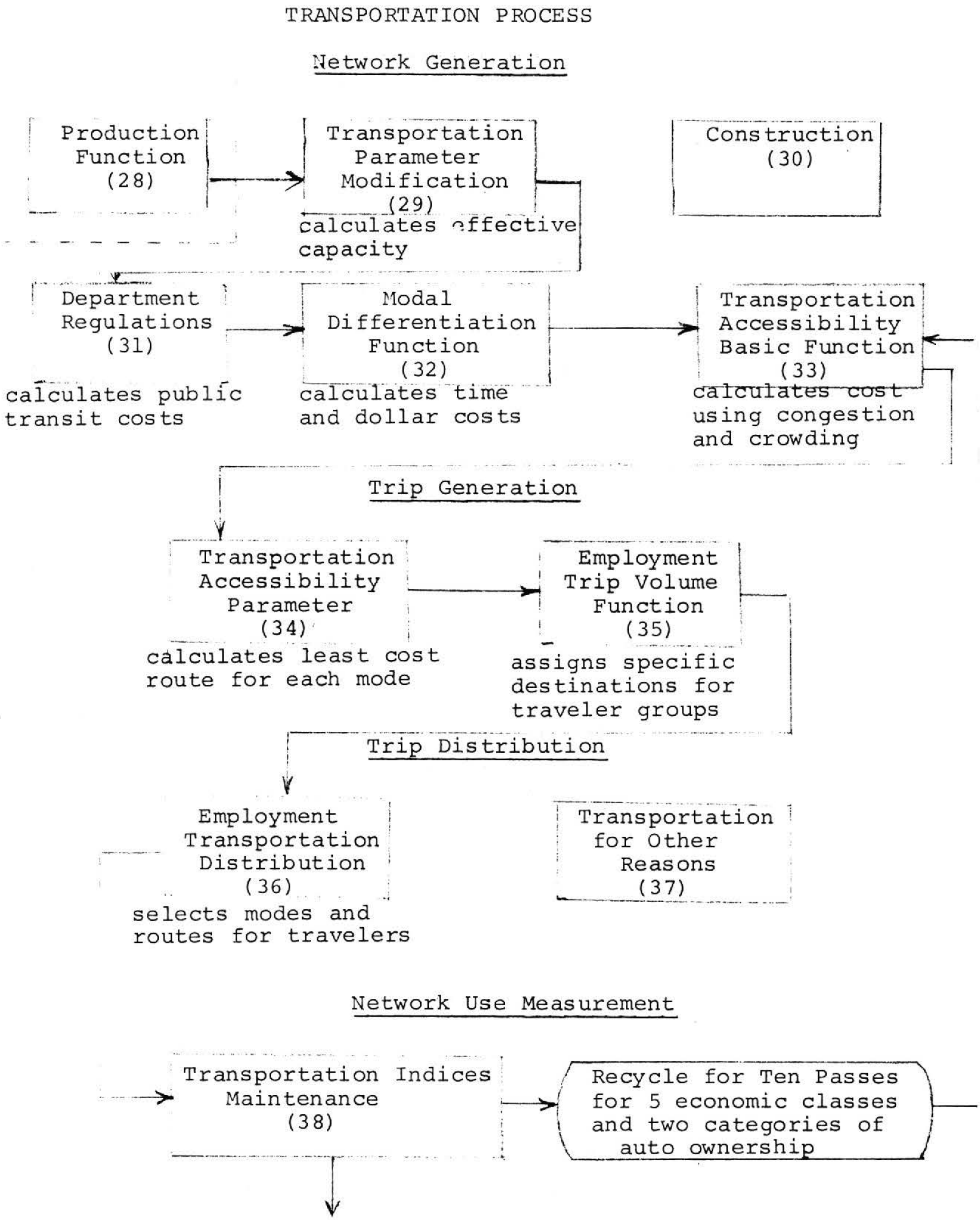
The Production Function (28) calculates the effective capacity of the new mode based upon the quantity and quality of the labor force hired and the vehicles used. This capacity is used in the Transportation Process (IID). Figure 4 is provided to show some of the detail that takes place within the Transportation Process for this particular decision.

The Network Generation sub-process is comprised of five modules. The Transportation Parameter Modification Module (29) would take the addition of the new public mode and calculate its effective capacity. The Transportation Construction Module (30) would not be needed by this decision unless the explicit construction of tracts, terminals, or storage facilities were required by the new mode. Departmental Regulations (31) would calculate the fares between all parcel pairs for the parcels served by the new mode. It could calculate fares on a per mile, per zone, or a flat fare basis depending upon the specifications of the decision input.

The Modal Differentiation Function (32) calculates the time and dollar cost for the new mode for every parcel to every other directly accessible parcel as a function of the design input speed, distances, and the percent urbanization in the specific parcels. At this juncture, workers are cycled through the transportation process in ten stages. First, the workers without access to a car are run for the five classes, the lowest class being run first. Next, the workers with access to an auto are run through for each of the five classes, low class first. The Transportation Accessibility Basic Function (33) calculates the basic time and dollar cost for this mode for every parcel to every other directly accessible parcel taking into consideration the congestion and crowding caused by the previous users of the transportation subsystem in this year.

The Trip Generation sub-process contains two modules that calculate the least cost modes and routes and assign the passenger units to specific work destinations. The

Figure 7 - Detail Activity Within the Transportation Process for Work Trips



Transportation Accessibility Parameter Module (34) calculates the least cost route for a population class on a parcel to all destination parcels for each mode.

The Employment Trip Volume Module (35) calculates the number of passenger units by class and car ownership category traveling to work from each residential parcel and assigns these to specific work destinations based upon the accessibility of modes of travel. Thus, in the first five cycles of the Transportation Process the workers being assigned are those without cars, so the automobile option is not considered for them.

The Employment Transportation Distribution Module (36) calculates the total passenger volume for each mode and distributes this over the various routes. This is of particular importance to auto users who will possibly take alternative routes when going from one origin to another destination.

The Transportation Indices Maintenance Module (38) calculates the congestion of transportation links and the crowding of vehicles caused by all travelers assigned to routes and modes thus far. Thus, it can be seen that some routes and modes may be eliminated from consideration by traveler groups that are run last in the Transportation Process.

After ten cycles through the Transportation Process for the five income classes and the two car ownership categories, the Model Phase continues into the Government Services Process and the Commercial Process. Nonwork trips result from these two processes which require a return to the Transportation Process to determine modal choice and transportation costs.

The allocations that result in the Government Services Process (specifically modules 40 and 42) for trips to schools, health services, and recreation are added to the trips generated as part of the Commercial Process. The commercial trips for Pl's are to retail establishments (food, durable, and other non-durable), services, and amusements. Other trips generated are for businesses in their dealings within the local system and their terminal demands resulting from interactions with the outside system. These trip types are run through the Transportation Process one at a time to determine modal choice, routing (in some cases), and transportation charges. Note at this point that the transportation charges paid by all users of the local transportation subsystem are generated within the model based upon such factors as mode used, transportation accessibility, congestion, crowding, fares, tolls, distances, parking charges, volume shipped, purchases made, and type of traveler.

The primary effects of the decision to implement a new public transit mode were highlighted in the previous paragraphs. There are, of course, many secondary effects and indirect impacts that this decision could have both in the year that it was implemented and in following years. For example, in succeeding years the selection of housing by population units might be altered by the changed accessibility brought on by the new mode decision. Similarly, new housing and changed patterns of land use density might develop over time in response to the new public transit mode.

A New Highway

The decision to build a new link of highway might differ in several respects from the previous example of a decision to implement a new public transit mode. Assume that it:

- requires a major capital cost
- requires rights-of-way
- depends in part upon Federal and State funding
- is affected by the local Transportation Construction firms

The highway construction decision is an input that changes the link network but does not alter the vehicle situation. It was assumed that the previous public transit decision was a vehicle operation decision that did not require any new links.

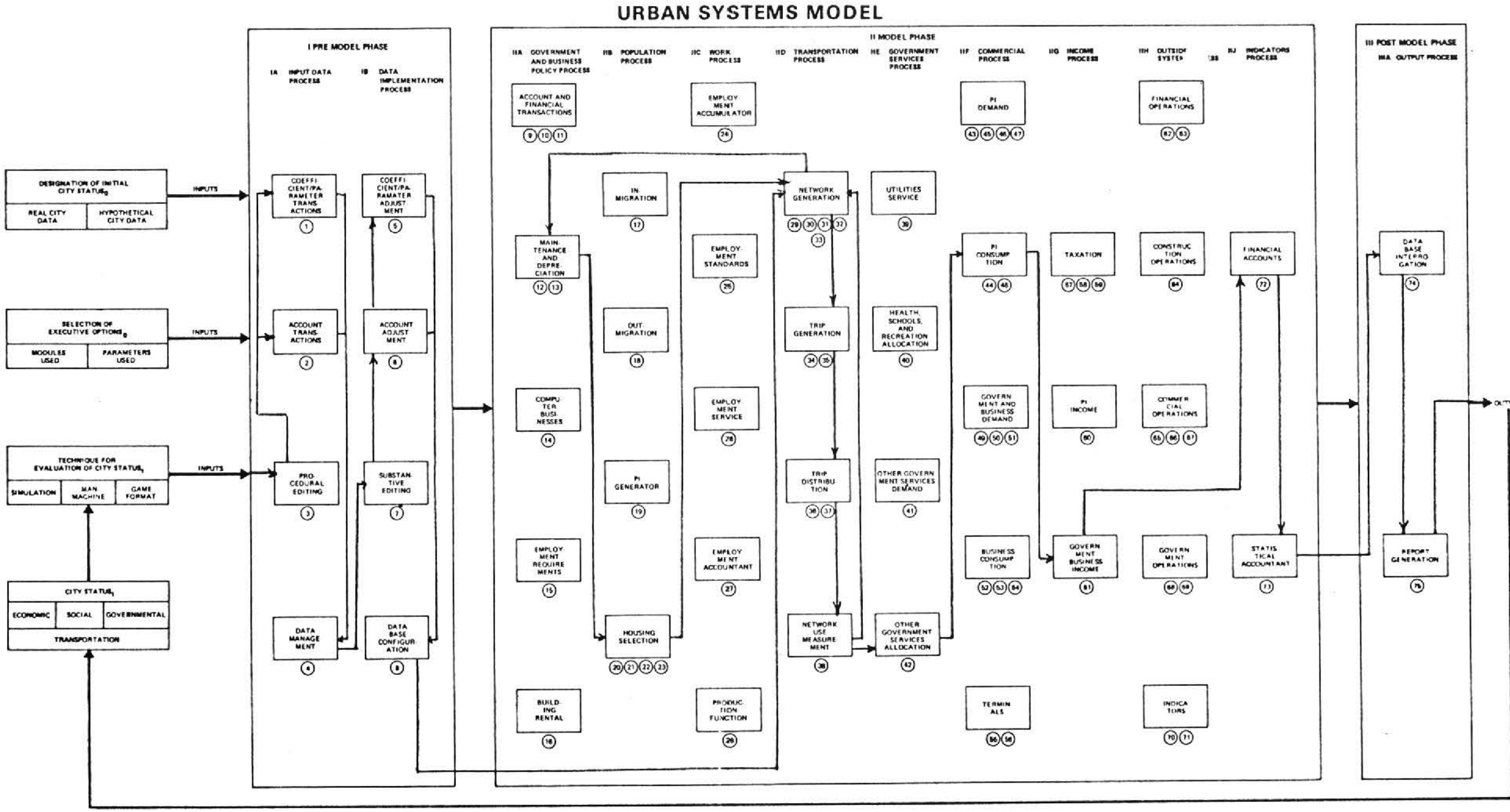
The highway construction decision actually involves several stages: planning, construction, and implementation. The modules involved in the planning stage might include Land, Building, and Corporation Purchase (10) which would be needed to finance the local share of costs; Assessment Taxation (58) which might be needed to raise more local taxes; and Federal Government Operation (68) and/or State Government Operation (69) which might be utilized to apply for and receive financial aid from higher level governments.

The construction phase would require interaction with either the Transportation Construction (30) or Building Construction (64) modules. In either event the employment impact of the new construction would be felt by the local community. The precise number of workers hired to complete any construction project may be traced through the model, as can the income effects.

The implementation phase actualizes the new link in the Pre-Model Phase. The Data Base Configuration module (8) must interact with the Transportation Parameter Modification Module (29) and the Transportation Accessibility Basic Function (33) in the Transportation Process before the conventional sequence of modules in the Model Phase are operated. This is necessary, because it is desired to have the new highway affect the accessibility used in the Population and Work processes which are run before the Transportation Process. Once the accessibilities are changed the usual sequence shown in Figure 8 can be followed.

FIGURE 8

SAMPLE OF THE FLOW OF IMPACTS FROM A DECISION
TO BUILD A NEW HIGHWAY



The modules directly affected by the new highway construction are Maintenance (12) and Depreciation-Obsolescence (13) which together determine the necessary costs to keep the road in the condition designated by the Highway Department. Housing Placement (22) uses the gross transportation check to limit housing choices for workers with jobs at specific locations. The new highway might alter the previous gross transportation numbers for certain parcel pairs.

The operations affected by the new highway in the Transportation Process are effective capacity between the two affected nodes is increased (29); dollar and time costs might be altered (32); least cost routes might change for some journeys (34); travelers might take different modes and/or routes (36); congestion might be diminished (38). The allocation of government services (42) might be affected by the new highway. Selection of stores for shopping by Pl's might change as a result of changed accessibility. For example, a different shopping area might now be easiest for a group of consumers to get to.

Government income (61) would be increased if a toll were associated with use of the new road and the road was utilized. The dollar amounts would be calculated (72) and the quantity and quality indicators for the new road would be generated (73). If any special information on the new road was requested by the model user, the Data Base Interrogation Module (74) would be operated and the results would be printed by the Report Generation Module (75).

RELATION TO OTHER MODELS

Urban transportation planners presently have available to them two standardized and computerized planning packages. One is the BPR Battery and the other is the HUD Transit Planning Package. The BPR Battery is a set of operational models funded by the Bureau of Public Roads and currently employed by most metropolitan area transportation boards. The BPR package deals with the testing of highway alternatives within a metropolitan context that is input by the user. That is, the location and characteristics of people, housing, jobs, and commercial activity must be specified by the model user.

The Transit Planning Package is similar in scope in that it is designed to deal with transit planning issues within a metropolitan context that is defined by the user.

Both of these canned models differ from USM in that they deal with only one Model Phase Process: the one for Transportation. With reference to Figure X , these models contain only the Input Data, Transportation, and Output processes. They were created simply to deal with specific transportation issues and that is what they do. USM was designed to go a major step beyond this and deal with the operation of the major functions of an urban area. Transportation was to be just one part of the overall system. Thus USM has nine processes as part of the Model Phase instead of only one.

Contrary to the BPR and HUD packages, the Transportation Process of USM combines highway (link) and transit (link and vehicle) planning within the same submodel. The general nature of the model allows an increase in the capacity or speed between two modes with regard to highways to be treated in the same way as an increase in service capacity or speed of travel for a bus, rail, or innovative public mode of travel.

The BPR and HUD packages do not allow for inputs from the remainder of the system such as a cutback in salaries, boycott of modes of travel, changing federal grant programs for transportation facilities, etc. that may be represented in USM. The impacts of these and many other decisions may be generated during a typical run of the Urban Systems Model.

The modular feature of USM would allow the use of the BPR or HUD packages as complete or partial substitutes for the Transportation Process included in this design document as long as the appropriate interfaces with the other processes were made. An original transportation component, however, was designed as part of the Urban Systems Model.

BPR Battery

As the BPR battery report states concerning the battery models themselves (pI-7):

> "This, of course, is a gross oversimplification of the transportation planning process. It does, however, establish the functional relationships of the major elements of the process. It is particularly important to look upon the several elements of the transportation planning process as integrated components. Often trip generation, distribution, assignment and the other elements of the process tend to take on an air of individuality as though the results of each constitute an end product. From a behavioral point of view, however, it is difficult to separate decisions to travel from the choice of destination. Nor can decisions about residential location and the length, number, and mode of trips be arrived at individually.
>
> This approach will ultimately lead to the development of models more sophisticated and complex than most of those in use today."

This quote indicates that BPR realizes a new generation of urban transportation models will eventually be built to supplement and/or complement the models presently available. The Urban Systems Model is a member of this new generation of models. As the first member of this new generation, USM may still have its rough edges and even appear simplistic in some of its individual parts. Three factors account for this and could be overcome with further design work:

1. USM was designed to be holistic, so details were sacrificed in some of its modules to allow development of relationships among the modules. In other words, tying together the subsystems was given priority over full elaboration of the subsystems themselves.

2. USM was designed to be operable using today's computer technology. The USM design can be programmed and then operated by a small number of persons. Four years of experience with this

TABLE 9

COMPARISON OF USM AND BPR BATTERY

Urban Systems Model	Battery Models
Load Initial Configuration (Including Transportation Subsystem)	Load Initial Configuration (Including Transportation System)
Decisions Made About Amount and Location of Most Business Activities	Amount and Location of Forecast of Population and Business Activities
Decisions About Residences Location	
Population Process determines amount and location of population	
Work Process, Government Services Process, and Commercial Process determines aggregate trips and their distinctions and feeds this to Trip Generation sub-process	Estimate Trips These Land Use Activities Will Generate Determine Where the Trips Will Go
Trip Distribution sub-process determines specifically the O-D, mode, and route for each traveller grouping for work trips. Non-work trips calculated using similar factors.	Determine the Mode Used Determine the Route Used
Transportation Indices Module calculates the congestion and crowding for links and vehicles	System Evaluation

holistic-type of man-machine modeling has forced the consideration of many operating problems and these have been resolved in the design.

3. USM was designed in less than a year by a handful of people who had no time to perform original research. Thus, many of the suggested parameters and coefficients may need to be modified as the result of empirical research. The model, however, does provide a useful framework for organizing such empirical studies.

The above quote from the BPR document points out that decisions to travel are related to the choice of destination and that residential location is affected by the transportation subsystem. USM takes these factors into explicit account. For example, the Work Process uses transportation accessibility as a factor in job selection for those residents who have housing but no job and the migration modules in the Population Process use transportation accessibility in housing selection for those residents who have jobs but no housing.

Urban Mass Transit Planning Project

The other battery model was prepared in 1968 by Alan Voorhees and Associates for the Department of Housing and Urban Development. This set of interrelated programs for a software package was to be used in the planning of public transportation. The transit battery contains eleven modules under three headings as shown and described along with those of the Urban Systems Model in Table 10.

The transit battery uses regression analysis to develop model parameters that change as a function of the loaded information. USM does not do this, but many of the parameters are changed as a result of the operating programs that precede transportation (particularly migration and employment).

The transit battery is ideally suited to test the effect of a single transit change on the system while everything else is left unchanged. The outcome will be different passenger loadings. The model does not indicate any effect on housing selection, work selection, shopping changes, tax changes, etc. that might also result from that decision. The transit battery was not designed to show various non-transportation impacts, whereas USM has been designed to show these other impacts as well as those for the transportation subsystem itself.

TABLE 10

LIST OF MODULES FOR USM AND THE TRANSIT BATTERY

Urban Systems Model

Module 29-calculates effective capacity
Module 30-constructs new links
Module 31-calculates fares and tolls
Module 32-calculates time and dollar cost by mode
Module 33-modifies time and dollar costs as result of congestion and crowding
Module 34-calculates least cost path
Module 26-matches workers to jobs (origins and destinations)
Module 35-calculates passenger units to each destination from each origin
Module 36-determines modal split and route taken
Module 37-calculates non-work transportation and assignment
Module 38-calculates congestion and crowding from each pass
Module 72-calculates total dollar costs to users for all transportation
Module 73-calculates transportation indices
Module 75-prints computer output

Transit Battery

Network Analysis (supply)

AVNET-describes transit system
AVPATH-calculates minimum cost paths for zone pairs
AVPSUM-calculates values for 12 interzonal matrices (such as transfers required, time spent, etc.)
AVFMTR-prints parts of AVPSUM
AVDZFS-calculates interzonal transit fares

Modal Split

AVDATR-prepares data that is necessary to generate demand
AVREGRE-uses regression analysis on data from AVDATR to develop parameters
AVMPSP-applies modal split model

Passenger Loading

AVLOAD-assigns passenger volume to minimum paths
AVPRAS-reads AVLOAD's output
AVSTOS-compiles a station-to-station volume matrix

Both the transit battery and USM have a large number of weights that may be manipulated by the user to approximate actual conditions or to perform experimentation.

Other Transportation Model Characteristics

A brief comparison of USM characteristics with those of conventional models follows:

Zones

USM and other models tend to use as few zones as possible and still achieve the objectives of the particular model use. USM has land areas called parcels (zones) that have geographic characteristics and other land areas (tracts) that comprise parcels but have no specific geographic location but only an areal size.

Origins and Destinations

Conventional transportation modelers usually make a single O-D study when constructing the model and then calibrate the model so that the O-D's are generated by it using regression techniques that relate travel to the socioeconomic characteristics of the population. In USM, the industries, commercial establishments, and public employers create the potential work and shop destinations. The population units (by income class) that live in the housing units provide the potential origins. Note that no work or shopping assignments are assumed at this point in USM. Population units are placed into housing units in the model using a migration routine that takes into account occupancy levels, social class mix, population categories, rent, quality of schools, quality of municipal services, housing quality, tax rates, and accessibility for units with jobs.

Modal Split

Conventional transportation models use either a predistribution modal split formulation based upon past data and changes in household income or a post-distribution modal split based upon a diversion curve that relates public transit trips to characteristics such as fares, travel time, and waiting time. In USM, the modal split determination is part of the trip distribution process. The choice of mode by a population unit is influenced by the availability of service, capacity, costs, time, automobile ownership, and class of traveler. Transportation decision-makers set service routes, capacities, and fares. The split between several modes is dependent upon the relative costs of the two least costly modes. Since the transportation process is run ten times, travelers in the last runs may have their modal split affected by the modal split of travelers run earlier.

Distribution

Origins are distributed to destinations by the conventional transportation models using either a gravity model or an opportunity model. In USM, the computer makes the employment and shopping assignments using the assumption that workers will attempt to satisfy certain criteria such as net income earned (salary minus transportation costs to work). Computer assignments may be affected by changing salaries, accessibility, preferences, etc..

Network Assignments

The conventional transportation models assign travelers to a particular route and/or mode using the all-or-nothing approach, the capacitated all-or-nothing approach in an iterative fashion, or one of the several incremental approaches.

In USM, travellers without access to automobiles are processed first so that they may have the first crack at public transit. General origins and destinations have been determined up to this point (a certain percent who live on this parcel work on several other parcels) but the distribution process determines which persons (based upon automobile ownership figures) actually go to which parcels and how. The entire transportation process is run ten times in each round with the costs, times, congestion, and crowding likely to change at the end of each run.

Network Evaluation

The conventional transportation models, to the extent that they have an evaluation component, usually make link by link comparisons. In USM, the model users evaluate the transportation system from the viewpoint of taxpayers, travelers, employers, retail merchants, transportation administrators, planners, elected officials, terminal users, and other decision-makers who affect and are affected by the transportation system. Model users may take action as a result of their evaluations that change the transportation system or the activities that use the system. They may also make link by link comparisons in terms of congestion and crowding.

The typical urban transportation models require as inputs (or generate) land use activity for the desired target date. Then the modules dealing with transportation are run (trip generation, modal split, trip distribution, and assignment). Many of these models do not deal with the effect of the transportation network on land use itself.

The conventional urban transportation models assume that trips are generated by land uses. Most models deal with very few land uses that are employment generators. USM would have at least eleven industry types, six commercial types, one state and one Federal government type, and several local government types. There are normal employment demands by economic class from each of these employer types, but the actual number of workers sought by any employer will depend upon a number of factors that are dependent upon the local situation. Workers might be laid off because of an economic downturn or the income class mix might change because of social pressures. USM deals with fairly precise employment opportunities on a spatial basis and on a year to year basis. Other models have tended to deal less precisely with employment opportunities and with some future period of time.

Furthermore, most of the conventional urban transportation models are concerned with growth (previously vacant land being developed for the first time) and are not equipped to deal with change such as minor declines or redevelopment. USM can deal with both growth and change.

Other Urban Models and Techniques

The broad scope of the Urban Systems Model makes it have points in common with several other urban modeling types. These types are:

- Non-Specific Area
- Broad Scope Models
- Locational or Land Use Models
- Sophisticated Urban Gaming Models
- Miscellaneous Urban Models
- System Models Being Developed
- Graphical Programs and Analysis
- Data Banks
- Theoretical Structures

Comments are presented for sample models from each of these categories for several purposes.

First, it may help to describe USM by showing how it is similar to and different from other models. Second, it is helpful to see what a broad range of model types are integrated within the USM framework. Third, some of these works and others from the nine categories would be examined more thoroughly once implementation of USM was begun.

Non-Specific Area Models

Most urban models have been developed for specific metropolitan areas. The major exceptions have been the area-independent models for transportation systems. Examples of these are:

- Control Data Corporation - Transportation Package (transportation planning package)

- BPR Battery Models - examined in an earlier section of this report.

- NBER - Urban Simulation Model (simulation of long run interdependencies among urban subsystems, particularly land use and transportation)

Although the first two of these models are limited in that they deal only with transportation planning and routing, they are able to reflect the state-of-the-art of area-independent or general models. These models have been looked at to see what insights can be gained from the experiences of other model builders who have been concerned with models that can be used in any area with minimum data requirements. The NBER model was not received early enough to influence the USM design. It would be analyzed closely as part of the USM implementation.

Broad Scope Models

A few models have been developed that were unusually broad in the range of issues and subsystems with which they dealt.

- Arthur D. Little - San Francisco CRP Model - (a detailed housing selection model)
- University of California - Bay Area Simulation Study or BASS - (an impact model for employment, transportation, and renewal danger)
- Battelle Memorial Institute - Susquehanna River Basin Model - (a projection model for a multicounty area)
- Guy Orcutt and others - Microanalytical Model - (detailed demographic-plus model)

USM is broader in scope but less detailed in certain sections than these models. They all have good associated empirical research that would be helpful in the USM implementation phase.

Locational or Land Use Models

The location of industrial, commercial, and residential activity has been a major concern to many urban model-builders. Land use has been the prime concern of many models, of which the following are examples:

- Kenneth Schlager - Land Use Plan Design Model - (an optimizing land use model)
- Stuart Chapin - A Model for Simulating Residential Development
- Ira Lowry - Pittsburgh Model - (an allocation model for basic, residential, and commercial land uses)

These models could be developed as modules to USM to simulate the location of basic, service, and residential land uses for those users of USM who were not interested in directly controlling these decisions or allowing them to be human inputs.

Sophisticated Urban Gaming Models

Naturally, the CITY MODEL developed by Envirometrics had a significant influence on the development of the Urban Systems Model. Two other urban gaming models have been investigated: the METRO-APEX model (Richard Duke) developed and operated at the University of Michigan and the GSPIA model (Clark Rogers) developed at the University of Pittsburgh. Both of these two models contain some features that are not found in any other urban model and both have been fitted with real data fairly inexpensively. Much can be learned from their experience in using secondary source material.

Miscellaneous Urban Models

A number of urban models are not easily categorized because of their unique approach or area of interest. Most notable of these are:

- Jay Forrester - Urban Dynamics - (highly controversial and imaginative simulation of urban growth and decay over a long period of time)
- Don Blumberg - PROMUS - (computerized model used by Toronto city officials)
- Pat Crecine - Government Budget - (model to determine budget allocations)
- Robert Yuill - A General Model for Urban Growth - (a spatial model)

In many respects these models are closer to actually being used by urban planners than most of the others, even though relatively little has been spent on developing them thus far.

Systems Models Being Developed

There are a number of models presently being developed thus far that would be thoroughly investigated as part of the implementation of the USM model. They had minimal effect on its design thus far.

- Planning Research Corporation - Urban Performance Model - (measures performance in terms of one index for quality and one for accessibility)
- University of California - Environment Model for California - (a system concept of interrelated sub-models designed for local and state planning purposes)

- William Goldner - PLUM - (an evolutionary projective land use model)

Graphical Programs and Analysis

USM like its predecessor models developed by Envirometrics is very much user-oriented. This means that it must have clear and easily interpreted computer output. Since it deals with spatial relationships, computer maps are essential. The following mapping techniques and the list processor will be implemented where appropriate in the operational Urban Systems Model.

- SYMAP

- Calcomp

- MAP01

- List Processor

Data Banks

It is very important that USM take advantage of the best data presently available to urban areas. Because of the comprehensive nature of USM, it can be viewed as a model that integrates the diverse information available in conventional data banks and generates an understandable status of the represented area.

- Limited Urban Observatory - (New Haven)

- SDC - Information Systems Manual - (general)

- USAC City Projects - (federally funded demonstration projects)

Theoretical Structures

These ground-breaking efforts are very likely to influence the final implementation of USM and its continual evolution.

- Walter Isard and others - General Theory - (of social, political, economic, and regional behavior)

- Anthony Cantanese and Alan Steiss - Systems Approach to Planning Complex Urban Systems

The above are only a select sample of the works that fall under the nine categories of related urban research.

USM relates to each of these nine categories, and in a sense provides a synthesis of much of the urban research that is being performed today.

DESIGN OF USM

The Urban Systems Model is a general man-machine simulation of a metropolitan environment. The model interrelates and calculates the effects of decisions made for the real or hypothetical urban area represented by the model.

The model is not designed to show its users what ought to be or to indicate what policies should be made. Rather, the model generates information, indicators and values of many types of economic, governmental, social, and physical phenomenon for the represented area. It is up to the users of the model to decide which of the indices and measures are important for their purposes. Therefore, even though the model does not set a standard for "good performance" or "success," it does contain the measures and indices necessary to evaluate "good performance" and/or "success" once the users have defined what they mean by these normative terms. Thus, the users provide the real normative input into the model through their interpretation and evaluation of the status of the urban area at various points in time.

If users set objectives such as maximizing family income, reducing transportation costs in terms of time and dollars to various travelers, and/or experimenting with new modes of travel, the model contains the measures and indices necessary to evaluate their success in achieving these self-set objectives.

Modularity

The Urban Systems Model will be modular in several respects:

1. Operating components (modules) will be replaceable by new components that have the same links to other components.

2. Parameters will be able to be changed easily.

3. New submodels can be added to the basic structure of the model.

In other words, the model provides a flexible framework for future modification and expansion.

Design Assumptions

The basic design assumption of the model is that if the major activities that take place within a metropolitan area are represented and related to one another, then the actual demands for and supply of transportation facilities will result from the operation of these activities. Likewise, the realistic way in which transportation decisions and their impacts affect the urban system can only be represented in a holistic model that incorporates public and private decision-making.

The major decision-making actors are business (the economic sector), the local population (the social sector) and public policy makers (the government sector). They interrelate with one another in a physical and institutional environment that takes into consideration spatial relationships, ties to a larger outside system, and allocates goods, services, labor, incomes, etc. by a number of market operations.

The major markets are:

1. Interrelationships with the Outside System
2. Migration and Housing
3. Employment and Transportation
4. Commercial and Transportation
5. Time Allocation and Transportation
6. Public Goods and Services
7. Allocation of Financial Resources

The four basic building blocks of the model are business types, population units, government functions, and parcels of land. All of these factors are dealt with in a micro manner. That is, an individual population unit (representing a given number of people with loaded or derived characteristics) finds housing at a specific location, is employed by a specific employer (if in fact it is employed), shops at designated locations, etc.

The following description is concerned with a description of the four building blocks and seven markets.

Since this document is a fairly detailed description of the Urban Systems Model and the programming specifications for the model, the many assumptions and parameters are specified. Examples of how the model parts would be made operational are given. These parameters and examples are included for descriptive purposes. They need not be followed precisely in the final implementation of the model if an improved alternative is selected.

Basic Building Blocks

Much of the design effort associated with the development of the Urban Systems Model was spent developing realistic, general, and usable concepts of land parcels, business activities, population units and government functions. Realism is required so that the model is able to represent actual metropolitan areas. A general concept is required so that any metropolitan area in the continental United States can be represented. The concepts must be usable in the sense that the users of the model are able to understand the basic system relationships of the model and the statistical output generated by the computer within a relatively short period of time.

Parcels of Land

The geographical area represented by the model will be comprised of land parcels. A parcel of land has the following characteristics:

1. A single point from which distance and time to other parcels is measured.

2. A size (number of acres or square miles), a shape (any irregular boundary is allowed), and a unique identification number.

3. A number of constituent tracts of land

A tract of land has the characteristics of being assigned to a parcel and having the same transportation characteristics as the parcel to which it belongs. A tract is further characterized by:

1. A size (acres or square miles) and an identification number.

2. A single owner.

3. A single zoning.

4. A single private land use

A parcel of land may be composed of up to fifteen tracts. Each tract may have a single type of private development, but no parcel may contain more than one development of each business type. For example, a parcel could have tracts owned by five corporations and each tract could contain a business activity, but no two business activities could be of the same type, e.g., chemical plants.

All geographical areas (such as political jurisdictions, special districts, utility districts, etc.) will be defined in terms of full parcels of land. It is expected that from 100 to 150 parcels of land will be sufficient to represent the major transportation and aggregate land use differences for middle to large-sized metropolitan areas. For example, the Washington, D. C. metropolitan area would probably contain approximately 150 parcels of land* and about 1500 tracts of land.

Since much of the actual data required to load the Urban Systems Model will come from sources dealing with census tracts and enumeration districts, having the model parcels and tracts be of flexible size and shape will expedite the loading process.

An important characteristic of the sum of all the parcels, which define the map boundaries, is that they define the geographical limits of the local system. All activities and decision-makers that are outside of the regional boundaries comprise the local system. There may be some activities (Federal installations and state institutions) and some decision-makers (at the Federal and state level) that are physically within the boundaries of the region. These activities are part of the local system, but their policy is made as part of the outside system (exogenous).

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* This number of parcels of land is of the same order of magnitude as the number of districts used by the EMPIRIC model for the D.C. area.

Population Units

A new concept for a population unit has evolved that should make the loading of the Urban Systems model easier than previously thought. The scale of the Pl will be 10, 100 or 1,000 people instead of households. The Pl's will be identified as being of one of five socio-economic classes, which set limits on some of the characteristics that a Pl may assume.

For example, a PL may not be able to attain a higher productivity level than 20 and it may never spend more than x percent of its income on education or health.

All of the Pl's of a given class on a parcel will be combined together for statistical purposes and an average Pl will be determined and it will have average characteristics. The characteristics of a Pl class on a parcel will be:

A. Characteristics of the Pl

- Percent of Potential Full-Time Workers
- Percent of Potential Part-Time Workers
- Percent Aged 0-18
- Percent Aged 19-35
- Percent Aged 36-65
- Percent Aged Over 65
- Percent Non-White
- Average Number of Years of School Completed
- Number of Elementary Students
- Number of Secondary Students
- Number of Post Secondary Students

The last three Pl characteristics will be derived from age cohorts.

B. Characteristics of the Workers (Class and Parcel)

- Percent Unemployed
- Percent Underemployed
- Productivity Index
- Percent with Automobile

Even with the characteristics of Pl's by class being averaged for a parcel, there will still be the need to have several standard Pl-types by class for use when moving Pl's into the system. There is no reason why all in-moving Pl's within a class should be identical.

The standard Pl types will be at least as numerous as the following four: population units with children, with old persons, with neither, and with both). They will also differ in racial mix and productivity index.

The new concept of a Pl will allow for more refinement and less lumpiness in two of the most important operating programs -- employment and transportation. Since employment groups and peak hour transportation users will be kept track of in actual number of workers and travelers, the model will now be sensitive to very small changes in employment and transportation inputs. The lumpiness of the CITY MODEL, wherein full population units (of 120, 160 or 200 workers) had to be hired and transported to work, will be avoided.

Previous model design improvements had been made with regard to the commercial process to avoid lumpiness. The new formulation of the Pl, however, will make off-peak transportation use, school use, and changes in the demographic characteristics of the local population less lumpy than in the previous models.

Business Activity

The Urban Systems Model contains business activity within four categories: manufacturing, commercial, residential, and automatic computer-controlled businesses. Within each of these categories there may be many specific business types. For example, eleven types of manufacturing have been designed, but the specific model user may create new manufacturing types, when he loads the model, that reflect certain special industries in a given metropolitan area.

Table 11 shows the types of activities within each of the four categories. The commercial category contains three sub-categories: Business Services, Transportation Construction Firms, and Personal Consumption business (retail food, durables, nondurables, and personal services). Note that the business types under the Automatic Businesses are quite diverse. The amount of employment and office space consumption of these activities is a function of city size and other local system conditions.

Business activities must be located in physical structures (i.e., buildings). Each building type may be able to house one or more types of businesses. By separating the business activity from the physical structure, the model is able to represent the vacating and underutilization of buildings in various areas of the local system. A building will be of a particular type, density (square feet of floor space per acre), and level (amount of floor space).

The production function for each manufacturing and commercial business is dependent upon the quantity and quality of building space, equipment, and labor hired. Tradeoffs will be possible among these factors of production as their relative prices change.

TABLE 11

Business Activities: Categories and Types

Manufacturing

- Furniture and Lumber
- Stone, Clay and Glass
- Primary Metals
- Fabricated Metals
- Non-electrical Machinery
- Electrical Machinery
- Transportation Equipment
- Food
- Textiles and Leather
- Paper
- Chemicals and Rubber

Commercial

- Business Services
- Transportation Construction Firm
- Personal Services
- Food
- Non-durable
- Durable

Residential

- Single Family Housing
- Garden Apartments
- High Density Housing

Automatic Computer-Controlled

- Non-transportation Construction Firms
- Transportation (other than public transit)
- Communication
- Wholesale
- Banking, Insurance, and Real Estate
- Amusement and Recreation

Evolution from CITY MODEL

CITY MODEL is an operating model that deals with and integrates more subsystems of the urban system than have been tied together before by any other model. The USM design expands upon these subsystems both quantitatively and in terms of sophistication.

For example, the CITY MODEL contains interdependent sub-models that:

- Calculate market values of land.
- Calculate neighborhood and personal indexes for the local population.
- Move populations into, around, and out of the local area being simulated.
- Match workers to jobs on the basis of skill class, salary offered, accessibility, and educational levels.
- Route peak hour workers to jobs by mode and route based upon dollar and time costs.
- Assign customers to stores.
- Allocate time budgets for the local population by class and location.
- Assign students to public and private schools.

No other previous model dealt with the above range of subsystems.

USM adds sophistication in the following ways:

- Neighborhood and personal indices have a larger number of components.
- The population units are expanded to five classes and four categories and they move for a larger variety of reasons.
- Worker productivity affects the output produced by employers and more factors are used to match workers to jobs.
- More flexible modes and routes are allowed in the transportation sector.
- Customers are assigned to several different stores in each of the five categories as a function of more factors than price and accessibility.

USM also deals with the following phenomena in a more sophisticated way: depreciation, recreation services, industrial purchases, terminal usage, business interaction with national markets, taxation, federal and state relations, and national indicators.

Another set of phenomena are interrelated in a comprehensive way for the first time in USM. These include: obsolescence of plant and equipment, separation of equipment from plant in the production process, computer operated local businesses, office rental space, flexible characteristics attached to in-migrating population units, employment and transportation assignment for workers who do not own cars, distribution of health care, consumption by population groups as a function of their actual annual income, business purchases of specific intermediate products, and representation of outside industry migration to a local area.

Modules as They Relate to the Building Blocks

Modules are directly related functionally to one or more of the system building blocks (Land, Population, Housing, and Business Activities). Because of the complexity of direct and indirect interrelationships among modules, it is impossible to effectively show all connections by the use of simple diagrams. As an alternative to this, the building blocks serve as focal points for organizing and clarifying the role of individual modules within the system as a whole.

These relationships are shown in the following four figures.

LAND

Jurisdiction Modification (9)

Land Purchase (10)

Transportation Accessibility Basic Function (33)

Assessment Taxation (58)

Building Construction (64)

Transportation Construction (30)

Terminal Consumption (56)

Statistical Accounts (73)

Figure 9 - Modules Related to Land

POPULATION

Out-Migration (18)

P1 Taxes (57,59)

In-Migration (17)

P1 Generator (19)

Housing Processes (20,21,22,23)

Statistical Accounts (73)

Employment Processes (24,25, 26,27)

Production Function (28)

Transportation for Employment and Other Reasons (32,33,34,35,36,37)

All Government Services Allocation Processes (39,40,41,42)

All P1 Consumption Processes (43,45,46,47,48,65)

P1 Income (60)

Figure 10 - Modules Related to Population

HOUSING

Land Purchase Service (10)

Building Construction (64)

Interest Rates (71)

Utility Service (39)

Migration Modules (17,18)

Housing Modules (20,21,22,23)

Employment Accumulator (24)

Transportation for Employment and Commercial (33,34,35,36,37)

Assessment Taxation (58)

Indicators (72,73)

Depreciation-Obsolescence (13)

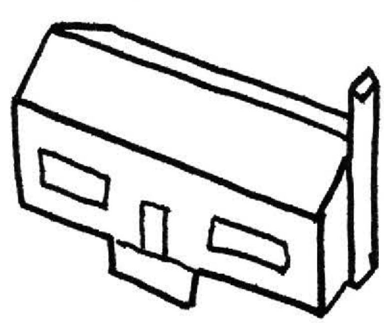

Figure 11 - Modules Related to Housing

BUSINESS ACTIVITIES

Depreciation Obsolescence Process (13)

Employment Requirements (15)

Building Rental (16)

Production Function (28)

Business Consumption (53)

Maintenance (12)

Employment Process (24,25,26,27)

Land, Building, Corporation Purchase (10)

Government Services (41,42)

Consumption Process (51,52,54,55,56)

Statistical Accounts (73)

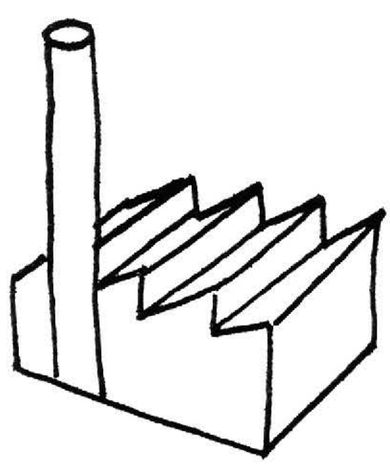

Figure 12 - Modules Related to Business Activities

CONCLUSION

Using the Model

The completed Urban Systems Model will be a tool that has utility that is dependent upon the quantity and quality of data loaded into its files, the executive options employed by the user, and the technique used to evaluate the city status and generate inputs to the model. These three types of inputs to the model are illustrated in Figure X.

The urban transportation planner would be interested in using real city data for his local area. The better his urban data bank, the easier this part of the input process would be. Analysis of this data base over time and using cross section techniques would allow the planner to develop parameter values that suit the modules he has selected to employ under his options as the executive of the model.

The planner is not constrained by "either-or" choices when it comes to the technique used to evaluate the local system and generate policy decisions. He may use a combination of all three methods: simulation, man-machine interaction, and a gaming format. He may run the model for the desired time period using alternatives of each of these options by themselves and using them in combination.

In short,.he will use the tool in a way that he finds best suits his purposes. It is a flexible model that will take on different forms in the hands of different users. USM provides a framework that is common for all urban transportation planners (much as a chemistry lab and the associated chemistry theory provide users of the lab with equal access to the facilities and accumulated knowledge). It allows the planner to use this framework and the computer programs associated with it to achieve a wide range of objectives (much as the chemist may use the lab for instructional, research or production purposes).

Although the Urban Systems Model as presently conceived in this report will not satisfy every need of the urban transportation planner, it does allow him the opportunity to deal with a large number of urban phenomena which up to now he has not been able to deal with in a simulated and collapsed-time environment.

Users of the Urban Systems Model are given control over all the resources of the local area being represented. Some of the local activities use the transportation subsystem while others do not. As a result of this, the transportation subsystem is of varying importance to the various activities represented by the model.

The Urban Systems Model is oriented toward user requirements such as generality of representation, flexibility of change, ease of inputs, and readability of output. The model provides, among other things, great detail on the use of the local transportation subsystem and the effects of transportation decisions on people and business activities. It also illustrates the impact of other decisions on the transportation networks, trips generated, modal choice, and route selection.

A single user or panel of experts could be used to generate inputs to the model when it is employed as a simulation model for research or indicative planning purposes. Users of the model may employ a multiple decision-maker format to generate goals for the represented area and decisions concerning the way economic, social, and government resources will be allocated on a year to year basis. Such a format may be used when the purpose of running the model is either to examine transportation issues within a realistic and comprehensive human decision-making environment or to achieve an educational or training objective.

A wide range of decisions and their consequences may be illustrated by the model. For example, in the economic sector the impacts of response to transportation decisions may be shown. In the social sector, the effect on housing selection, employment, shopping, and leisure activities are influenced by transportation accessibility and costs. The impacts of many government decisions may be shown: comprehensive transportation programs, subsidization of mass transit, implementing new modes of transportation and many more.

The users of the model may make a wide range of private and public policy decisions which affect transportation phenomena and others. The detailed and summary computer output reveals the interactions of these decisions and the collective impact they have on the environmental quality of the represented area. Since each cycle of the model represents the passage of a year of time in the area being represented, the model may be run for as many cycles as the users find desirable.

The model describes and interrelates many of the actual economic, social, and governmental activities that comprise metropolitan areas. The metropolitan area represented by the model is described by three types of computer output: maps, tabular statistics, and indicators.

The maps show the spatial characteristics of the represented area. The tabular output shows general information of interest to the users of the model as well as specific data concerning businesses in the economic sector, groups of people in the social sector, and government departments in the government sector. The economic, social, and governmental indicators are quality measures such as the economic rate of return, the social dissatisfaction level, the quality of local government services, and transportation indicators.

Of the dozens of maps, the Land Use Map stands out as the one of single most importance. Any represented area may be defined by spatially locating land use activity and the highway network within any desired parcel and tract configuration.

The initial starting position of the model is very flexible in several ways. First, any desired initial land use pattern may be represented. Thus, a model run could begin with development ranging from a blank board to a fully occupied land area. Also, from one to fifteen separate local governments can be represented.

Second, the population classes placed into housing, rents charged at housing, prices charged at stores, salaries offered by employers, taxes charged by local governments, etc. can be set in an infinite number of patterns. For example, the five population classes could be distributed among the housing stock in such a way that there was much or little income segregation, overcrowding or underoccupancy, etc. Or any transportation subsystem configuration could be represented.

Third, the control over the economic, social, and governmental resources of the represented area can be allocated among users of the model in any way desired. For example, if a single person were using the model for research or simulation purposes, all of the economic assets could be placed under the control of a single corporation. If the model is being used for citizen participation or educational purposes, the director of the model might choose to have the resources of the community allocated in such a way that some corporations own only one type of economic activity (industry, commercial establishments, residences, or land) or several types of activities (a mix of industrial, commercial, residential, and vacant land).

The economic, social, and government sector computer output describes the details of the resources in these sectors. In addition to this specific information, general and summary statistics describing the represented area are available as general information.

Model users provide the evaluation of the status of the area as a whole and of the individual sector resources in particular, develop goals and objectives, formulate strategies, and make decisions for the coming calendar year. All the information on the computer print-outs describes the represented area at one point in the year. All decisions that are made take affect at that time and their impact is not seen until the decisions are processed through the computer and a new status is generated for the next year.

The Evolutionary Nature of USM

Comprehensive urban modeling is still in its infancy. The USM design represents an early point along what will probably be a continuum of evolutionary comprehensive urban models that deal with the urban environment (in the broad sense of the term) and with transportation as a subsystem within this larger system.

Two forms of evolution can be made in the basic USM design described in this report. The first is evolving good model accounts, parameters and coefficients. This will involve empirical research. Unlike most modeling efforts, USM is a model design that has been completed without any original data collection and equation fitting. With a comprehensive and holistic model it is preferable to have a complete and operable theoretical design before the first real data is collected. This does not mean that the USM design was completed without much reference to the past empirical research performed by others. Quite to the contrary, the USM design incorporates the findings of others in many parts of the model. However, it must be realized that USM deals with many relationships that have not yet been researched at all. For instance, studies do not exist that deal with employment selection on a micro level. On the other hand, some previous work has been done on such things as industrial land consumption by industry type and employment needs by business type. The results from these studies have been incorporated into the basic USM design.

A second type of evolution is to modify and add to the basic relationships represented in USM. It is not claimed that USM contains every factor that an urban decision-maker or an urban transportation planner wants to consider when making a decision. It does, however, contain many factors - more than any previous urban model. Because of the modular design of USM it may be modified and additions to it may be made with a minimum of difficulty. An advantage of USM is that new modules are made a part of an operable holistic model and the phenomena represented are not treated in an isolated fashion.

The evolutionary model building experience indicates that benchmark models must be programmed, operated, and tested to further the evolutionary process. Thus, more model building advancement above and beyond the USM design will be aided as a result of the testing of the implemented Urban Systems Model.

USM As A Set of Urban Accounts

Since USM is a model of an entire urban system, there is the requirement that accounts balance within the local system. For example, every expenditure for one activity is an income for another activity. Similarly, local sales and income from services rendered are actually derived by totaling the expenditures made by the Pl's or business activities for these goods and/or services. Therefore, the impact of transportation decisions on the financial accounts for various population groups and by location can be followed over time. Not only are ridership figures calculated, but also expenditures for transportation. Furthermore, since Pl expenditures are separated into four categories (primary, secondary, tertiary, and other) the impact that various transportation expenditure levels have on the standard of living (as measured by secondary and tertiary expenditures) may be calculated. In short, USM is a systems accounting framework as well as an integration of many market models within a spatial context.

The File Handling System

Operational benefits have already resulted from the Urban Systems Model design project. The file handling routines (developed in the early part of 1971) to be used in the Urban Systems Model were utilized in the development of the CITY IV and RIVER BASIN models. Both of these latter models which are operational on the IBM 360 system evolved from the earlier CITY MODEL which was operational on the UNIVAC 1108 system. In the conversion and modification process to arrive at CITY IV, many programs and routines were re-written. The file handling routine used in CITY MODEL was not as flexible or as adaptable for use on various machines as was desired. The USM file handling routine suited the needs of the revised model, so it was employed. This allows the CITY IV model to be more flexible for modification purposes and easier to be made operational on various computer systems. Furthermore, the USM file handling routine facilitated programming of CITY IV. This use of the USM file handling routine confirms that it is a highly useful file structure that assures flexibility, adaptability to various computer systems, and ease of programming.

All three of these system characteristics (flexibility, adaptability to various computer systems, and programming facility) are highly desirable in a model such as USM. The flexibility assures that USM will be modular and therefore. easy to modify and add to. The adaptability assures that the model will be operational on any computer with adequate capacity. This is a characteristic that most urban program packages do not have. For example, the BPR battery was programmed for the IBM 360 system. The programming facility is helpful because it reduces costs on the programming and debugging of the model when it is first implemented and it reduces the need for using the original programmers when future modification and changes are made in the model.

USM as a Systemic Model

The Urban Systems Model may be characterized as a systemic model. That is, it is a model of the interactive workings of the system it represents. USM is not a predictive, projective or normative model. It does not predict a future state of the urban area represented, although it does predict the immediate status of the urban area given all the resources of the system and the policies attached to the use of those resources. Therefore, it is more of an impact model (one year at a time) than any kind of predictive model.

USM is not a projection model because it does not extrapolate present circumstances and relationships into the future. In other words, the user of USM does not "turn it on" and generate a set future status states for the urban area represented. USM cycles in one year increments, and in a sense, it could be used for projection if the user made the year to year decisions for the urban area for a twenty or thirty year time period. But because of the broad scope of the model and the wide range of decisions that can be made in the economic, social, and government sectors, this particular use of the model should not be looked on as a simple task.

Furthermore, USM is not a normative or optimizing model. It will not itself generate optimal policy decisions. USM produces a thorough set of indicators and measures of the urban status at discrete points in time (the end of each year) and it is up to the user of the model to apply his own set of objective and subjective criteria to evaluate the absolute or relative quality of the urban environment. For example, the model will contain measures of travel times for commuters by income class and location, of highway congestion, of public transit crowding, of poor schools, of economic rates of return, of housing quality, of municipal services quality, of social dissatisfaction, etc. and the user of the model must determine the values to be placed on these measures as the urban area makes policy decisions for future years.

A systemic urban model such as USM endeavors to represent the workings of the urban system and its major subsystems. This is done by selecting the major activities that comprise the urban system (people in households, businesses, and government agencies) and representing the actions that they pursue on a year to year basis. Population groups reside in housing, earn incomes, purchase goods and services, take part in leisure activities, utilize government and institutional services, and transport themselves as they interact with activities that are spatially separated from their places of residence. Businesses purchase goods and services, hire labor, require utilities, produce output, sell output, pay taxes, and invest earnings and also have a need for transportation service for some of these interactions. Government agencies receive funds, purchase necessary goods, services, and labor, provide service, and set policy. They may or may not have strong transportation requirements depending upon their service characteristics.

As a systemic model, USM deals with transportation as a subsystem that naturally gains in importance as the number and types of activities increase and as they are distributed in a spatial plane. Transportation is also important in relationship to how the represented area is situated with regard to the regional and national distribution of activities. In this way, transportation becomes a good that can be traded off with other goods such as leisure time, spatial arrangement of activities, residential density, environmental considerations, and cost factors. Within a systemic model which represents the whole urban system, transportation planning takes on a perspective that allows transportation to be treated as a means to man rather than as an end in itself.

FIGURE X

URBAN SYSTEMS MODEL