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A HEURISTIC SCHEME FOR URBAN PLANNING

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TABLE OF CONTENTS

Page

LIST OF TABLES

LIST OF FIGURES

Figure		Page

ABSTRACT

This dissertation project was part of a larger research program concerned with investigating ways for solving urban problems. The work comprising the dissertation project consisted of developing a scheme (framework) for solving these problems and one of the models used in the scheme. This model (a spatial model) was the key which allowed the scheme to function as a planning tool.

The purpose for developing the scheme was to allow planners to take all the most significant parts of the urban system into account when trying to solve urban problems. During this development phase of the scheme, the emphasis was on engineering aspects, but included social, economic and ecological elements as well. The scheme as used in this study consisted of a system of models usable by most urban planning agencies. Included in the system were a set of mathematical models (population, housing, transportation, water supply, sewage, solid waste, drainage and air pollution) developed by others involved in the larger research program. The "key" model in the system was the spatial model which allowed for the economic, social and ecological inputs.

The spatial model is a heuristic model used for predicting land use and gathering information of spatial character in general which would have a significant impact on the solution of urban problems. The model has two sequential components: a modified Delphi and gaming. An embedded iterative process is used to obtain answers to the questions under consideration. The output from this spatial model consists of projected land use and recommendations for alleviating problems in the study area. Though heuristic this model makes the scheme a useful planning tool.

CHAPTER 1

INTRODUCTION

1.1 PROBLEM AND PURPOSE

Starting in the 1950's, the scope of city planning was expanded to include not just the city but the entire metropolitan region. At approximately the same time, the concept of city planning began to change to include broadened views of economics, social well-being, and the environment (26). As a consequence, planners soon discovered that their planning methods were grossly inadequate in this new planning ethic. Lowdon Wingo gives one example of the situation:

> "In the good old days we tackled the slum in a straighforward way by tearing it down. Now we know the slum to be a complex social mechanism of supportive institutions, of housing sub-markets, of human resources intertwined with the processes of the metropolitan community as a whole...To distinguish favorable policy outcomes from unfavorable ones is no longer a simple matter. Decisions by governments, firms, and individuals in metropolitan areas turn on the state of such interdependent spatial systems as use of recreation facilities, transportation and communication nets and the markets for land, housing, and even labor, rather than on the highly localized consequences directly elicited by policy actions (28)."

In essence, planners found themselves prisoners of the discovery that "Everything seemed to be an urban problem, and everything seemed interrelated: the whole world was a jumble of secondary and iterative side effects" (19).

Two schools of thought on how to deal with this situation soon developed. One group believed that what was needed was a scientific method of problem solving that would give the planner the ability to deal conceptually with large-scale systems (4). This would enable him to make better plans. The other group held that administrators could not make decisions according to goals or plans but only in response to incremental problems within one's sphere of influence, and a method taking this into account was needed (15).

The purpose of the study reported here was to develop a scheme (framework) that would allow one to take the most significant parts of the urban system into account when trying to solve urban problems. The study was based on the supposition that it is not only possible but essential to make some sense out of this jumble of secondary and iterative side effects and to consider these when seeking the solutions to urban problems. Though trying to deal conceptually or numerically with such a complex, large-scale system as the urban system might stretch the limits of the current state of the art in some cases, it was considered better to include all the highly significant effects in an analysis than to assume that they were nil.

The scheme was developed around a system of models usable by most of those in the planning profession. It is flexible enough to be used in many planning situations and to address many types of questions. Of great importance, the scheme is designed to answer questions planners encounter in "day-to-day" operations. Some of the models incorporated into the scheme were already in use. Additional forecasting and optimizing models, both mathematical and scenario, were developed by interdisciplinary teams. The development of the scheme and these additional models comprised the bulk of the study. The scheme and the model (land use model) allowing the models to function as a system are the subject of this dissertation.

1.2 OBJECTIVES

The primary objective of this research was to demonstrate the feasibility of modeling an urban system using an interdisciplinary group. The study employed university faculty and students, city officials, and industry personnel working on urban problems in a planning environment. An interdisciplinary team was formed to develop each of the models used in the system so that many professional viewpoints would be incorporated. By incorporating varied professional viewpoints, it would be possible to develop a useful tool acceptable to all those in the decision making process. If this were achieved, then the scheme would be deemed a valid tool for planning purposes.

The key to achieving the primary objective of developing the scheme and demonstrating its validity was the land use model. This model was considerably different from the other models in the system or from any other done previously in this type of work. Before checking this specific model's validity, it was necessary to demonstrate the validity of the basic method (the Delphi and heuristic gaming) in producing useful results in this application. Following this, it was then necessary to demonstrate the model's and the scheme's validity in a planning environment.

1.3 DEFINITIONS

To eliminate possible misinterpretations of the discussions that follow, working definitions have been established for four common terms: systems analysis, operations research, model, and validation.

Systems Analysis is defined as, "an inquiry, from the view point that that which is under investigation is part of larger system, to aid in the choice of a course of action by systematically investigating objectives, and comparing the cost, effectiveness, and risks associated with the alternative policies or strategies for achieving them"(23). A "system", as used here, is a set of interrelated elements having the following properties (1):

1. The properties or behavior of each element has an effect on the properties or behavior of the whole.

2. The properties and behavior of each element and the way they affect the whole depend on the properties and behavior of at least one other element of the set.

3. Each subgroup of elements in the set has an effect, but not an independent effect, on the whole.

The analysis of a system has five basic elements (21):

1. Definition of objectives.

2. Formulation of measures of effectiveness.

3. Generation of alternatives.

4. Evaluation of the alternatives

5. Selection of one or more alternatives.

Although the above definition assumes the use of mathematical models are almost always used, the emphasis in this type of analysis is not on mathematical models.

Operations research (OR) is defined as "a scientific method of decision-making based on the mathematical techniques of optimization, the objective being to determine the most effective utilization of limited resources"(3). The procedures used for an operations research study generally involve (27):

1. Definition of the problem.

2. Construction of a model.

3. Solution of the model.

4. Validation of the model.

5. Implementation of the final results.

The term "model", as used in steps 2, 3 and 4, is usually a mathematical model such as linear programming, some variation of linear programming, or a stochastic mathematical simulation. As indicated, the primary emphasis is on a restricted type of model. Thus, the above techniques are only useful when applied to certain well-defined, highly structured problems with simple goals (12).

A model is defined as "any device that provides a logical means to predict and compare the outcome of alternative actions" (24). This definition is an extension of the usual concept of a model which is restricted to iconic, analog, or mathematical models. In the restricted sense, the model is either a physical or mathematical representation of the modeled object. Unfortunately, these types of models are particularly difficult to create when political and social factors predominate. If the term "symbolic" is substituted for "mathematical", then operation gaming can be catagorized as a model under the restricted definition. This is one way to include political and social factors through models, but the concept should be extended further. Removing the restrictive representational features of the traditional model gives modelers a great deal of freedom in the choice of available methods (25). By doing so in this study, the Delphi method (which is explained later) was available for use in the model system.

Validation A model of the growth of a bacteria culture in a closed system is an example of a model which could easily be validated or rejected. All one would have to do would be to perform an appropriate number of controlled laboratory experiments and compare the results with the model. Furthermore the results are unambiguous - if the model accurately represented bacterial growth in the experiments, one could expect the model to accurately predict bacterial growth in similar situations, at least over a range of conditions not much beyond those used in the experiments.

Finding a method for validationg this scheme of models was as much of a problem as was the conception and formulation of the models. The general procedure followed by many researchers is basically as follows. First the framework of the model is created. This framework is then "calibrated", meaning that the framework is made to replicate recent history. The model is then validated by testing it to see if it can produce the present situation from a point in recent history. In this (an admitted over-simplification) circular approach, the "calibration" phase of model development overlaps the validation phase. The model is generally made to fit by the addition of numerous "factors" or adjustments to internal parameters until it is deemed valid. It would be surprising if any model couldn't be made to produce reasonable results by such a method.

The question arises, "Is there really a measure of validity?" In some cases, this type of validity may even be considered to be a mute question. Is anything really gained by altering a model to make it fit a special case (recent history)? It could well be argued that perhaps the original model, though not replicating recent history, might be a more valid model than the one which was made to fit. In fact, many decision-makers in the field of urban planning argue that this is only a minor importance to them (14), (15). What is important is whether the model produces "convincing" results, i.e. everybody concerned can agree that they are what should be planned for.

Still the idea of producing reasonable results is basic to model validation. Yet, this one criteria indicates nothing about the usefulness of the model in question and usefulness should also be a necessary criteria for validity. In this study, in addition to the requirement of producing reasonable results, a valid model is one judged useful to those for whom the model was intended. Though this requirement is "above and beyond" that normally required for a model to be deemed valid, what is to be gained if one produces a most reasonable predictor if it can not be used in a day to day planning situation? Therefore, we shall extend the definition of validity to that of a declaration of usefulness.

An operational game is not a game at all - in the sense of "fun and games" - but an important laboratory for modelling reality. It is a simulation that allows a decision maker to perceive many aspects of urban phenomena at once so that he may grasp the system, at least in an intuitive fashion. It can be used as on information gathering device, as a means of learning through experimentation, or for prediction. It should be emphasized, however, that gaming does not produce an optimal solution.

The use of the game will determine it's form, but it will always have the representative features of the original system. Generally the game will have:

1. A game board (usually a map of the area).
2. Role playing - where the players act as they think factions of the urban system would act.
3. Ruler - either formally stated or implicit from the system.

A Delphi is a method of soliciting and pooling individual opinion without face-to-face discussion (24). In this case, the opinion is a forecast. A Delphi is an alternative to more rigorous methods of forecasting, such as OR techniques, when the capacities of those method are exceeded. In general, a Delphi has three features:

1. Anonymity - to reduce the effect of dominant individuals.
2. Controlled feedback between iterations to reduce the noise of unimportant information.
3. Statistical group response to reduce group pressure for conformity.

The procedure followed in a Delphi is to:

1. Query the group by means of questionnaire.
2. Summarize the response statistically.
3. Provide the group with the summarized information.
4. Repeat steps one through four until a sufficient closure is reached.

1.4 THE SYSTEMS APPROACH

The urban system is perhaps the most complex system on which a sustained effort has been made to use the systems approach to problem solving. The original systems studies using the approach were logistical systems related to military efforts during World War II. After World War II, industrial, commercial, transportation, and other systems were also successfully analyzed and improved by using the OR models developed during the 1940's. These systems, though often large, were relatively simple. The urban system is highly complex. It has a great number of physical, economic, and social elements, and a still greater number of interactions among these elements. In addition, there are several measures of the states of being associated with each element.

Although many simpler systems have been successfully analyzed and manipulated using the systems approach, until now the effort spent on urban systems has produced minimal practical results. Perhaps the most successful attempt was an early example, the Chicago Area Transportation Study, CATS (9). This study used a land use model which was rare in that it was seriously used in conjunction with a planning effort (18). More typical was the San Francisco Housing Market Study for the San Francisco Community Renewal Program. William B. Ross, then a Deputy Undersecretary at HUD, had this to say about the study:

> "We are quite proud to have funded the San Francisco Housing Market Study, but it is still a disappointment to find that it had no relation either to the community renewal program or to the process of renewal in the City of San Francisco (11)."

Plagued by the inability to truly cognize the system, yet having the conviction that the total system must be taken into account, the planner built larger and larger models hoping to eventually cover all points of the system. Few planners appreciated the fact that largeness and comprehensiveness are not necessarily synonymous in computer modelling. The early success of the CATS models was not due to the size of its computer program. It had a much less formal structure than the later models (18). At the same time it was perhaps the most comprehensive. This was due to the nature of the ad hoc judgments that could be introduced at many points in the forecasting process (18).

As the efforts in modelling increased, a corruption of the systems approach developed. Since the most attractive element of the approach was the construction of computer models, this is where the major effort was spent. This effort was so intense that model builders attained a degree of detachment from the everyday problems of planning. The result was that models became the "ends" rather than the "means" and the few models that were developed which had some degree of relationship with the system being simulated were not useful within the context of systems analysis.

Because of the difficulties encountered and the many ill conceived models produced, many planners became highly skeptical that the sytems approach would be fruitful in this application (14). The failures, though, were not that of the approach. At the root of the apparent failures in implementing the systems approach was first, a naiveté about what the systems approach involved. There was a misconception that the main element of the approach involved writing a computer program to obtain solutions to problems. Second, there seems to have been an over-optimism about the capabilities of OR models. Developed for simple systems, OR techniques could not handle systems as large and complex as the urban type.

1.5 RECENT MODELLING EFFORTS

As the first generation of model builders became frustrated and abandoned large-scale urban models, a resurgence of interest in these models developed among others. Typical of this second generation of modelling activity are the Forrester Model (7), the National Bureau of Economic Research (NBER) Simulation (20), and the Projective Land Use Model (PLUM) (8).

The Forrester Model is an elaboration on the structure of a successful model, Industrial Dynamics (5), of a manufacturing company. It consists of a set of differential equations which are solved iteratively by means of a special computer language, Dynamo (22). The model starts the solution process with some initial solution estimate: the present state of the urban area. As the model seeks a solution (steady state), intermediate iterations are recorded having a locus of variable values. The dynamic behavior (variable response) of a system can thus be studied by altering the relationships between variables in the differential equation (6).

The approach has received a lot of attention and has attracted a large following (13). However, as a tool for urban planning, the model is open to serious criticism. First the model's response is built in according to predetermined concepts of what the results should be. Second it is of an abstract city and is not spatially disaggregated.

The NBER Simulation is similar to past models. The major emphasis of this simulation is on a housing model which is similar to the one developed for San Francisco (16). In this case, housing location is based on access to employment as in the Lowry model (17). It is much more ambitious in scope than earlier models and also more disaggregated. This model is still in the developmental stage.

The major drawback to this model is its size and scope. It is a larger dose of the hopelessly ponderous San Francisco simulation. Lee (14) presents an intuitive graph (Figure 1-1) which expresses the idea that, as this type of model becomes larger and larger, more is learned about large models, but they are less useful after some point.

PLUM is one of the most operational of land use models. It has been used by a number of planning agencies to forecast land use. It is based on the Lowry model (17), using slightly different relationships for household location. Household location is still based on access to employment,

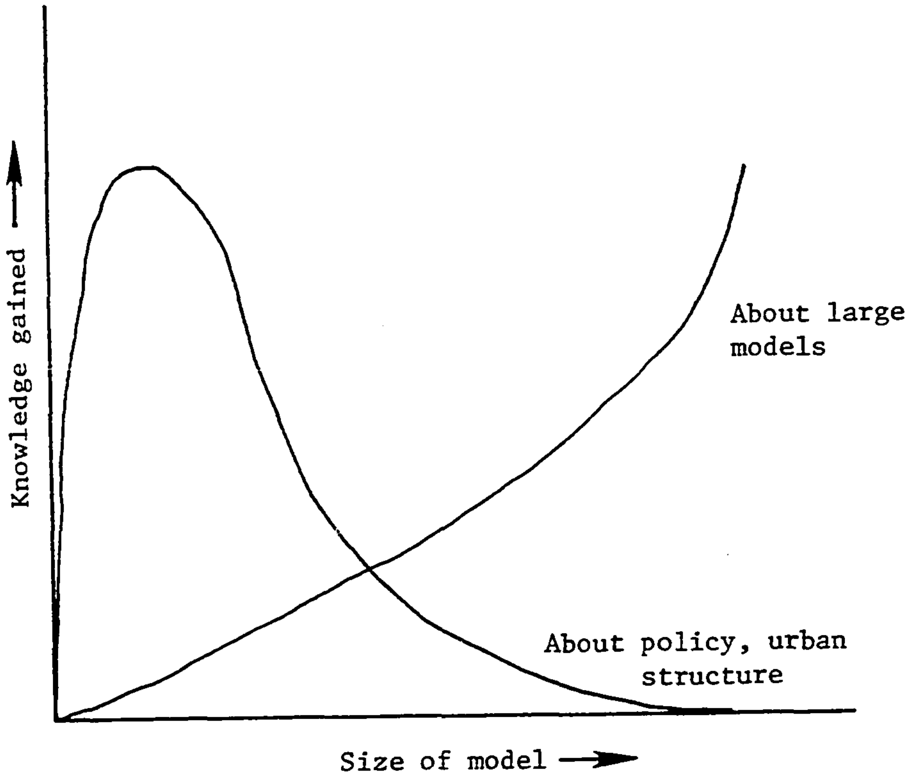


Figure 1-1. Knowledge Gained From Models (14)

yet it contains enough adjustments, and empirical discription relationships to produce reasonable results.

The problem with the PLUM is that it is almost totally opaque, a "black box". Its success stems from the fact that it comes with initial constants so that a planner can realistically hope to get a land use forecast from it.

1.6 GUIDELINES FOR USEFUL MODELS

As Lee (14) points out, the recent efforts in model building show an apparent disregard for the causes of previous failures. He lists seven characteristics of past large-scale model which contributed to their failure.

1. Hypercomprehensiveness - replication of too complex a system in a single shot and intention of serving too many purposes at the same time.
2. Grossness - insufficient detail for a less than comprehensive view.
3. Hungriness - enormous data requirements.
4. Wrongheadedness - governed by implicit relationships which are not perceived.
5. Complicatedness - too many interactions to allow for control of the model or for much learning.
6. Mechanicalness - immersion in trivial details of programming.
7. Expensiveness - too expensive to build and run.

In addition to avoiding these seven pitfalls, three principles were followed when constructing the scheme presented here. First the models were to be simple, even at the expense of some accuracy. As discussed earlier, a model's validity as a planning tool is dependent on the model being understood, trusted, and used. Second, the scheme was to rely on both theory and intuition. Lacking sufficient theory, partial reliance of intuition is not only desirable, but necessary. In this scheme, the part played by intuition was to be highly visible - not hidden in the computer program. Third, the scheme was to be flexible. High flexibility would allow for the proper sequence of problem solving, i.e. start with the problem..., without having to construct new models for each problem.

1.7 THE CONCEPTUAL SCHEME

Following the above guidelines, a conceptual scheme was developed to allow the planning profession to utilize the systems approach to solving urban problems. As shown in Figure 1-2, the total urban system started with the existing population model which projects population by cohort survival analysis and a disaggregation method. The output of the population model is then used by the housing model to project future housing needs by distributing households into housing units. A heuristic land use model, which employs Delphi and gaming techniques, is then used to project future land use.

For future implementation several information models, which are not presently developed, could be included in the total urban system model for use with the land use model. A multiplier demand model based on outputs from the population model and the housing model could be used to indicate the demands for transportation, water, utilities, revenues, employment, education, recreation, etc. These demands would be used as guidelines for the participants of the land use model. A public sector budget model, based on the multiplier demand model, might also be developed

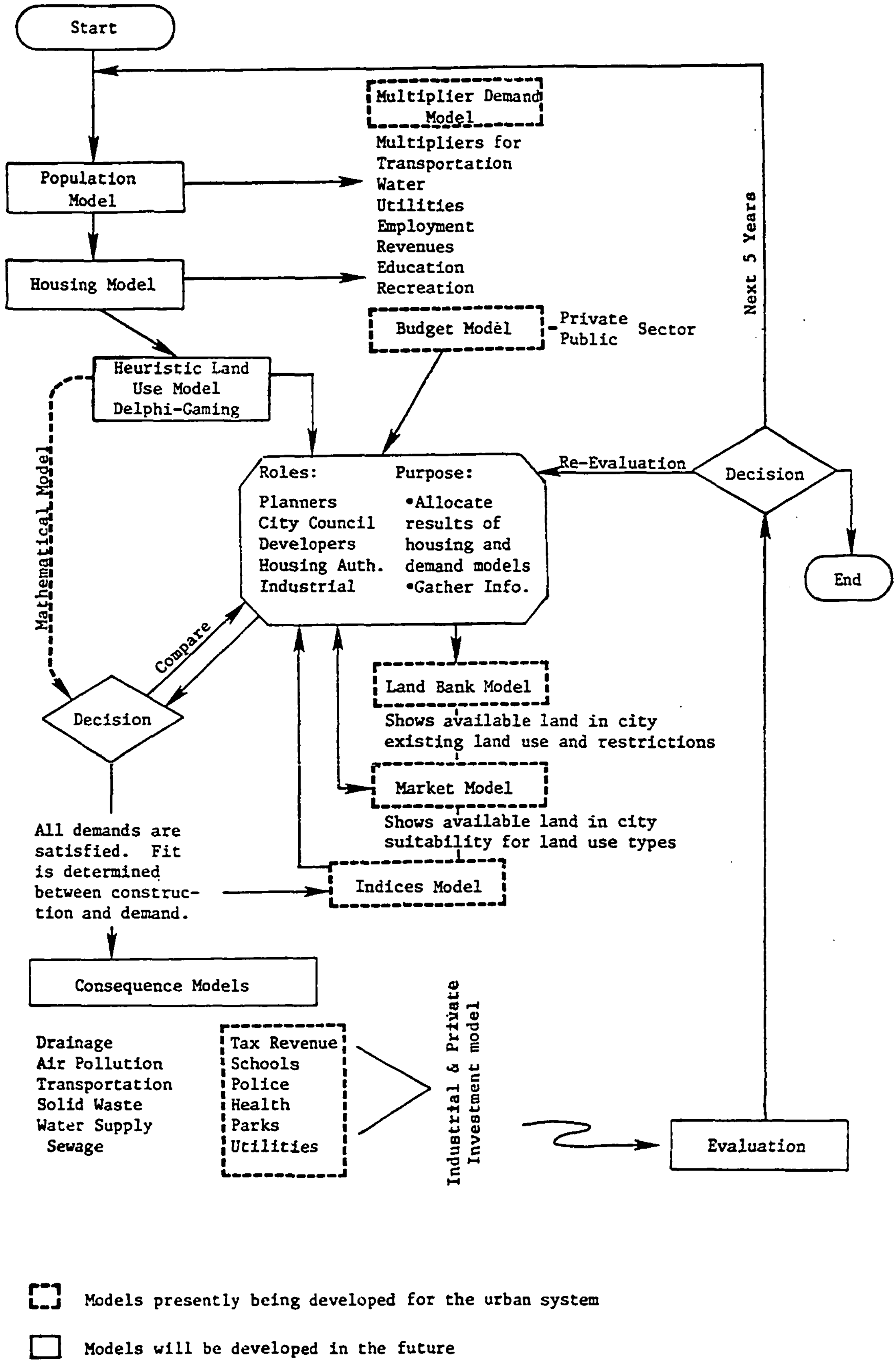


Figure 1-2. The Total Urban System

at this point to indicate the future financial prospects of the urban area under analysis.

A land bank model, another information model under consideration, would constitute an inventory of characteristics such as ecological, cost, size, zoning, and land use. This model would supply diverse classifications per grid, such as land use, transportation, land cost, surface water, effluent capacity, public services and environmental data. Automatic updating of this data base would provide the planner with a continuously current inventory of his region.

A fourth information model being proposed is the market model, which would determine the suitability of sites for industry, residences, commercial establishments, etc. The planner's expert judgement on preferences would supply part of the input for decisions on ideal location sites.

The last information model is the indices model, which alerts decision-makers to the potential decline of the areas under analysis.

To compare with the heuristic land use model, a mathematical programming model could also be part of the complete urban system scheme. This model would serve as an analytical justification for the outputs from the heuristic land use model so that recommendations presented to the decision-makers would be based not only on heuristic gaming results but on indications derived from the analytical approach. Outputs from the land use model and the mathematical programming models could then be used to determine future development, and decisions could also be evaluated to ascertain that all demands are satisfied.

The outputs of decisions regarding future development are fed into several consequence models, some of which were developed for this study (the transportation model, water supply model, sewerage model, solid waste model, air pollution model, and drainage model). Other consequence models being considered are in the areas of education, economics, security, revenue, public facilities and utilities in addition to water supply and sewerage. The objectives of the consequence models are to determine whether the decisions made to meet demands are all satisfied and/or to obtain indicators derived from the outcome of these decisions. To accomplish this, a model using expert evaluation could be used to give a more systematic evaluation, although it would not be essential. The experts would be the professionals (that is, managers, technicians, engineers, economist, etc.) who evaluate the output indicated by the developed consequence models. In other words, no formal modelling was implemented in evaluating outcomes from the consequence models.

In the conceptual system, a feedback loop would start a new set of decisions and evaluations in the land use model if demands are not being met or results from the consequence models indicate that the decisions are unrealistic or impractical. Otherwise, the procedure would continue to the next increment of the planning period where the population model will again be run to start a new loop of urban system analysis. This completes the entire cycle of the total urban system model. Because this would be a closed loop program, the entire system could be operated over time, providing multilevel, multistage construction and articulation, with feedback over time towards possible and probable goals.

1.8 SCOPE

Because of time and funding limits, the parent project concentrated on developing seven technical models which are basic to urban systems:

a housing model, heuristic land use model, transportation model, water supply model, sewerage model, solid waste model, and drainage model.

The scope of this dissertation was therefore limited to these models. The actual work done for the dissertation consisted of developing the heuristic land use model and tying the models together into a workable system. In some cases, this involved changing some of the models. In other cases, the models could be used as they were.

1.9 REFERENCES

1. Ackoff, R. L., "Science in the System Age: Beyond IE, OR, and MS". Operations Research, Vol. 24, No. 2, June, 1973, pp. 661-671.

2. Alonso, W., "Predicting Best With Imperfect Data". Journal of the American Institute of Planners, Vol. 34, No. 4, 1968, pp. 248-255.

3. Churchman, C. W., Ackoff, R. L. and Arnoff, E. L., Introduction to Operations Research, John Wiley & Sons, New York, 1957.

4. Cooper, W. W., et al, "Systems Approach to Urban Planning: Mixed, Conditioned Adaptive and Other Alternatives". Policy Sciences, Vol. 2, No. 4, December 1971, pp. 397-406.

5. Forrester, J. W., Industrial Dynamics, MIT Press, Cambridge, Massachusetts, 1961.

6. Forrester, J. W., Principles of Systems, Wright-Allen Press Inc., Cambridge, Massachusetts, 1968.

7. Forrester, J. W., Urban Dynamics, MIT Press, Cambridge, Massachusetts, 1968.

8. Goldner, W., et al, Projective Land Use Model, 3 vols., Institute of Transportation and Traffic Engineering, Berkeley, 1972.

9. Hamburg, J. R., and Sharkey, R. H., "Land Use Forecast". Document No. 32, 610, Chicago Area Transportation Study, Chicago, 1961.

10. Harris, B., ed., "Urban Development Models: New Tools for Planning". Journal of the American Institute of Planners, Vol. 31, No. 2, 1965.

11. Hemmens, G. C., ed, "Urban Development Models". SR 97, Highway Research Board, Washington, D. C., 1968.

12. Hoos, I. R., Systems Analysis in Public Policy, University of California Press, Berkeley, 1972.

13. Kadanoff, L. P. and Weinblatt, H., "Public Policy Conslusions from Growth Models". IEEE Transactions on Systems, Man, and Cybernetics, SMC-2, No. 2, April 1972, pp. 159-165.

14. Lee, D. B. Jr., "Requiem for Large-Scale Models". AIP Journal, Vol. 39, No. 3, May 1973, pp. 163-178.

15. Lindblom, C. E., "The Science of Muddling Through", Public Administration Review, Vol. 19, No. 1, Spring 1959, pp. 79-88.

16. Little, A. D., Model of the San Francisco Housing Market, Arthur D. Little, Technical Paper No. 8, San Francisco, 1966.

17. Lowry, I. S., A Model of Metropolis, RM-4035-RC, the RAND Corp., Santa Monica, 1964.

18. Lowry, I. S., "Seven Models of Urban Development: A Structural Comparison", Journal of the American Institute of Planners, Vol. 31, No. 2, 1965.

19. Lowry, I. S., "A Short Course in Model Design", AIP Journal, Vol. 31, No. 3, May 1965, pp. 158-166.

20. National Bureau of Economic Research, 51st. Annual Report, National Bureau of Economic Research, New York, 1971.

21. Neufville, R. de, and Stafford, J. H., Systems Analysis for Engineers and Managers, McGraw-Hill Book Company, New York, 1971.

22. Pugh, A. L., DYNAMO User's Manual, MIT Press, Cambridge, Massachusette, 1963.

23. Quade, E. E., "Introduction", Analysis for Military Decision, E. S. Quade, ed., Rand McNally, Chicago, 1967.

24. Quade, E. S., "An Extended Concept of 'Model'", P-4427, The Rand Corp., Santa Monica, 1970.

25. Quade, E. S., "On the Limitations of Quantitative Analysis", P-4530 The Rand Corp., Santa Monica, 1970.

26. Scott, M., American City Planning Since 1890, University of California Press, Berkeley, 1969.

27. Taha, H. A., Operations Research, MacMillian Publishing Co., New York, 1971.

28. Wingo, L., Elements of Regional Accounts, W. F. Hirsch, ed., Johns Hopkins Press, Baltimore, 1964.

CHAPTER 2

DESCRIPTION OF THE SYSTEM OF MODELS

2.1 INTRODUCTION

The system of models developed for this research is described in this chapter. The description is for the entire system as it would be if it were used in developing a comprehensive plan. The system parts are used in modes other than comprehensive planning, but their description is the same.

All the models and their interrelationships are shown in Figure 2-1. The driving force for the other models in the system is the population model which was developed to forecast population. Population forecasts are first used to determine housing demand via the housing model for an urban area. The heuristic land use model is then used to project urban land use by utilizing human insight in addition to outputs generated from the housing and population models. The housing and land use models can be considered allocation models which distribute households to housing units and land use to different urban locations.

The other models are consequence models. Included are those for the areas of transportation, water supply, sewerage, solid waste, air pollution, and drainage. The consequence models are generally used to evaluate the tentative land use and planning policies related to the projected urban growth. Most of the inputs for these consequence

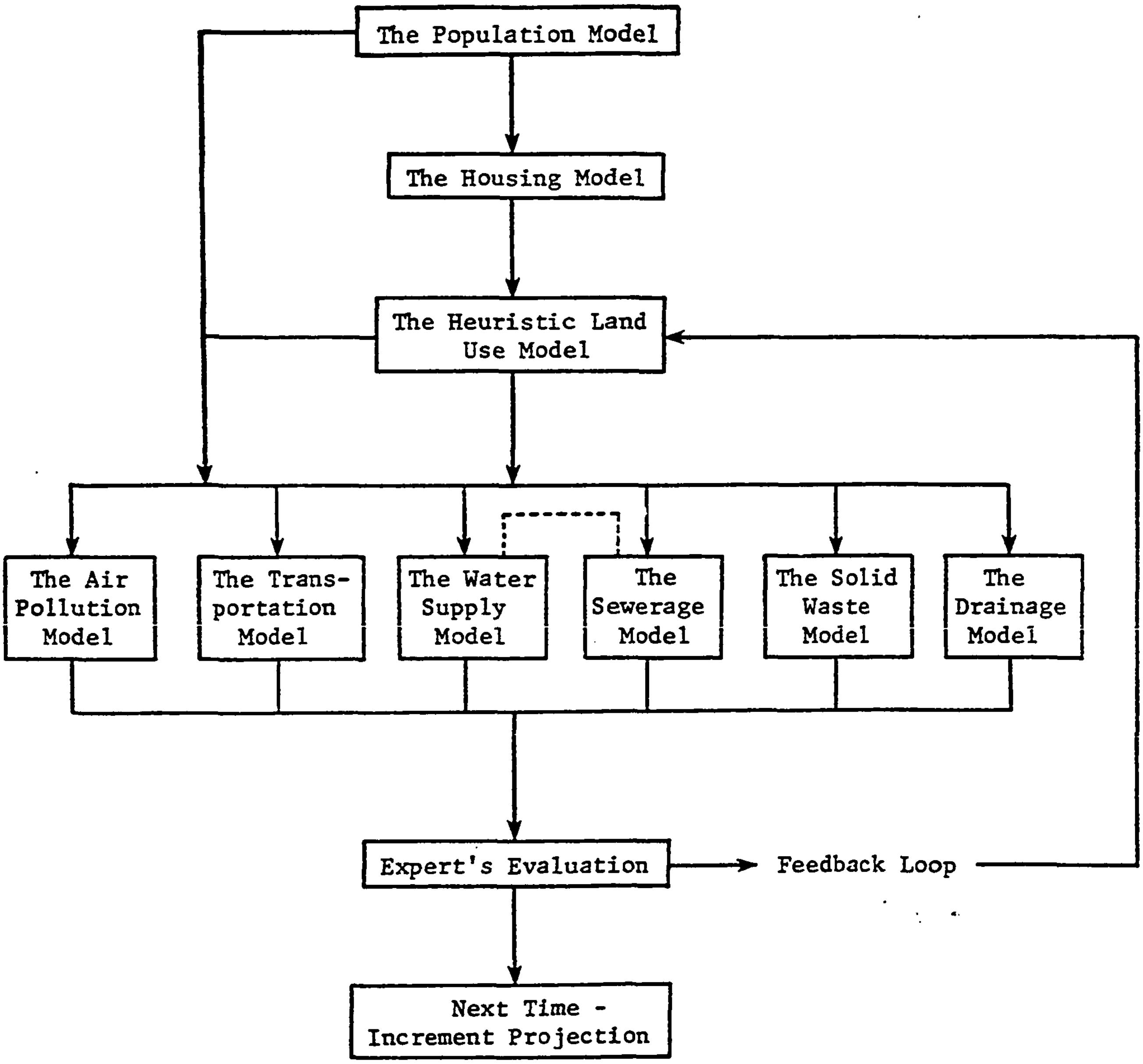


Figure 2-1. The System of Models

models are from outputs of the land use model and the population model.

Results from the consequence models are then examined by experts in their respective fields. If the results indicate favorable consequences from the projected land use, the projecting process can proceed to the next time increment. Otherwise, the tentative land use projection can be modified or re-evaluated until the consequence models indicate satisfactory results are reached.

2.2 THE POPULATION MODEL

The population model was developed for making population forecasts for urban areas. It is the driving force for the complete urban modeling system. The model uses two methods of making population forecasts, the cohort-survival method and a disaggregation technique.

The cohort-survival method (Figure 2-2) is used to analyze population by age, sex, race, occupation, employment and income, and to project the population growth through natural increase and migration. Projections are made for five-year increments by cohorts starting with the base year to any year in the future. Forecasts by the cohort-survival method can represent forecasts based entirely on past records, or can be made to reflect anticipated changes in birth and/or migration rates and economic trends. If based on past records, the forecast uses appropriate census figures for birth and death rates, the net migration for the previous five year period and past economic multipliers are used. If the forecast is to reflect anticipated changes from past conditions, the procedure is to again use appropriate census figures for birth and death rates. Migration is broken down into in and out-migration. Out-migration was found to be highly correlated with existing

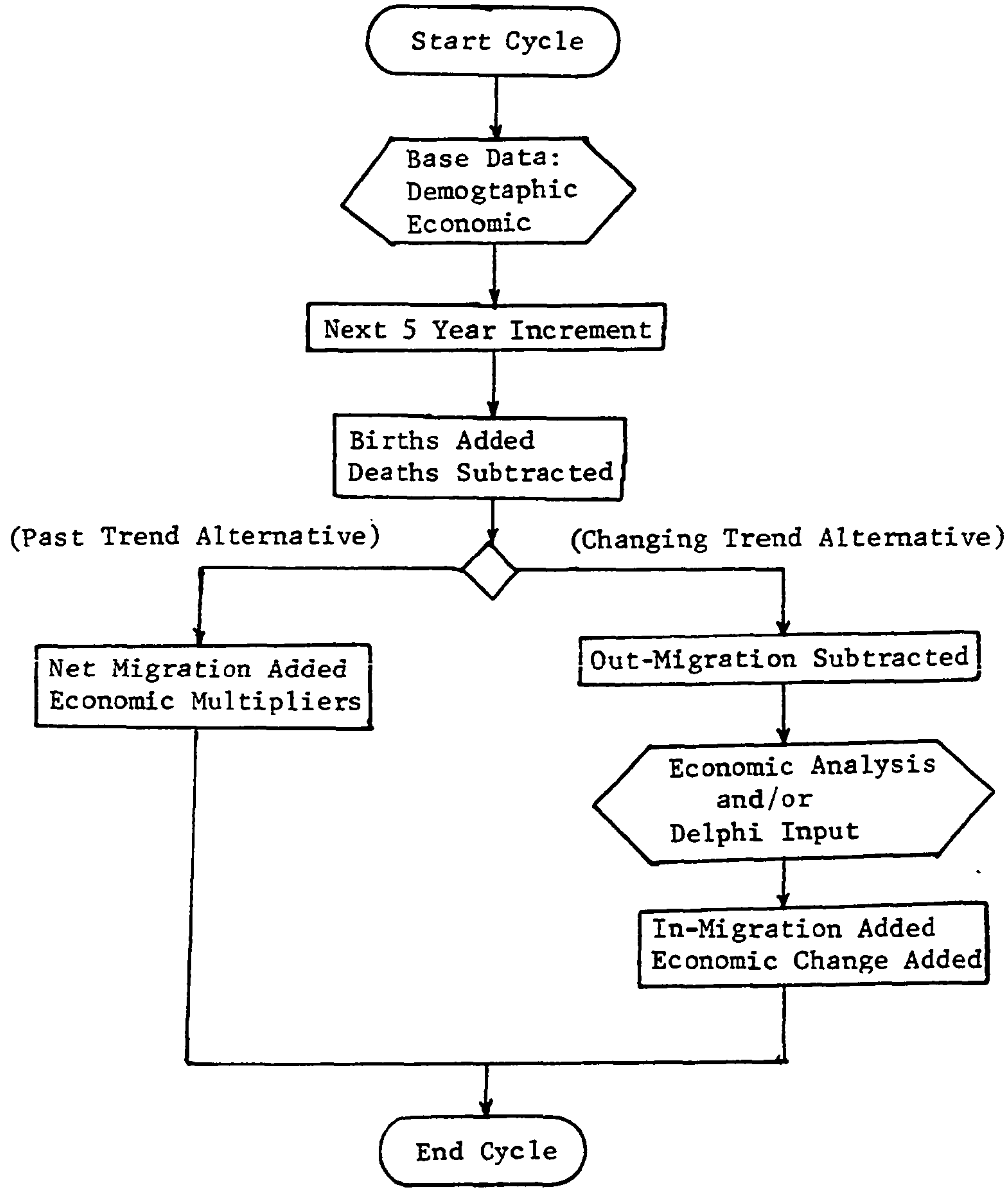


Figure 2-2. Cohort-Survival Population Sub-Model

population. Here past census figures are used. In-migration and economic trends are determined by means of a Delphi (see Chapter 3). Model in-put and example out-put are shown in Figures 2-3 and 2-4 respectively.

The disaggregation method (Figure 2-5) is used to distribute the national or a state population projection to a county or urban area. For example, if the national projection is based on projections published by the Bureau of Census, the procedure might first distribute the national projection among states, then distribute a state's share among its counties.

The disaggregation procedure can be handled through a static or a dynmaic approach. The static method is based on either the past population ratio between an area and its sub-area, or prorating according to cohort-survival projections. In the dynamic procedure, if population is disaggregated from an area to a sub-area, the disproportionate sub-area change, either relative growth or recession, is determined by using weighting factors that are based on policy decisions. The weighting factors are determined by growth standards, indices, and the development potential of the sub-area. The technique used is based on the decomposition of the resources capability in the past, the present, and the future. The action and behavior of people constitutes the resources in this context. Example weighting factors are shown in Figure 2-6.

Comparing the cohort-survival method and the disaggregation technique, the former projects the existing population cohorts and provides a more refined projection of the age distribution of the population, whereas the disaggregation technique takes an area's population at some time and divides it geographically to each sub-area. By combining the two methods, a balanced projection and disaggregation is obtained. In

BASE POPULATION *

AGES	MALE	FEMALE
0 - 4	14 714	13 946
5 - 9	17 095	16 848
10 - 14	18 088	17 057
15 - 19	15 320	15 699
20 - 24	11 929	15 227
25 - 29	13 320	13 607
30 - 34	11 064	11 328
35 - 39	10 697	11 299
40 - 44	11 227	11 654
45 - 54	11 416	11 804
55 - 64	7 735	8 766
65 - 99	15 989	12 985

MALE 5-YEAR SURVIVAL RATES *

AGES	1960	1970	2010	2015
0 - 4	.99538	.99622	.99632	.99632
5 - 9	.99741	.99779	.99803	.99803
10 - 14	.99551	.99545	.99622	.99622
15 - 19	.99218	.99146	.99312	.99312
20 - 24	.99117	.99051	.99224	.99224
25 - 29	.99081	.99038	.99206	.99206
30 - 34	.98804	.98761	.98983	.98983
35 - 39	.98171	.98154	.98455	.98455
40 - 44	.97025	.97127	.97528	.97528
45 - 54	.95081	.95412	.95978	.95978
55 - 64	.88987	.89376	.90841	.90841
65 - 99	.58204	.70311	.72989	.72989

FEMALE 5-YEAR SURVIVAL RATES*

AGES	1960	1970	2010	2015
0 - 4	.99633	.99704	.99706	.99706
5 - 9	.99829	.99853	.99867	.99867
10 - 14	.99789	.99793	.99828	.99828
15 - 19	.99689	.99648	.99742	.99742
20 - 24	.99606	.99624	.99675	.99675
25 - 29	.99477	.99508	.99564	.99564
30 - 34	.99253	.99274	.99375	.99375
35 - 39	.98867	.98905	.99069	.99069
40 - 44	.98262	.98352	.98597	.98597
45 - 54	.97395	.97539	.97889	.97889
55 - 64	.94175	.94735	.95291	.95291
65 - 99	.66506	.70178	.69475	.69475

FERTILITY RATE*

AGES	1960	1970	2010	2015
15 - 19	.455	.330	.355	.355
20 - 24	1.285	.825	1.010	1.010
25 - 29	.985	.665	.830	.830
30 - 34	.560	.365	.400	.400
35 - 39	.285	.175	.140	.140
40 - 44	.080	.050	.030	.030

*U.S. Dept. of Commerce, Bureau of the Census

Figure 2-3. Population Sub-Model Input

AGE	WHITE MALE	WHITE FEMALE	NON-W MALE	NON-W FEMALE	TOTAL WHITE	TOTAL NON-W	TOTAL MALE	TOTAL FEMALE	TOTAL POP.
0- 4	9998.	9372.	365.	348.	19370.	712.	10362.	9720.	20082.
5- 9	6682.	6481.	351.	337.	13163.	688.	7033.	6818.	13851.
10- 14	6017.	5825.	319.	308.	11843.	626.	6336.	6133.	12469.
15- 19	8390.	7322.	316.	292.	15712.	608.	8707.	7613.	16320.
20- 24	9705.	7380.	305.	250.	17086.	554.	10010.	7630.	17640.
25- 29	7985.	6541.	272.	229.	14526.	501.	8257.	6771.	15027.
30- 34	6647.	6108.	251.	240.	12754.	491.	6898.	6347.	13245.
35- 39	5207.	5636.	236.	220.	10844.	456.	5443.	5857.	11300.
40- 44	4778.	5298.	218.	183.	10076.	401.	4996.	5481.	10477.
45- 49	4092.	4428.	176.	154.	8520.	330.	4268.	4582.	8850.
50- 54	3455.	3647.	131.	123.	7102.	255.	3586.	3770.	7356.
55- 59	3007.	3124.	97.	105.	6131.	202.	3105.	3228.	6333.
60- 64	2524.	2821.	82.	80.	5345.	163.	2607.	2901.	5508.
65- 69	2112.	2383.	67.	64.	4495.	130.	2178.	2447.	4625.
70- 74	1477.	1848.	35.	50.	3325.	85.	1512.	1898.	3410.
75- 79	988.	1435.	24.	36.	2423.	60.	1012.	1471.	2483.
80- 84	568.	1040.	15.	27.	1607.	42.	583.	1067.	1649.
85 +	494.	1002.	15.	29.	1496.	44.	509.	1031.	1540.
TOTAL	84125.	81690.	3276.	3074.	165815.	6350.	87401.	84764.	172165.
PERCENT	48.9	47.4	1.9	1.8	96.3	3.7	50.8	49.2	100.0
MEDIAN AGE	25.8	28.4	24.7	25.1	27.0	24.9	25.8	28.3	26.9

Figure 2-4. Population Model Output -- Population Projection

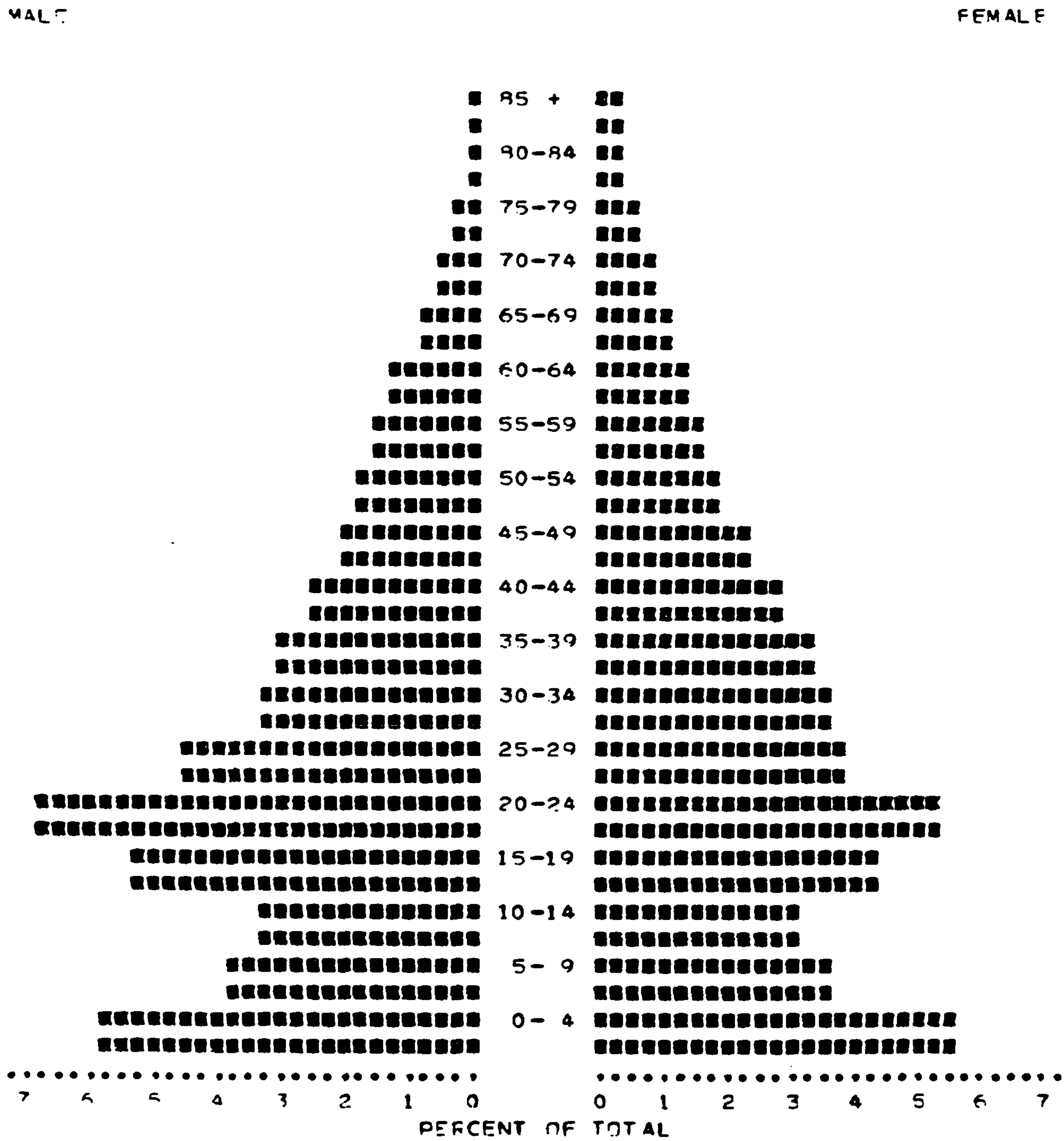


Figure 2-4 (Continued). Population Model Output --
Distribution by Age and Sex

AGE GROUP	NET MIGRATION WHITE FEMALE	NON-W FEMALE	WHITE MALE	NON-W MALE	TOTAL
0 - 4	575.	38.	630.	36.	1279.
5 - 9	920.	43.	1022.	54.	2039.
10 - 14	822.	45.	917.	50.	1834.
15 - 19	963.	58.	1086.	63.	2170.
20 - 24	1591.	55.	1334.	68.	3048.
25 - 29	928.	33.	854.	46.	1861.
30 - 34	628.	29.	681.	36.	1374.
35 - 39	423.	27.	472.	26.	948.
40 - 44	407.	21.	466.	19.	913.
45 - 49	351.	16.	338.	25.	730.
50 - 54	220.	18.	256.	14.	506.
55 - 59	211.	16.	214.	13.	454.
60 - 64	201.	12.	187.	8.	408.
65 - 69	182.	14.	79.	10.	285.
70 - 74	157.	7.	113.	5.	282.
75 - 79	145.	4.	81.	3.	233.
80 - 84	108.	3.	59.	2.	172.
85 +	76.	2.	49.	1.	128.
TOTAL	8908.	441.	8838.	479.	18666.

Figure 2-4 (Continued). Population Model Output -- Net Migration

POPULATION BY OCCUPATION

OCCUPATION	POPULATION
PROFESSIONAL	24074.
MANAGERS	13095.
CLERICAL	20283.
SALES	5802.
FARMERS	1614.
FARMLABORER	896.
SKILLED LBR	10350.
OPERATORS	8564.
HSFHOLD WKRS	17.
SERVICE WKRS	11542.
LABORERS	2980.
UNEMPLOYED	4152.
NOT EMPLABLE	54883.
ARMED FORCES	1423.
TOTAL	159674.
% UNEMPLOYED	4.02

TOTAL LABOR FORCE BY INDUSTRY

INDUSTRY	LABOR FORCE
AGRICULTURE	485.
MINING	1452.
CONSTRUCTION	2502.
MANUFACTURNG	18753.
TRANSPORTION	1888.
TRADE	16407.
FINANCE	3397.
SERVICES	36076.
GOVERNMEMENT	22408.
TOTAL	103367.

Figure 2-4 (Continued). Population Model Output --
Occupation and Industry

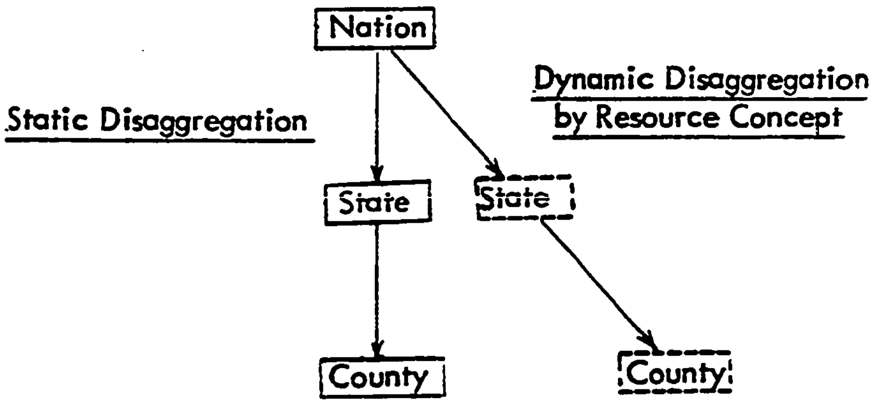


Figure 2-5. Disaggregation Population Sub-Model

Sample Age and Sex Disaggregation Equations

β Values

F_i	Inter-cept β_0	Density β_1	Urbani-zation β_2	Energy β_3	Water β_4	Land β_5	Income β_6
Male Age							
0-4	-0.06246	-0.02164	-0.01191	-0.00542	0.26193	-0.00335	0.00000
5-19	0.04791	0.18038	0.0054	-0.00118	0.26668	-0.00126	0.00000
20-24	0.11493	0.00549	0.00126	-0.00009	-0.02387	0.00009	0.00000
25-44	0.09795	-0.00663	-0.00324	-0.00059	-0.00430	0.00019	0.00000
45-64	-0.00552	-0.00634	-0.04353	-0.01257	0.15000	0.00063	0.00000
65+	-6.13428	0.38398	0.00930	-0.12765	7.99316	-0.13807	-0.00021

$$F_i = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6$$

Figure 2-6. Disaggregation Weighting Factors both cases, computer printouts of the population projections by five-year increments are listed according to sex, age, household and labor force by income, population by occupation, and labor force (employment) by industry.

Other population models could be used. For instance, Forrester's, the system dynamic model (8), or tabulation of preconceived, or agreed to population values can be used. A more detailed discussion of the above model can be found in references (13) and (14). The computer programs can be found in reference (11).

2.3 THE HOUSING MODEL

The housing model was designed to determine the housing needs in an urban area. The model deals with households and housing units on an area wide basis. Households categorized and forecasted in the population model are used as inputs for the housing model. The output from the housing model includes the area wide housing needs by the type of household and the type of housing.

A general flow chart of the housing model is shown in Figure 2-7. The model is essentially a cohort-survival model in which housing units go through an aging process. Households are also aged, but outside the housing model. The household data come from the population model. The model begins by aging housing units using a transition matrix. The housing transition matrix give the probability of moving a housing unit from one of the eighteen types of housing to another type within a certain time span. By this process, the area's housing inventory changes in value, type of structure, and type of occupancy. This matrix, and other matricies used in the model are given in Figure 2-8.

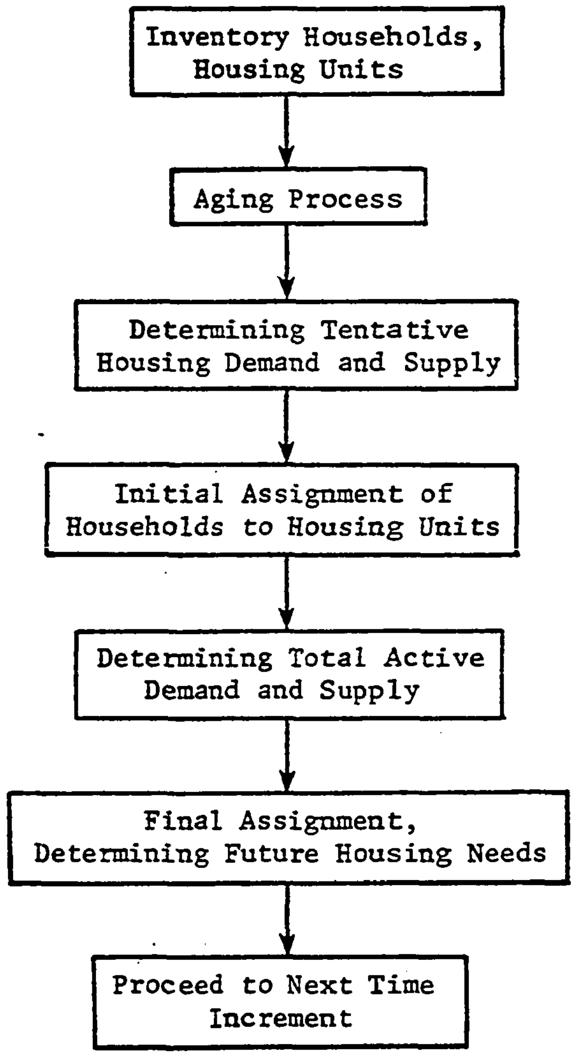


Figure 2-7. The Housing Model (14)

Housing type	Value*	Tenure	Structure
1	low	owner-occupied	single-family
2	low	owner-occupied	multi-family
3	low	renter-occupied	single-family
4	low	renter-occupied	multi-family
5	medium	owner-occupied	single-family
6	medium	owner-occupied	multi-family
7	medium	renter-occupied	single-family
8	medium	renter-occupied	multi-family
9	high	owner-occupied	single-family
10	high	owner-occupied	multi-family
11	high	renter-occupied	single-family
12	high	renter-occupied	multi-family
13	low	owner-occupied	mobile
14	low	renter-occupied	mobile
15	medium	owner-occupied	mobile
16	medium	renter-occupied	mobile
17	high	owner-occupied	mobile
18	high	renter-occupied	mobile

*For owner-occupied units, value categories are defined according to the value of the housing:

low - less than $15,000.00
medium - $15,000.00 - $25,000.00
high - $25,000.00 or more

For renter-occupied units, value categories are based on rent and defined as follows:

low - less than $100.00/month
medium - $100.00 - $150.00/month
high - $150.00/month or more

Household type	Age of household head	Household income*
1	less than 25	low
2	25-29	low
3	30-34	low
4	35-39	low
5	40-44	low
6	45-49	low
7	50-54	low
8	55-59	low
9	60-64	low
10	65 or over	low
11	less than 25	medium
12	25-29	medium
13	30-34	medium
14	35-39	medium
15	40-44	medium
16	45-49	medium
17	50-54	medium
18	55-59	medium
19	60-64	medium
20	65 or over	medium
21	less than 25	high
22	25-29	high
23	30-34	high
24	35-39	high
25	40-44	high
26	45-49	high
27	50-54	high
28	55-59	high
29	60-64	high
30	65 or over	high

*Household income categories are defined as follows:

low - annual income of less than $5,000.00
medium - annual income of $5,000.00 - $12,000.00
high - annual income of $12,000.00 or more

Figure 2-8. Housing Model Matrices -- Terms Used (14)

To housing type:

From housing type:

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Demolished
1	.85	.00	.05	.00	.06	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.04
2	.00	.88	.00	.05	.00	.05	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.02
3	.02	.00	.87	.00	.00	.00	.04	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.07
4	.00	.02	.00	.90	.00	.00	.00	.03	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.05
5	.01	.00	.00	.00	.88	.00	.05	.00	.04	.00	.00	.00	.00	.00	.00	.00	.00	.00	.02
6	.00	.01	.00	.00	.00	.90	.00	.05	.00	.03	.00	.00	.00	.00	.00	.00	.00	.00	.01
7	.00	.00	.01	.00	.02	.00	.91	.00	.00	.00	.02	.00	.00	.00	.00	.00	.00	.00	.04
8	.00	.00	.00	.01	.00	.02	.00	.93	.00	.00	.00	.01	.00	.00	.00	.00	.00	.00	.03
9	.00	.00	.00	.00	.02	.00	.00	.00	.92	.00	.05	.00	.00	.00	.00	.00	.00	.00	.01
10	.00	.00	.00	.00	.00	.02	.00	.00	.00	.92	.00	.05	.00	.00	.00	.00	.00	.00	.01
11	.00	.00	.00	.00	.00	.00	.02	.00	.02	.00	.94	.00	.00	.00	.00	.00	.00	.00	.02
12	.00	.00	.00	.00	.00	.00	.00	.02	.00	.02	.00	.95	.00	.00	.00	.00	.00	.00	.01
13	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.73	.05	.02	.00	.00	.00	.20
14	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.02	.76	.00	.02	.00	.00	.20
15	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.10	.00	.69	.05	.01	.00	.15
16	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.10	.02	.72	.00	.01	.15
17	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.12	.00	.73	.05	.10
18	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.12	.02	.76	.10

Figure 2-8 (Continued). Housing Model Matrices -- Transition Matrix

Housing Type

Household Type	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	4	3	2	1	13	14	8	7	6	5	15	16	12	11	10	9	17	18
2	3	4	1	2	13	14	7	8	5	6	15	16	11	12	9	10	17	18
3	1	2	3	4	13	14	5	6	7	8	15	16	9	10	11	12	17	18
4	1	2	3	4	13	14	5	6	7	8	15	16	9	10	11	12	17	18
5	2	1	4	3	13	14	6	5	8	7	15	16	10	9	12	11	17	18
6	1	3	2	4	13	14	5	7	6	8	15	16	9	11	10	12	17	18
7	1	3	2	4	13	14	5	7	6	8	15	16	9	11	10	12	17	18
8	1	3	2	4	13	14	5	7	6	8	15	16	9	11	10	12	17	18
9	4	2	3	1	13	14	8	6	7	5	15	16	12	10	11	9	17	18
10	4	2	3	1	13	14	8	6	7	5	15	16	12	10	11	9	17	18
11	8	7	6	5	15	16	4	3	2	1	13	14	12	11	10	9	17	18
12	7	8	5	6	15	16	3	4	1	2	13	14	11	12	9	10	17	18
13	5	6	7	8	15	16	1	2	3	4	13	14	9	10	11	12	17	18
14	5	6	7	8	15	16	1	2	3	4	13	14	9	10	11	12	17	18
15	6	5	8	7	15	16	2	1	4	3	13	14	10	9	12	11	17	18
16	5	7	6	8	15	16	9	11	10	12	17	18	1	3	2	4	13	14
17	5	7	6	8	15	16	9	11	10	12	17	18	1	3	2	4	13	14
18	5	7	6	8	15	16	9	11	10	12	17	18	1	3	2	4	13	14
19	8	6	7	5	15	16	4	2	3	1	13	14	12	10	11	9	17	18
20	6	6	7	5	15	16	4	2	3	1	13	14	12	10	11	9	17	18
21	12	11	10	9	17	18	8	7	6	5	15	16	4	3	2	1	13	14
22	11	12	9	10	17	18	7	8	5	6	15	16	3	4	1	2	13	14
23	9	10	11	12	17	18	5	6	7	8	15	16	1	2	3	4	13	14
24	9	10	11	12	17	18	5	6	7	8	15	16	1	2	3	4	13	14
25	10	9	12	11	17	18	6	5	8	7	15	16	2	1	4	3	13	14
26	9	11	10	12	17	18	5	7	6	8	15	16	1	3	2	4	13	14
27	9	11	10	12	17	18	5	7	6	8	15	16	1	3	2	4	13	14
28	9	11	10	12	17	18	5	7	6	8	15	16	1	3	2	4	13	14
29	12	10	11	9	17	18	8	6	7	5	15	16	4	2	3	1	13	14
30	12	10	11	9	17	18	8	6	7	5	15	16	4	2	3	1	13	14

Figure 2-8 (Continued). Housing Model Matrices -- Preference Matrix

After the aging processes for housing, households are assigned to housing according to a housing preference matrix. The housing preference matrix indicates the preferences of thirty different types of the households for each one of eighteen types of housing.

After the initial housing assignment, dissatisfied households are considered. The probability of a household's dissatisfaction with present housing depends on its relative preferences for that housing. Thus, a very small percentage of households will be dissatisfied if their present housing is their first choice, while for those whose currently assigned housing is their last choice, the percentage of dissatisfied households will be large. By applying these probabilities of dissatisfaction to the initial housing assignment, the dissatisfied households can be otained.

The model then determines the number and types of new housing which need to be added to the study area. This is done by comparing the vacant housing with the number and type of households that are dissatisfied with their current housing and those which have recently migrated to the area.

Next, new housing is "built" in the sub-model based partially on historical trends and partially on current demands. Three options are available for this new housing "building" process:

1. Let the model automatically "build" the required housing according to a pre-programmed ratio indicating the distribution of new housing "built" based on the historical trends and current demand.
2. Participate in the decision making by changing the pre-programmed ratio.
3. Execute the entire "building" process outside the model by adding a certain amount of new housing units to the market.

To complete the assignment of households to housing, the total active demand and the total active supply in each cycle are determined. The total active demand includes: households without housing due to aging (of households or housing); households without housing due to dissatisfaction; and newly in-migrated households which are obtained from the population model. Those included in the total active supply are: housing vacant due to aging (of households or housing); housing vacant due to dissatisfaction; and newly "built" housing.

After the total active demand and supply have been determined, the total active demand is assigned to the total active supply by utilizing housing preferences as a guideline. This produces the complete assignment of households to housing for the study area for the particular time being considered. An example of the model out-put is shown in Figure 2-9.

The present housing model developed in conjunction with this research was based on the New York State housing model (15). A more detailed description of the present model can also be found in reference (14).

2.4 THE HEURISTIC LAND USE MODEL (SUMMARY)

The heuristic land use model was designed to assist in urban land use planning and as a means of disaggregating the results of the population and housing models, which are for an urban area, to small unit areas. In doing so it provides the "key" to making the system of models work. Because of its heuristic nature and flexible structure, the model could also be designated more generally, as the spatial structure model. To be more specific, the model is used for predicting land use and gathering information of spatial character in general which might have a significant impact on the solution of urban problems.

Housing Type

Household Type

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	0.	0.	30.	45.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
2	0.	0.	153.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
3	46.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
4	58.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
5	60.	30.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
6	109.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
7	91.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
8	87.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
9	0.	0.	56.	56.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
10	0.	0.	571.	571.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
11	0.	0.	400.	333.	0.	0.	67.	33.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
12	0.	0.	1709.	0.	0.	0.	171.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
13	892.	0.	0.	0.	89.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
14	1127.	0.	0.	0.	113.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
15	1402.	0.	0.	0.	142.	46.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
16	2154.	0.	0.	0.	113.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
17	1805.	0.	0.	0.	95.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
18	1717.	0.	0.	0.	90.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
19	0.	0.	541.	387.	0.	0.	4.	76.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
20	0.	0.	1411.	1008.	0.	0.	0.	202.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
21	0.	0.	375.	375.	0.	0.	0.	197.	0.	0.	0.	20.	0.	0.	0.	0.	0.	0.
22	0.	0.	1922.	0.	0.	0.	506.	0.	0.	0.	51.	0.	0.	0.	0.	0.	0.	0.
23	3333.	0.	0.	0.	877.	0.	0.	0.	88.	0.	0.	0.	0.	0.	0.	0.	0.	0.
24	4215.	0.	0.	0.	1109.	0.	0.	0.	111.	0.	0.	0.	0.	0.	0.	0.	0.	0.
25	3002.	1367.	0.	0.	1380.	0.	0.	0.	183.	23.	0.	0.	0.	0.	0.	0.	0.	0.
26	3448.	0.	0.	0.	1653.	0.	0.	0.	126.	0.	0.	0.	0.	0.	475.	88.	0.	0.
27	2005.	0.	0.	0.	1948.	0.	0.	0.	106.	0.	2.	0.	0.	0.	0.	0.	62.	22.
28	1908.	0.	0.	0.	1004.	0.	0.	0.	174.	0.	54.	0.	0.	0.	0.	0.	0.	0.
29	0.	0.	674.	959.	1375.	0.	0.	0.	0.	0.	258.	86.	0.	0.	0.	0.	0.	0.
30	0.	0.	0.	1561.	148.	0.	1021.	0.	0.	0.	135.	119.	0.	0.	0.	0.	0.	0.

Figure 2-9. Housing Model Output -- Dissatisfied Households (14)

Housing Type

Household Type

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	0.	0.	0.	1055.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
2	0.	0.	3757.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
3	1220.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
4	1206.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
5	0.	1248.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
6	2189.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
7	1835.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
8	1747.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
9	0.	0.	0.	1496.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
10	0.	0.	0.	15411.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
11	0.	0.	0.	587.	0.	0.	292.	1500.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
12	0.	0.	2092.	0.	0.	0.	6277.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
13	517.	0.	0.	0.	3545.	0.	0.	0.	0.	0.	0.	0.	0.	0.	571.	93.	0.	0.
14	0.	0.	0.	0.	4474.	0.	0.	0.	0.	0.	0.	0.	0.	0.	198.	0.	0.	0.
15	0.	0.	0.	0.	2738.	2099.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
16	0.	0.	0.	0.	4546.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
17	0.	0.	0.	0.	3312.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
18	0.	0.	0.	0.	3628.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
19	0.	0.	0.	0.	777.	0.	0.	2330.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
20	0.	0.	0.	0.	1532.	0.	508.	6119.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
21	0.	0.	0.	0.	0.	0.	348.	0.	0.	0.	0.	1043.	0.	0.	0.	0.	0.	0.
22	0.	0.	0.	0.	0.	0.	1238.	0.	0.	0.	3715.	0.	0.	0.	0.	0.	0.	0.
23	0.	0.	0.	0.	2325.	0.	0.	0.	6976.	0.	0.	0.	0.	0.	0.	0.	0.	0.
24	0.	0.	0.	0.	2298.	0.	0.	0.	6894.	0.	0.	0.	0.	0.	0.	0.	0.	0.
25	0.	0.	0.	0.	2379.	0.	0.	0.	1329.	5809.	0.	0.	0.	0.	0.	0.	0.	0.
26	0.	0.	0.	0.	2008.	0.	0.	0.	7577.	0.	133.	0.	0.	0.	0.	0.	329.	56.
27	0.	0.	0.	0.	0.	0.	0.	0.	7626.	0.	844.	0.	0.	0.	0.	0.	0.	0.
28	0.	0.	0.	0.	0.	0.	0.	0.	8063.	0.	0.	0.	0.	0.	0.	0.	0.	0.
29	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1726.	5179.	0.	0.	0.	0.	0.	0.
30	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	553.	6095.	0.	0.	0.	0.	0.	0.

Figure 2-9 (Continued). Housing Model Output -- Final Assignments

**** NUMBER OF UNITS AND TYPE TO GIVE ALL HOUSEHOLDS ****
***** FIRST CHOICE *****

HOUSEHOLD	1 NEEDS	0.	HOUSES OF TYPE	4
HOUSEHOLD	2 NEEDS	0.	HOUSES OF TYPE	3
HOUSEHOLD	3 NEEDS	0.	HOUSES OF TYPE	1
HOUSEHOLD	4 NEEDS	0.	HOUSES OF TYPE	1
HOUSEHOLD	5 NEEDS	0.	HOUSES OF TYPE	2
HOUSEHOLD	6 NEEDS	0.	HOUSES OF TYPE	1
HOUSEHOLD	7 NEEDS	0.	HOUSES OF TYPE	1
HOUSEHOLD	8 NEEDS	0.	HOUSES OT TYPE	1
HOUSEHOLD	9 NEEDS	0.	HOUSES OF TYPE	4
HOUSEHOLD	10 NEEDS	0.	HOUSES OF TYPE	4
HOUSEHOLD	11 NEEDS	850.	HOUSES OF TYPE	8
HOUSEHOLD	12 NEEDS	2092.	HOUSES OF TYPE	7
HOUSEHOLD	13 NEEDS	1182.	HOUSES OF TYPE	5
HOUSEHOLD	14 NEEDS	198.	HOUSES OF TYPE	5
HOUSEHOLD	15 NEEDS	2738.	HOUSES OF TYPE	6
HOUSEHOLD	16 NEEDS	0.	HOUSES OF TYPE	5
HOUSEHOLD	17 NEEDS	0.	HOUSES OF TYPE	5
HOUSEHOLD	18 NEEDS	0.	HOUSES OT TYPE	5
HOUSEHOLD	19 NEEDS	777.	HOUSES OF TYPE	8
HOUSEHOLD	20 NEEDS	2040.	HOUSES OF TYPE	8
HOUSEHOLD	21 NEEDS	348.	HOUSES OF TYPE	12
HOUSEHOLD	22 NEEDS	1238.	HOUSES OF TYPE	11
HOUSEHOLD	23 NEEDS	2325.	HOUSES OF TYPE	9
HOUSEHOLD	24 NEEDS	2298.	HOUSES OF TYPE	9
HOUSEHOLD	25 NEEDS	3708.	HOUSES OF TYPE	10
HOUSEHOLD	26 NEEDS	2526.	HOUSES OF TYPE	9
HOUSEHOLD	27 NEEDS	844.	HOUSES OF TYPE	9
HOUSEHOLD	28 NEEDS	0.	HOUSES OF TYPE	9
HOUSEHOLD	29 NEEDS	1726.	HOUSES OF TYPE	12
HOUSEHOLD	30 NEEDS	553.	HOUSES OF TYPE	12

**** NUMBER OF UNITS AND TYPE TO GIVE ALL HOUSEHOLDS ****
***** FIRST AND SECOND CHOICE *****

HOUSEHOLD	1 NEEDS	0.	HOUSES OF TYPE	4
HOUSEHOLD	2 NEEDS	0.	HOUSES OF TYPE	3
HOUSEHOLD	3 NEEDS	0.	HOUSES OF TYPE	1
HOUSEHOLD	4 NEEDS	0.	HOUSES OF TYPE	1
HOUSEHOLD	5 NEEDS	0.	HOUSES OF TYPE	2
HOUSEHOLD	6 NEEDS	0.	HOUSES OF TYPE	1
HOUSEHOLD	7 NEEDS	0.	HOUSES OF TYPE	1
HOUSEHOLD	8 NEEDS	0.	HOUSES OF TYPE	1
HOUSEHOLD	9 NEEDS	0.	HOUSES OF TYPE	4
HOUSEHOLD	10 NEEDS	0.	HOUSES OF TYPE	4
HOUSEHOLD	11 NEEDS	587.	HOUSES OF TYPE	8
HOUSEHOLD	12 NEEDS	2092.	HOUSES OF TYPE	7
HOUSEHOLD	13 NEEDS	1182.	HOUSES OF TYPE	5
HOUSEHOLD	14 NEEDS	198.	HOUSES OF TYPE	5
HOUSEHOLD	15 NEEDS	0.	HOUSES OF TYPE	6
HOUSEHOLD	16 NEEDS	0.	HOUSES OF TYPE	5
HOUSEHOLD	17 NEEDS	0.	HOUSES OF TYPE	5
HOUSEHOLD	18 NEEDS	0.	HOUSES OF TYPE	5
HOUSEHOLD	19 NEEDS	777.	HOUSES OF TYPE	8
HOUSEHOLD	20 NEEDS	2040.	HOUSES OF TYPE	8
HOUSEHOLD	21 NEEDS	348.	HOUSES OF TYPE	12
HOUSEHOLD	22 NEEDS	1238.	HOUSES OF TYPE	11
HOUSEHOLD	23 NEEDS	2325.	HOUSES OF TYPE	9
HOUSEHOLD	24 NEEDS	2298.	HOUSES OF TYPE	9
HOUSEHOLD	25 NEEDS	2379.	HOUSES OF TYPE	10
HOUSEHOLD	26 NEEDS	2393.	HOUSES OF TYPE	9
HOUSEHOLD	27 NEEDS	0.	HOUSES OF TYPE	9
HOUSEHOLD	28 NEEDS	0.	HOUSES OF TYPE	9
HOUSEHOLD	29 NEEDS	1726.	HOUSES OF TYPE	12
HOUSEHOLD	30 NEEDS	553.	HOUSES OF TYPE	12

Figure 2-9 (Continued). Housing Model Output -- New Housing Needed

The basic structure of the model is shown in Figure 2-10. The model consists of three main elements:

1. Information gathering.
2. Individual evaluation.
3. Group Evaluation.

These elements are designed to interact with one another and with the total system of models. Two main sequential components of the model are the modified Delphi and the gaming. The spatial model as a whole uses an embedded iterative process to obtain answers to the questions under consideration.

The model, as shown in Figure 2-10, begins with an information element consisting of both "hard" information and "soft" information. The "hard" information is that provided to the respondents being queried by the model user or documental information which he has access to from other sources. "Soft" information is that which the respondent has in his "head" (his feelings, intuition, etc.) that has been acquired previous to participating in the running of the model. Respondents selected are not a random sample of the population; they are those who have the motivation for investing the time necessary to synthesize the information provided to them. To make realistic land use projections, the respondents selected are also those from land use or planning related agencies; e.g., city councilmen, city planners, real estate developers, concerned citizens, etc. The information presented to the respondents changes with each iteration; some of the changes are due to additional information reflecting what transpired in the previous iteration.

The second element of the model, individual evaluation, consists of the respondent's evaluation and response by means of a questionnaire. An

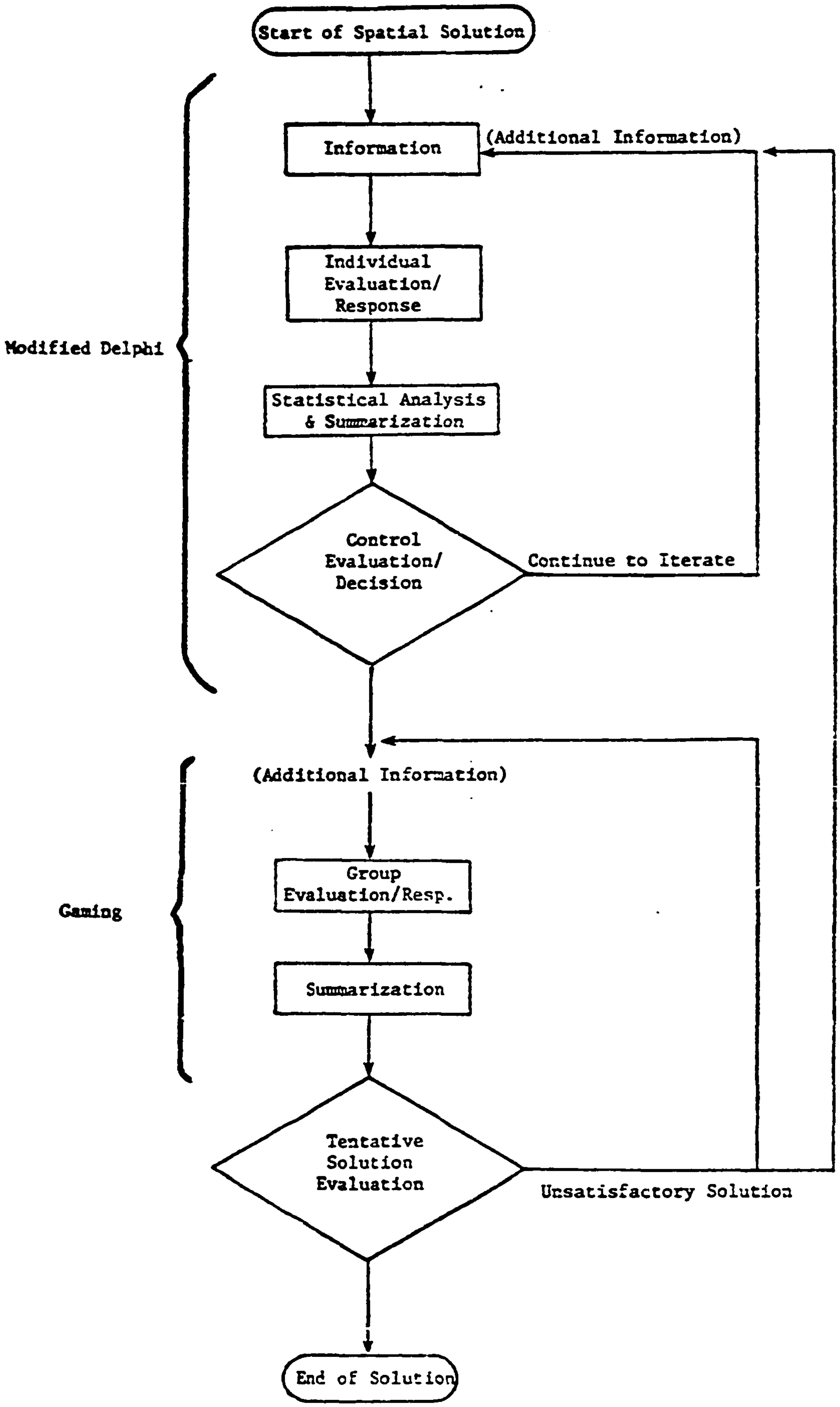


Figure 2-10. Schematic of the Spatial Model

example of a response to a questionnaire is the projection of land use by categories; e.g., residential, commercial, industrial, etc.

The responses are next summarized statistically, or graphically if mapping is involved. The results are then evaluated and may also be used as information for the next iteration. This summarization is actually the last step of the modified Delphi component of the model. Several iterations of this Delphi can be used until there is an indication of sufficient consensus or stabilization to proceed to the next form of questions, gaming.

The next element in the spatial model is another questionnaire presented this time to the entire group of respondents and answered by means of a combination of a game response and a written response. Information gathered at this stage will be evaluated by the whole group and then summarized.

The summarization is the same as the previous summaries. However, all the analysis and summarization that was done before is done again while the additional information that came out of the game is added. This additional information will be of two types, factual and subjective. The factual information will either be presented as a list or a map, whichever is appropriate. The subjective information will be in the form of a scenairo. This summarization also ends the gaming component of the spatial model.

The last element in the spatial model is the evaluation of a tentative solution. Results from the modified Delphi, the game, and the additionally written responses are synthesized and evaluated. Then, there are three options available for the next step:

1. The spatial model is brought to a conclusion and the next model is considered.

2. Additional gaming is pursued.

3. The whole spatial model is repeated.

In most cases, option (1) would be the choice or one additional clarifying written response would be necessary. If option (3) is chosen, the Delphi process is changed somewhat because there has been a face-to-face confrontation between the respondents; however, this does not necessarily degrade the procedure.

The output from this spatial model will be certain guidelines and recommendations for the projected land use in the study area to be used for future planning. If the model is used for several time increments, the projection for each time increment should be evaluated by the consequence models before the next time increment is considered.

2.5 THE TRANSPORTATION MODEL

The objective of the transportation model was to develop a methodology which could be used to assist in the planning of an urban area transportation system. The network system transportation model developed initially contains some mathematical programming difficulties and requires further testing. The model was not used, but is included here for reference.

The initially developed network system transportation model was based on goal-directed/backward-seeking model system. In this system, one starts with the goals for selection of transportation alternatives and then proceeds through the consequences of alternative plans to the selection of the alternative plan which will best, or at least satisfactorily, achieve the desired goals. The components of the transportation system which are being considered in this model are:

1. Activity system.
2. Vehicle or person flow network.
3. Fixed plant network.

Input models to the present model system are:

1. Boston direct travel demand model.
2. The network performance or supply model.
3. The cost models.

The major components of the network system models are:

1. The network generation model.
2. The optimal multimodal network model (auto and bus only).
3. The capital cost model.
4. The optimal network development model.

The selection of the optimal network is done by mathematical programming with an objective function formulated to minimize the cost of the fixed plant of the transport system while being subjected to constraints which include demand, technology, level of service, or accessibility. A simple flow chart of the network transportation system model is shown in Figure 2-11. A more detailed discussion of this model can be found in reference (14).

2.6 THE WATER SUPPLY AND SEWERAGE

The water supply and sewerage models were developed to assist in the planning of urban or regional water supply and sewerage systems. The proposed methodology can also be used to test alternative designs and development phases which will then provide a basis for the scheduling of these

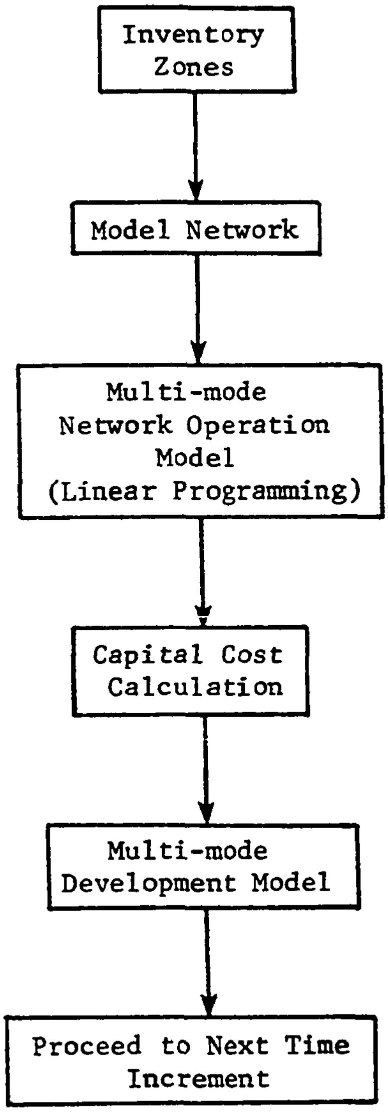


Figure 2-11. The Network Transportation System Model (14)

developments. The model was developed first for application to the water supply system, and with minor modifications, was applied to the sewage system.

The model first deals with three functional sectors of the urban area:

1. Demographic sector.
2. Industrial sector.
3. Agricultural sector.

These functional sectors are used to gather information for a demand sub-model which provides input for the water supply and sewage network sub-models.

The demographic sector relates the general population to the normal water consuming and sewage producing activities of the population: domestic, commercial, and public. Also included in this category are municipal losses which can be attributed to leakage and unmetered connections. Water demands for this sector are measured on a per-capita basis. The industrial sector is concerned with the manufacturing uses of water as identified by the Standard Industrial Classification (SIC) codes. These uses include that which is needed for cooling, boiler feed water, processing, and cleaning. The requirements for this sector are measured on a per-employee basis. The agricultural sector relates to the water used for irrigation and is measured on a per-acre basis.

The demand sub-model supplies information about the water demands and sewage outputs for the study area based on current and projected data accumulated from the output from the population model and other sources. The model uses selected technical coefficients that were developed or acquired from other sources. These coefficients are then applied to the data files to acquire the water and sewage outputs.

The water network sub-model is very extensive and has many elements: resources, withdrawal, consumption, quality, transmission, treatment, storage, and distribution. The sewage network sub-model also deals with many elements: return flows (both quantity and quality), collection, treatment, discharge, receiving streams, and quality criteria.

Figure 2-12 shows the structure of the water supply network sub-model. The model begins with the formulation of alternative network and continues with a coarse sort of the alternative networks. By using an out-of-kilter linear programming algorithm, feasible alternatives are analyzed, together with their associated costs, to reach the optimal solution. The sewerage model also has the same format as the water supply model.

The model components and their sequential arrangement in general are indicated in Figure 2-13. The first step is to conduce the required inventories for the demand sub-model. Next, the projections of the sector parameters are made. Then, based on these projections and a set of unit-use factors developed for the models, estimates of the total water system requirements and sewage loads are determined. The water and sewage plan alternatives are then determined. Once the alternatives are developed they are evaluated in terms of the operational criteria established for measuring cost and effectiveness. Finally, the compatibility of the resulting plan with the comprehensive regional development goals must be evaluated and, if necessary, modifications of the plan may be made to meet these goals. A more detailed discussion of the water and sewage models can be found in references (1) and (14). Example factors used in the water model, and example inputs and outputs are shown in Figures 2-14 through 2-16.

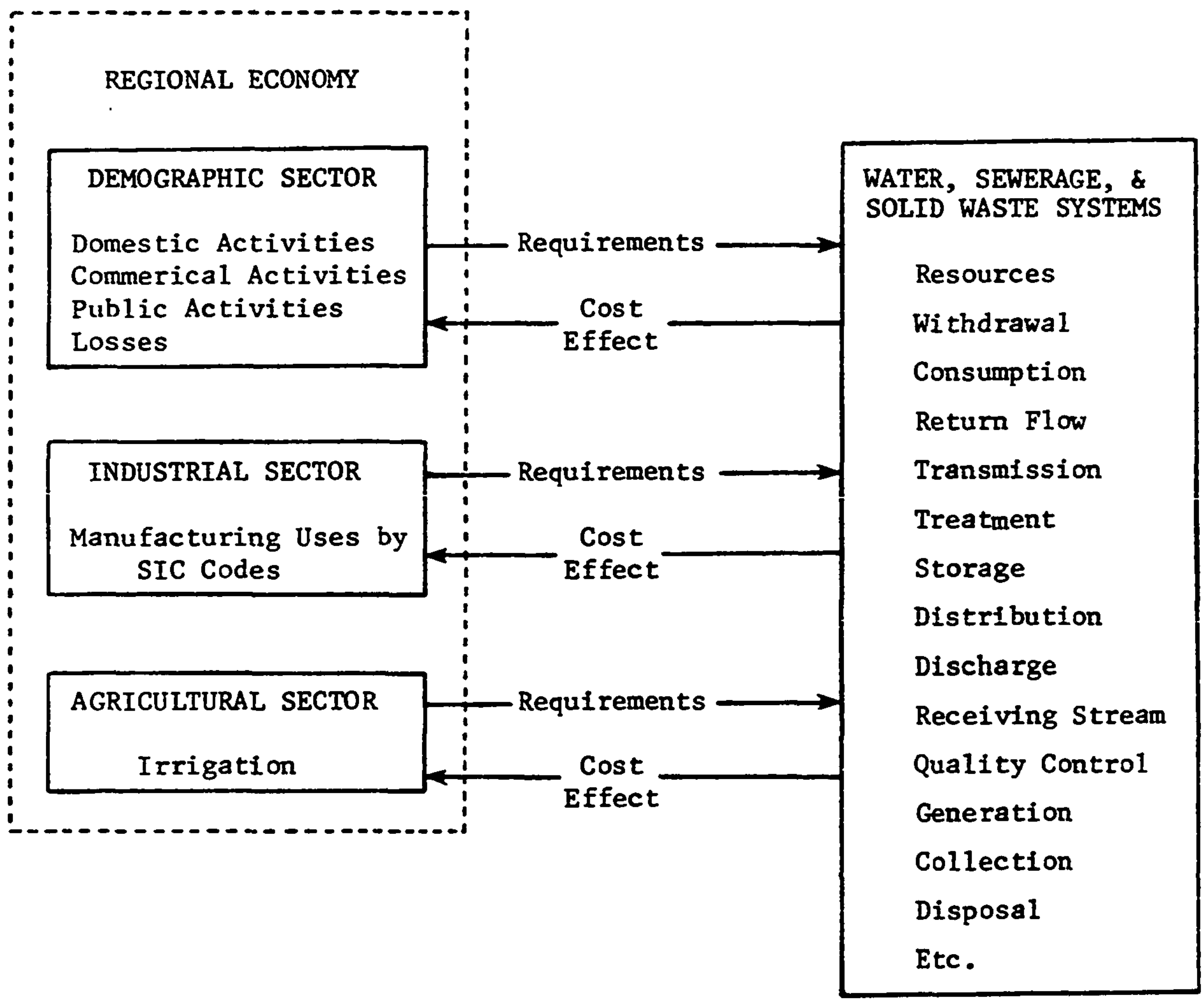


Figure 2-12. The Water Supply Network Model (11)

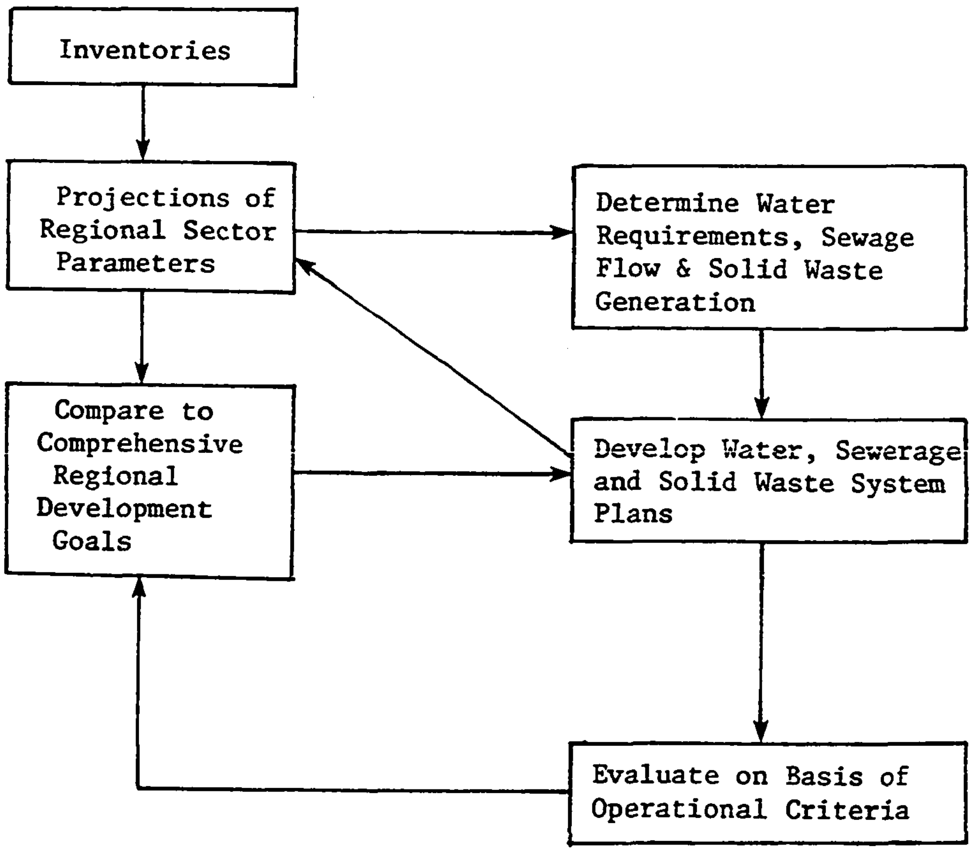


Figure 2-13. Water and Sewage Models (11)

Unit capital costs for impounding reservoirs, including intake and pumping station, are given by

$$C_R = 74.2\, X_R^{-.38}$$

where

C_R = annual unit cost of impounding reservoirs in thousands of dollars per billion gallons.

X_R = design capacity of reservoir in billions of gallons.

Equivalent annual cost for capital investment in pipelines is given by

$$C_P = 41.3\, X_P^{-.49}$$

where

C_P = equivalent annual cost for pipelines in thousands of dollars per mile per mgd.

X_S = design capacity in mgd.

Annual operation and maintenance costs for pipelines can be expressed as

$$A_P = 1.32\, X_P'^{-.49}$$

where

A_P = annual operation and maintenance cost in thousands of dollars per mgd of flow.

X_P' = pipeline utilization level in mgd.

Treatment plant costs include the costs of the treatment plant and treated water pumping plant. Unit capital costs are given by

$$C_T = 25.6\, X_T^{-.257}$$

where

C_T = equivalent annual unit cost of treatment plant in thousands of dollars per mgd.

X_T = design capacity of treatment plant in mgd.

Operation and maintenance costs of the treatment plant, exclusive of chemical and power costs, are given by

$$A_T = 7.25\, X_T'^{-.257}$$

where

A_T = annual operation and maintenance of treatment plant in thousands of dollars per mgd.

X_T' = operating level of plant in mgd.

Figure 2-14. Water Model Cost Factors (11)

The unit capital cost for each pumping station is given by

$$C_n = 6.65\, X_p^{-.314}$$

where

C_n = equivalent annual unit cost of pumping stations in thousands of dollars per station per mgd.

X_p = design capacity of pipeline.

Annual operation and maintenance costs for pumping stations are given by

$$A_n = 2.12\, X_p'^{\,-.314}$$

where

A_n = annual operation and maintenance cost in thousands of dollars per station per mgd of flow.

X_p' = pipeline flow level in mgd.

Treated water storage requires a capital investment of

$$C_{ts} = 14.3\, X_{ts}^{-.274}$$

where

C_{ts} = equivalent annual unit cost for treated water storage in thousands of dollars per million gallons.

X_{ts} = design capacity of treated water storage facilities in millions of gallons.

The design capacity is estimated as 25 percent of the maximum daily use. Operation and maintenance costs for treated water storage are given by

$$A_{ts} = 1.80\, X_{ts}^{-.274}$$

where

A_{ts} = annual operation and maintenance costs in thousands of dollars per million gallons.

The capital cost for raw water storage is

$$C_{rs} = 1.55\, X_{rs}^{-.201}$$

where

C_{rs} = equivalent annual unit costs for raw water storage in thousands of dollars per million gallons.

X_{rs} = raw water storage design capacity in millions of gallons.

The operation and maintenance costs for raw water storage are

$$A_{rs} = 0.10\, X_{rs}^{-.201}$$

where

A_{rs} = annual operation and maintenance cost in thousands of dollars per million gallons.

Figure 2-14 (Continued). Water Model Cost Factors

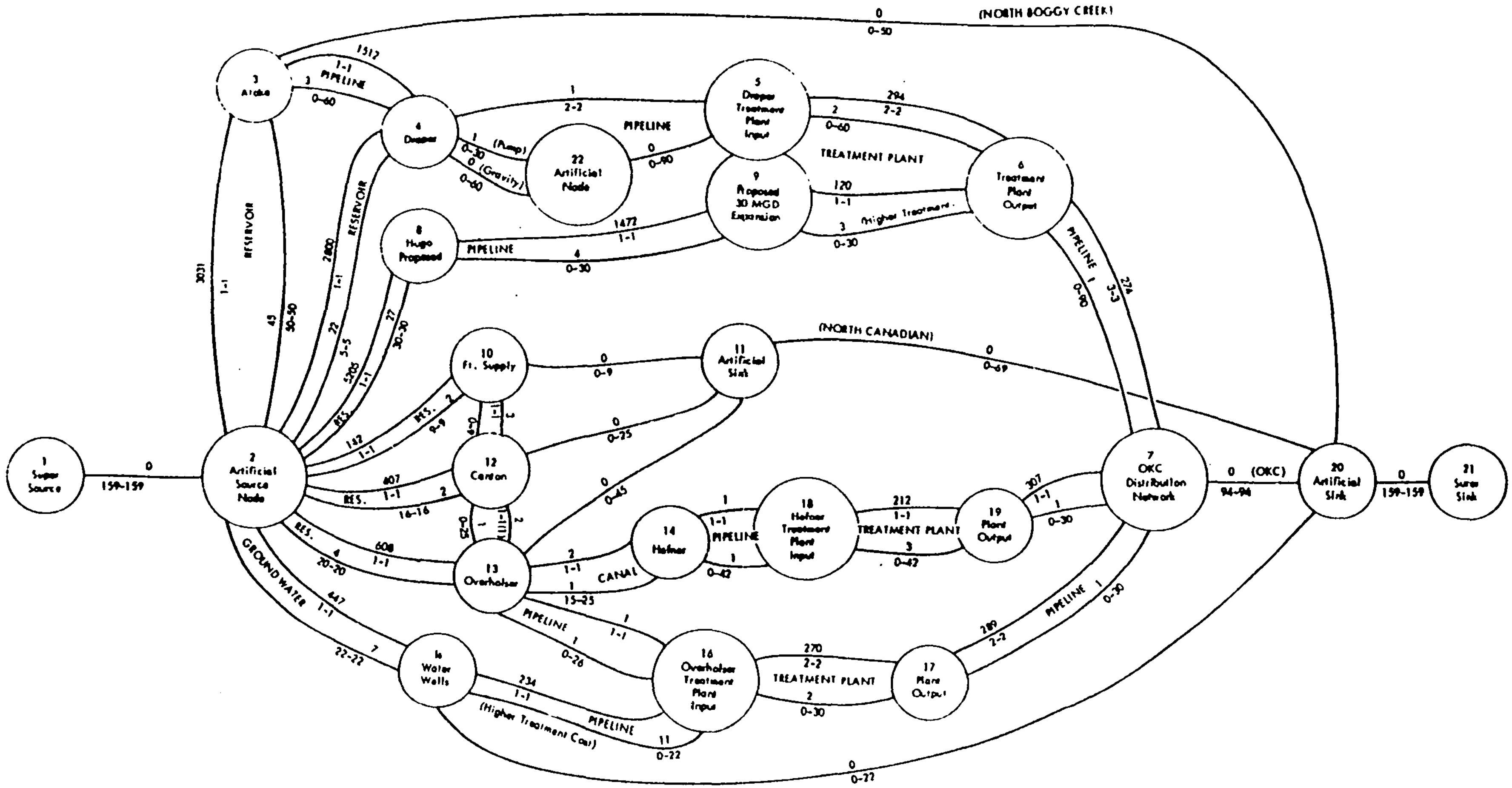


Figure 2-15. Water Model Input -- Network (11)

WATER BY WATER TREATMENT PLANT THOUSANDS OF GALLONS PER DAY YEAR 1970- 0

	1	2	3	4	5	6	7	8
DOMESTIC	9767.3	3456.0	1834.8	19736.1	0.9	510.7	6536.2	2676.5
INSTITUTIONAL	3731.2	1656.1	0.	1313.6	0.	0.	433.8	34.7
COMMERCIAL	544.8	53.9	0.	717.4	0.	0.	169.2	23.7
IRRIGATED LAND	0.	1252.5	0.	0.	0.	0.	0.	0.
SIC 19	36.7	12.0	4.1	16.3	2.0	9.0	2.0	69.6
SIC 20	252.0	82.6	28.0	112.1	14.0	61.6	14.0	478.8
SIC 21	30.2	9.9	3.4	20.3	1.7	7.4	1.7	57.5
SIC 22	115.9	38.0	12.9	51.6	6.4	28.3	6.4	220.2
SIC 23	56.0	3.5	1.2	234.8	0.6	7.0	0.6	20.5
SIC 24	2400.1	15487.3	18.1	7589.1	9.0	255.8	9.0	309.2
SIC 25	14.2	4.7	1.6	6.3	0.8	3.5	0.8	27.0
SIC 26	1757.2	576.0	195.2	781.9	97.6	429.5	97.6	3338.6
SIC 27	46.8	15.3	5.2	20.8	2.6	11.4	2.6	[illegible]
SIC 28	2625.1	860.5	291.7	1168.2	145.8	641.7	145.8	4987.7
SIC 29	4528.3	1484.3	503.1	2015.1	251.6	1106.9	251.6	8603.7
SIC 30	429.4	66.7	22.6	90.5	11.3	49.7	11.3	[illegible]
SIC 31	38.7	12.7	4.3	17.2	2.2	9.5	2.2	73.5
SIC 32	258.1	84.6	28.7	114.9	14.3	63.1	14.3	490.4
SIC 33	2019.3	660.6	223.9	896.8	112.0	492.6	112.0	[illegible]
SIC 34	44.8	14.7	5.0	19.9	2.5	11.0	2.5	65.2
SIC 35	75.8	24.8	8.4	33.7	4.2	18.5	4.2	144.0
SIC 36	47.5	15.6	5.3	21.1	2.6	11.6	2.6	[illegible]
SIC 37	99.2	32.5	11.0	44.1	5.5	24.2	5.5	[illegible]
SIC 38	65.3	21.4	7.3	29.1	3.6	16.0	3.6	124.1
SIC 39	31.5	10.3	3.5	14.0	1.7	7.7	1.7	63.6
SIC OTHER	419.1	1098.7	25.2	832.9	12.6	72.8	12.6	432.6
TOTAL ALL SIC'S	15387.3	20616.7	1409.6	14131.0	704.8	3338.9	704.8	24108.4
TOTAL ALL USER	29430.6	27035.1	3244.4	35898.1	705.7	3849.6	7844.0	[illegible]

Figure 2-16. Water Model Output -- Demand (11)

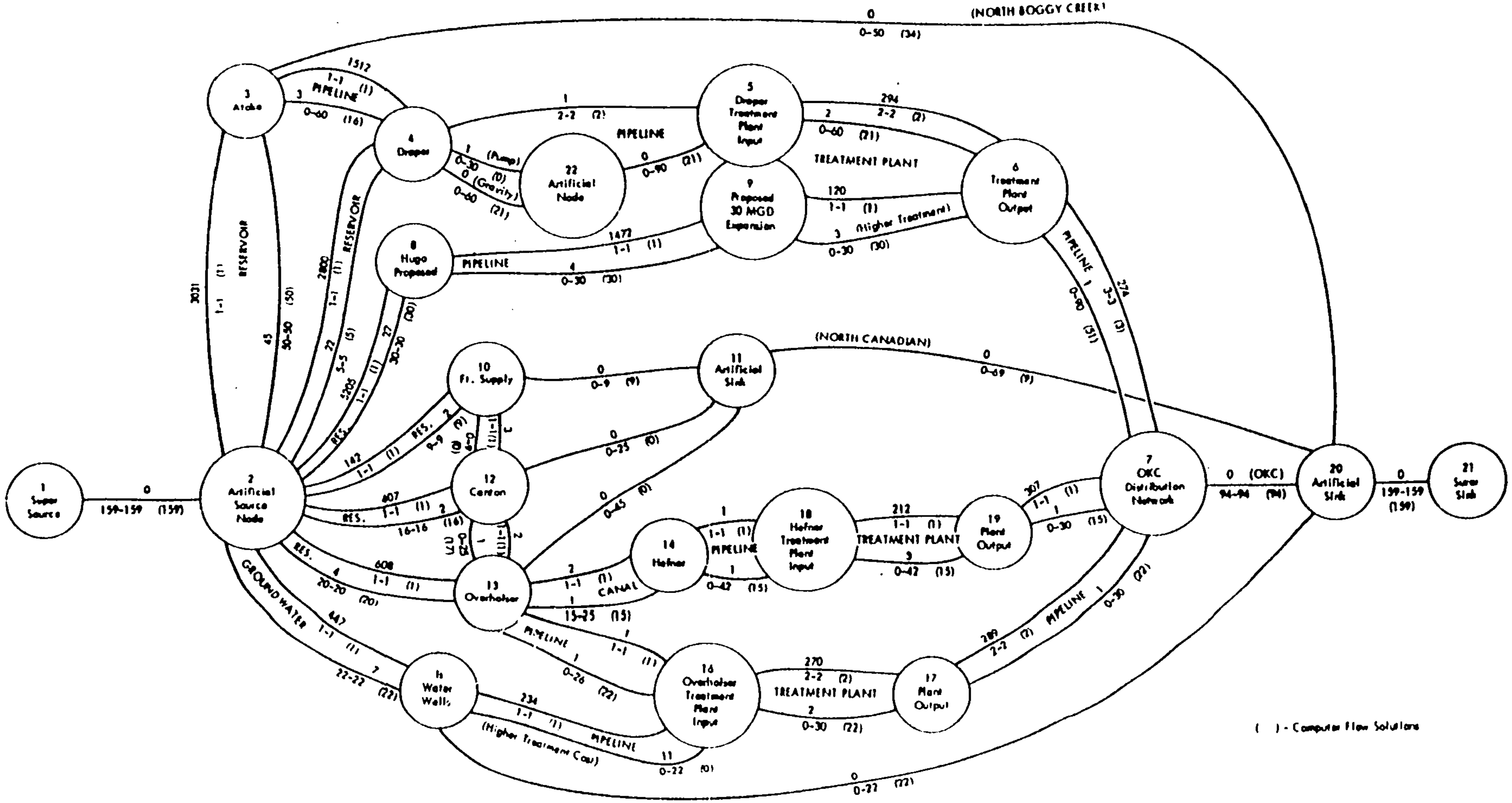


Figure 2-16 (Continued). Water Model Output -- Network (11)

2.7 THE SOLID WASTE MODEL

The solid waste model was proposed to be used to assist in the planning of urban or regional solid waste systems. As proposed the model consisted of three sub-models. The first sub-model is completely developed and validated. The second and third sub-models are formulated but not validated. However, they were sufficiently developed to be used in testing the system of models.

The model concept is similar to the water supply and sewage models. Three sub-models are used together as shown in Figure 2-17. Starting with the present time, the cycle is repeated in five year steps until the desired forecast year is reached. At that time, alternative solid waste disposal plans are investigated using the same procedures as with the water supply and sewage models. Each of the three sub-models is described below.

The total solid waste generation sub-model for a typical U. S. metropolitan area uses the predictions of the population model to predict the volume of residential and commercial-industrial solid waste per year at a future year. In addition to the predictions from the population model, it is assumed that there will be an annual increase in the amount of solid waste generated per person.

The small area sub-model is used for predicting future residential, commercial, and industrial solid wastes for areas within the metropolitan area. It uses the predictions of the population, housing and land use models, plus the results of the sub-model above. The procedure disaggregates the results of the first sub-model based on demographic characteristics of the small areas and the location of commerical and industrial sources.

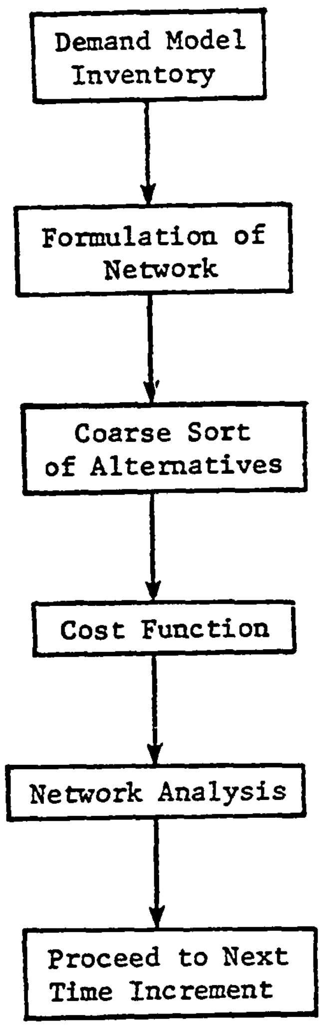


Figure 2-17. The Solid Waste Model (14)

The solid waste collection and disposal sub-model minimizes the systems cost by a trial and error process. First, given the sources and amounts of solid waste to be collected and the existing disposal sites, the cost of collection and transportation from each generation site to all reasonable disposal sites is calculated. Second, the cost of collection and transportation from each generation site to all reasonable additional disposal sites being considered is calculated. Third, an integer programming problem is solved using the branch and bound algorithm. The solution to this problem will show the least cost and the way the collections should be made for the disposal sites being considered. Fourth, the cost of the disposal sites used are added to the other costs. Fifth, the process is repeated using more or less sites until the least expensive combination of disposal sites is found.

The first and second sub-models have not been published. The third sub-model has not been published as proposed, but is similar to a model published by Williams Brothers Engineering Company (15).

2.8 THE AIR POLLUTION MODEL

The air pollution model was developed by using demographic parameters to predict future air pollution emissions, concentrations, and cost-to-abate for urban areas. A simple diagram of the model structure is shown in Figure 2-18.

The demographic parameters used are population, number of passenger vehicles registered in the county, and the percent of the work force employed in manufacturing. The types of pollutants considered are particulates, sulfur dioxide, carbon monoxide, nitrogen oxides, and hydrocarbons. By using the results from regression analysis, future air

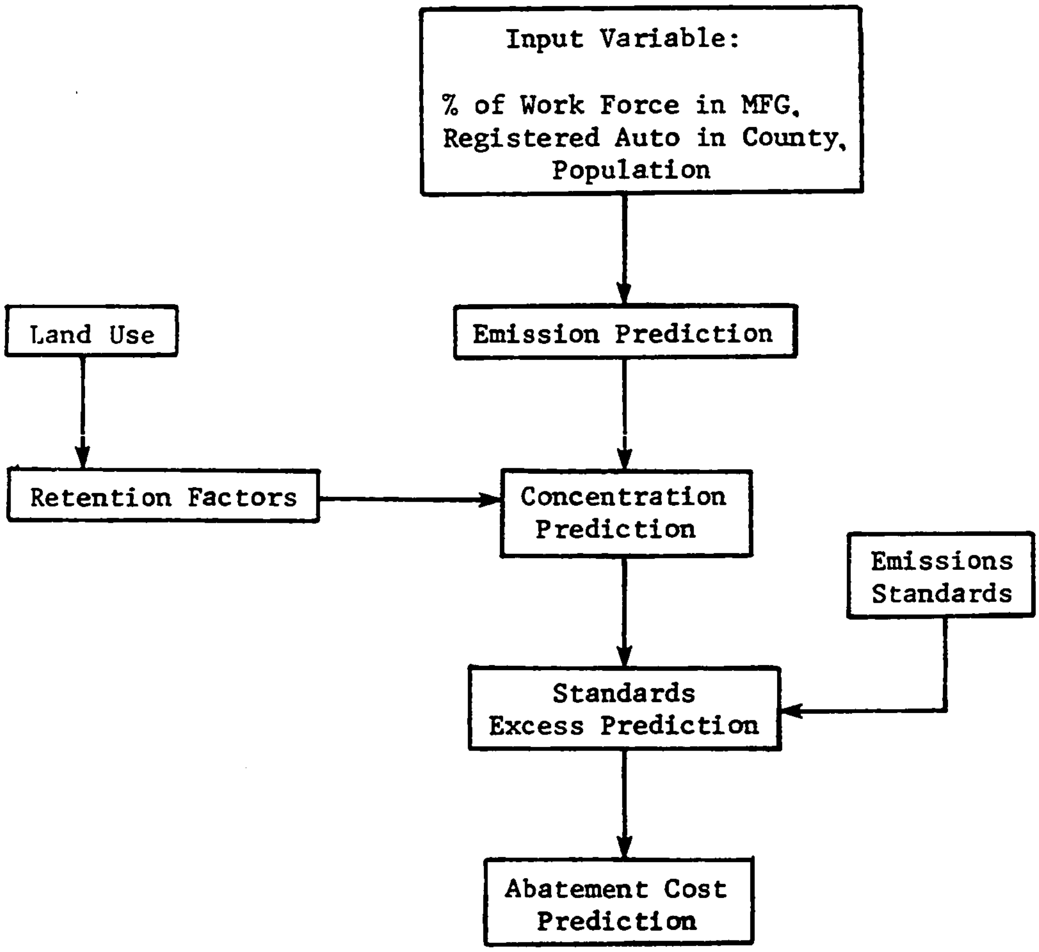


Figure 2-18. The Air Pollution Model (14)

pollution emissions, measured on one-ton-per-square-mile-per-year basis, can then be predicted within a reasonable level of confidence for an urban area.

Reduction in air pollution emissions from mobile sources, as a result of the Air Quality Acts (7) requirement for manufacturers of reduced pollution engines by 1975-1976, is also considered in predicting future pollution emissions. Assuming that a 10-year period will be required for the eventual replacement of high pollution potential engines, a step function was included in the model to complete the reduction in air pollution emissions from mobile sources.

A meteorological retention factor, developed by George C. Holzworth (9), was also included in predicting the future concentration of air pollution in a city. Holzworth's retention factors are presented as isopleth values. This averaging is justified by the fact, that the progression of the values between isopleths was practically linear.

The model also determines if the predicted air pollution concentration will be within the limits of the existing legal standards. This is done by computing the difference between the predicted concentration and the standards. If the concentrations exceed the standards, the amount of the excess is considered to be the amount that must be abated in the future. Finally, the model predicts the total costs-to-abate by multiplying the number of tons in excess of the standards by an average cost-per-ton-to-abate, developed by Le Sourd, et. al. (10).

A more detailed discussion of this model can be found in reference (4) and (14). An example of this model's output is shown in Figure 2-19.

Predicted and Measured Concentrations for Validation Cities

CITY	CONCENTRATION ($\mu g/M^3$)									
	PART		SO_2		CO		NO_x		HC	
	PRED	MEAS	PRED	MEAS	PRED	MEAS	PRED	MEAS	PRED	MEAS
Detroit	171	140	328	300						
Memphis	82	90	127	130						
Denver	30	40	44	60	253	320				
Chattanooga	55	72	72	52			45	58	320	404
St. Louis	74	95	121	130	683	650				
Atlanta	60	70	90	100						
Indianapolis	68	80	107	130	606	540				
Milwaukee	100	117	169	156						
Tulsa	39	53	54	78			37	40		
Average Prediction Accuracy %	81.33		84.62		87.77		85.04		79.20	

Figure 2-19. Air Pollution Model Output (14)

2.9 THE DRAINAGE MODEL

The main objective of the drainage model was to develop a method which can be used to provide indicators concerning pollution loads in storm run-off drainage. The model used here was taken from three previous studies (2), (3), (6). In these studies regression analysis was used as the technique for obtaining indicators.

Two predictions of water run-off volume are used in the present study. The first prediction is for the volume of run-off of individual events. The method for estimating this storm water run-off volume is the "Rational Method" (5). The second prediction estimates the average monthly, seasonal or annual run-off volume. The method used in the second prediction is to calculate the total area of impervious surface then multiply by an appropriate run-off coefficient and by local precipitation data to determine the run-off from the impervious portion of the watershed. Run-off data for a primarily undeveloped watershed in the vicinity are then used to estimate run-off volumes from the pervious areas of the drainage shed in question. The total amount of run-off is given by the sum of run-off volumes from the impervious and pervious areas.

The parameter concentrations are obtained through regression analysis. The four pollutant items studies are total coliform, COD, total solids, and soluble orthophosphates. Regression equations of these pollutant items are derived for residential areas, commercial and industrail areas, and combined land use. These models are based on the estimation of dispersed, rather than localized, pollution sources. The existence of localized sources of pollutants within the watershed being studies would, of course, result in higher concentrations than would be predicted by the models. An example of one portion of the model (total solids) is shown in Figure 2-20.

The best regression equations for total solids and their coefficients of correlation (R)

for combined land use area:

$$M_4 = 2.12 + 50.2\,(X_{15})$$
$$R = 0.733$$

for residential area:

$$M_4 = -139 - 15.4\,(X_{10}) + 16.0\,(X_{12}) + 2.57\,(D_4)$$
$$R = 0.765$$

for commercial and industrial area:

$$M_4 = 162 + 67\,(X_{15})$$
$$R = 0.839$$

where,

M_4 = Total solids (Arithmetic mean) in mg/l.

D_4 = Fall of drainage area in ft.

X_{10} = Covered sewer/total length

X_{12} = Non-arterial streets in area/total area

X_{15} = Unused space in area/total area

Figure 2-20. Total Solids Sub-Model (14)

2.10 SUMMARY

The system of models is based on the population model, the driving force of the complete urban system. The housing model and heuristic land use models are then used to project future housing needs and land use. The results of these projections are evaluated by the consequences models: the transportation model, the water supply model, the sewerage model, the solid waste model, the air pollution model, and the drainage model. Outputs from these consequence models are evaluated by experts in their respective fields.

In the system of models presented here, no formal experts' evaluation procedures are formulated. The results from the present consequence models are presented to the professionals (e.g., engineers, managers, technicians, etc.), and they will evaluate the decision consequences. If the evaluation indicates that demands are not being met or results indicate that the decisions are unrealistic or impractical, a feedback loop will enable a new set of decisions to be made in the land use model. Otherwise, the projection will proceed to the next increment of the planning period by running the population model again to start a new loop of the urban system analysis.

A summary of all the sub-models is shown graphically in Figure 2-21. Table 2-1 is the summary of all sub-models indicating the objectives, the basic methodology, input data, and output of each model.

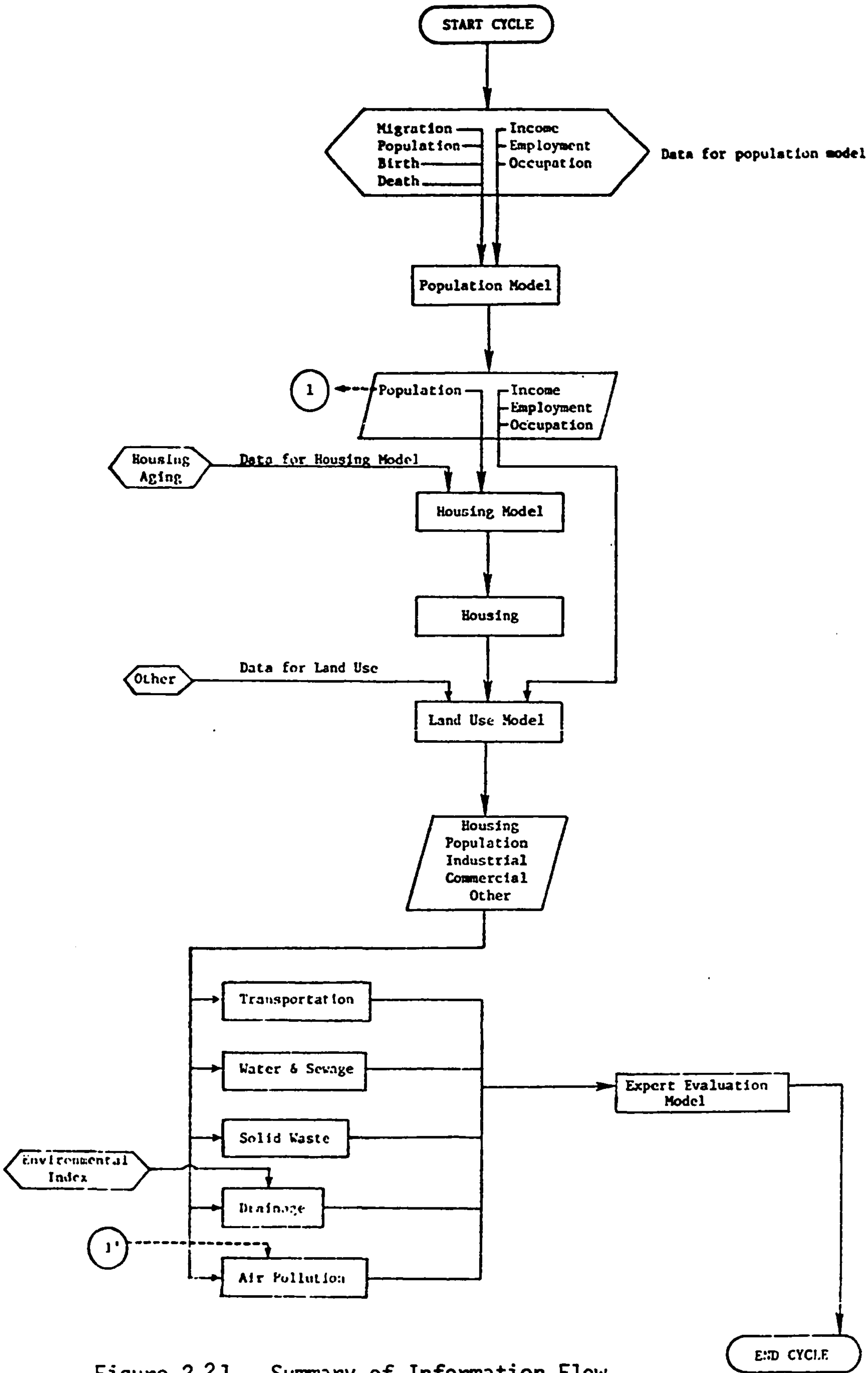


Figure 2-21. Summary of Information Flow

Table 2-1. Summary of Models

Model	Objective	Method(s)	Input	Output
Population	Forecast regional population	Cohort survival or disaggregation	Base population, Fertility and survival rates, and migration	Population
	Forecast income Forecast employment and occupation	Statistical distribution regression		Income Employment and occupation
Housing	Forecast regional housing demand	Input-Output matrix and cohort survival	Base housing and population and income	Housing requirements
Land Use	Forecast land use and periphial attributes,	Delphi and Gaming	Output from population and housing models Existing land uses and personal information	Population and housing by small areas, land uses and personal insights concerning development
Transportation	To provide information to assist in urban transportation planning	Mathematical programming (Separable variable programming)	Transport demand by modes. Network performance cost.	Transport network based on cost and need.
Water Supply	To provide information to assist in urban water planning	Mathematical programming (Out-of-kilter algorithms)	Current water use by type of users. Unit cost of water network.	Projected water use by categories. The flow for each link in the network and cost.
Sewage	To provide information to assist in urban sewerage planning	Same as water model	% of water used that is returned as sewage. Unit cost of sewage network.	Projected sewage volume. The flow for each link in the network and cost.
Solid Waste	To provide information to assist in urban solid water management	Same as water model	Waste generation. Unit cost for transport and disposal. Network.	Projected solid waste generation. The load in each route in the network and cost.
Drainage	To provide indicator concerning storm runoff drainage in an urban environment.	Regression Analysis	Population, % of arterial streets., length of main stream, % of unused space, % industrial land.	Consentration of Coliforms COD, total solids, soluble orthosphosphates.
Air Pollution	To predict future air pollution	Correlation Analysis	Population, Auto registration, % of work force in manufacturing.	Emission concentration and abatement cost prediction.

2.11 REFERENCES

1. Alguire, R. T., Computer Model for Regional Planning of Water and Sewer Systems. Ph.D. Dissertation, University of Oklahoma, Norman, Oklahoma, 1974.

2. AVCO Economic Systems Corporation, A Multi-phasic Component Study to Predict Storm Water Pollution from Urban Areas, U.S. Department of Interior, Office of Water Resources Research, December 1970.

3. AVCO Economic Systems Corporation, Storm Water Pollution from Urban Land Activity. U.S. Department of Interior, Federal Water Quality Administration, FWQA Publication No. 11034FKL, July 1970.

4. Carter, J. W., An Urban Air Pollution Prediction Model Based on Demographic Parameters. Ph.D. Dissertation, University of Oklahoma, Norman, Oklahoma, 1973.

5. Chow, Ven Te, Ed., Handbook of Applied Hydrology. New York, McGraw-Hill Book Company, 1964.

6. Cleveland, Jerry G., Evaluation of Dispersed Pollutional Loads from Urban Areas. Bureau of Water Resources Research, University of Oklahoma, Norman, Oklahoma, April 1970.

7. Federal Register, National Primary and Secondary Ambient Air Quality Standards. Federal Register, Volume 36, No. 84, Title 42, April 30, 1971.

8. Forrester, J. W., Urban Dynamics. M.I.T. Press, Cambridge, 1969.

9. Holzworth, George C., Air Pollution Climatology and Forecasts: A Review. Presented at the Conference on Air Pollution Metheorlogy of the American Meteorological Society, Raleigh, N.C., April 5-9, 1971.

10. Le Sourd, D. A. and Fogel, M. E., Comprehensive Study of Specified Air Pollution Sources to Assess the Economic Effects of Air Quality Standards. Research Triangle Park, N.C.: Environmental Protection Agency, 1970.

11. Reid, G. W. and Alguire, R. T., Systems Approach to Metropolitan and Regional Area Water and Sewer Planning. Bureau of Water and Environmental Resources Research, University of Oklahoma, Norman, Oklahoma, May 1973.

12. Reid, G. W. and Bollinger, H. K., Multistructured Population Forecasting Model. Bureau of Water and Environmental Resources Research, University of Oklahoma, Norman, Oklahoma, 1969.

13. Reid, G. W. and Lawrence J. F., Models of Urban Environment. Presented at the Joint National Meeting of the Operations Research Society of America, ORSA, The Institute of Management Sciences, TIMS, and the Systems Engineering Group of the American Institute of Industrial Engineers, AIIE, Atlantic City, N.J., November 1972.

14. Reid, G. W., Lawrence, J. F. and Law, S. Y., An Urban Model for the Evaluation of Alternative Growth Policies. Bureau of Water and Environmental Resources Research, University of Oklahoma, Norman, Oklahoma, October 1975.

15. Sears, D. W., The New York State Regional Housing Model: Simulation for Public Policy Making, Working Paper DWS-701. Office of Planning Coordination of the State of New York, March 1971.

16. Williams Brothers Engineering Company, Solid Waste Management Study for the INCOG Region, Resource Sciences Center, Tulsa, Oklahoma, September 1972.

CHAPTER 3

OPERATION OF THE SYSTEM OF MODELS

3.1 USES OF THE MODELS

The system of models is intended to suggest what an urban area can reasonably become or be made to become by selecting certain planning options. By so doing, the system can be of further use in indicating which options can move the urban area toward or away from a future state described by the models. The end result is to clarify the viable options and to influence the choice of alternative actions in the present. These models do predict a future state, but no model yet conceived can predict the future with absolute accuracy. The intent here was to produce a set of models with sufficient forecasting ability for use as a planning base.

The nature of urban planning is such that for a model or set of models to be most useful, indeed even used at all, it must have the capability to produce more than long-range comprehensive forecasts. Comprehensiveness is necessary to produce realistic long-range forecasts, yet the practicing planner is more often concerned with incremental problems. If he does not have a practical capability of looking at these day-to-day situations in the light of comprehensive guide lines, then the effectiveness of the systems approach is greatly diminished. Thus, in addition to being used for looking at an urban area from a comprehensive view point, these models are intended to be useful in addressing questions that need to be answered quickly and from a limited point of view. This duality of use requirement is facilitated by means of a system of relatively simple modular models which can function either as a system when a comprehensive forecast is desired or as individual models or subset of the system when the situation requires this. The modular scheme gives the system the following additional capability. Political and economic considerations dictate that any system of models, such as that presented here, must also have the capability of being used in conjunction with existing models which might previously have been developed or adopted. Further, the scheme allows for ever present political realities such as commitments to previous forecasts that might be compromised by a new forecast. In these situations, a system that could not incorporate previous work would not be useful simply because the users would not want to use it. Although compatibility with unknown models and forecasts cannot be guaranteed, this system of models should be usable in most situations.

The system of models can also be used as a teaching device and an information gathering device. Though not designed for this use, the gaming part is especially well suited for both applications. For example, its use in the education of lay decision makers might be attractive. Perhaps of more interest to the practicing planner, these games can also be used as an information gathering device. The nature of the interaction that occurs during a game stimulates the exchange of information between players. If tapped, this information could be of use in decision making.

The intended users of the system were originally envisioned to be an interdisciplinary team of experts in the urban area. Such a situation may not always be possible but by designing the system for use by such a team, the flexibility is always there to substitute persons not recognized as experts. The system can be used by any group intimately knowledgeable about the particular urban area. Each individual does not have to be knowledgeable about the whole urban area, but as a group the users must have as great a knowledge of many aspects of the urban area as possible.

3.2 SYNOPSIS OF MODEL USAGE

During the development and in the testing of the individual models and sub-systems of models, the Indian Nations Council of Governments (INCOG) region of northeast Oklahoma or, in one case, the Association of Central Oklahoma Governments (ACOG) region of central Oklahoma was used as the study area. The use of the models in these test cases were analogous to the role of looking at specific, timely questions from a limited point of view: the use situation mentioned above. In all cases, except that of land use, the staffs of the planning agencies of the region and the faculty and staff at the University of Oklahoma were used to run the models. In the case of the land use model, various classes at the University of Oklahoma were used for development and testing. These clases were either in sociology or engineering and approximated in the interaction that might be expected from an interdisciplinary group.

A detailed summary of the usage of the land use model as a individual model is given in the following chapter. A cursive summary of usage of the models as sub-systems and individuals is given below.

Various forms of the population model have been used a number of times previous to and concurrently with this study. For the purposes of this study, the model was modified to make it easier to use and to mesh easily with the other parts of the system as explained before. As an independent model, it was used to predict future population for the INCOG area. As part of a sub-system, it was used with each of the other sub-models except for the land use model. When used with the housing model, the program was modified slightly so that the two models actually became one computer program. Here, again, INCOG was the area used. In the case of the water and sewage models, these models (water, sewage, and population) were used as a sub-system. Here, ACOG was the area used.

The land use model, as an individual model, did not use the results of the population model; rather, exogenous population and housing forecasts for the INCOG area were used. The gaming part of the land use model was developed first. The refinement of the land use game took place in three different classes at the University of Oklahoma: one undergraduate civil engineering class and two different undergraduate sociology classes. These first games provided situations for gaming experience with the game and refining the mechanics. Next the Delphi part of the land use model was added and a fourth class, a graduate civil engineering class on urban systems, used the whole model. This time, the model was more tightly structured and tested the hypothesis that this method provided convergence with respect to the formulation of a consensus of opinion on the use of the land. In all four classes, the students were briefly introduced to the concept of gaming; the graduate class also received instruction in the Delphi technique as a method of problem solving. Next the land use model was run using a specially designed and prepared map of the Tulsa metropolitan area as a game board.

A detailed summary of the operation of the total system of models is given below. This investigation of the usefulness of the total system of models in a comprehensive long-range planning role was done by producing a long-range plan for the small urban area of Washington and Benton Counties in northwest Arkansas. The primary urban center in this area is Fayetteville, where the University of Arkansas is located (Figure 3-1). Here, the students taking a short course on urban environmental systems were used to test the whole system, except for the air pollution and drainage models which were included in the test later by the staff at the University of Oklahoma.

The students taking part in the short course included professional engineers, a staff member from the regional planning agency, graduate students from the schools of engineering and public administration and undergraduate engineering students: a total of 17 students. All the participants had some knowledge of the entire area, though in some cases with the students from the University, knowlege was concentrated on the area surrounding the University of Arkansas, Fayetteville, and Springdale. Approximately one-third of the participants had worked for or with an urban or regional planning agency.

After the students were introduced to the methods and models, they were asked to take part in a Delphi probe to establish future trends in migration and housing characteristics for the area and to collect statistics on historical data for analysis (Figures 3-2 & 3-3). The resulting forecasts were used, along with other data, to run the population and housing model computer programs. The other data was base population and housing inventories from censuses. In the population model, the fertility rates and death rates used for the INCOG studies were assumed to be correct for this area also. The matricies used in the housing model were also basically those

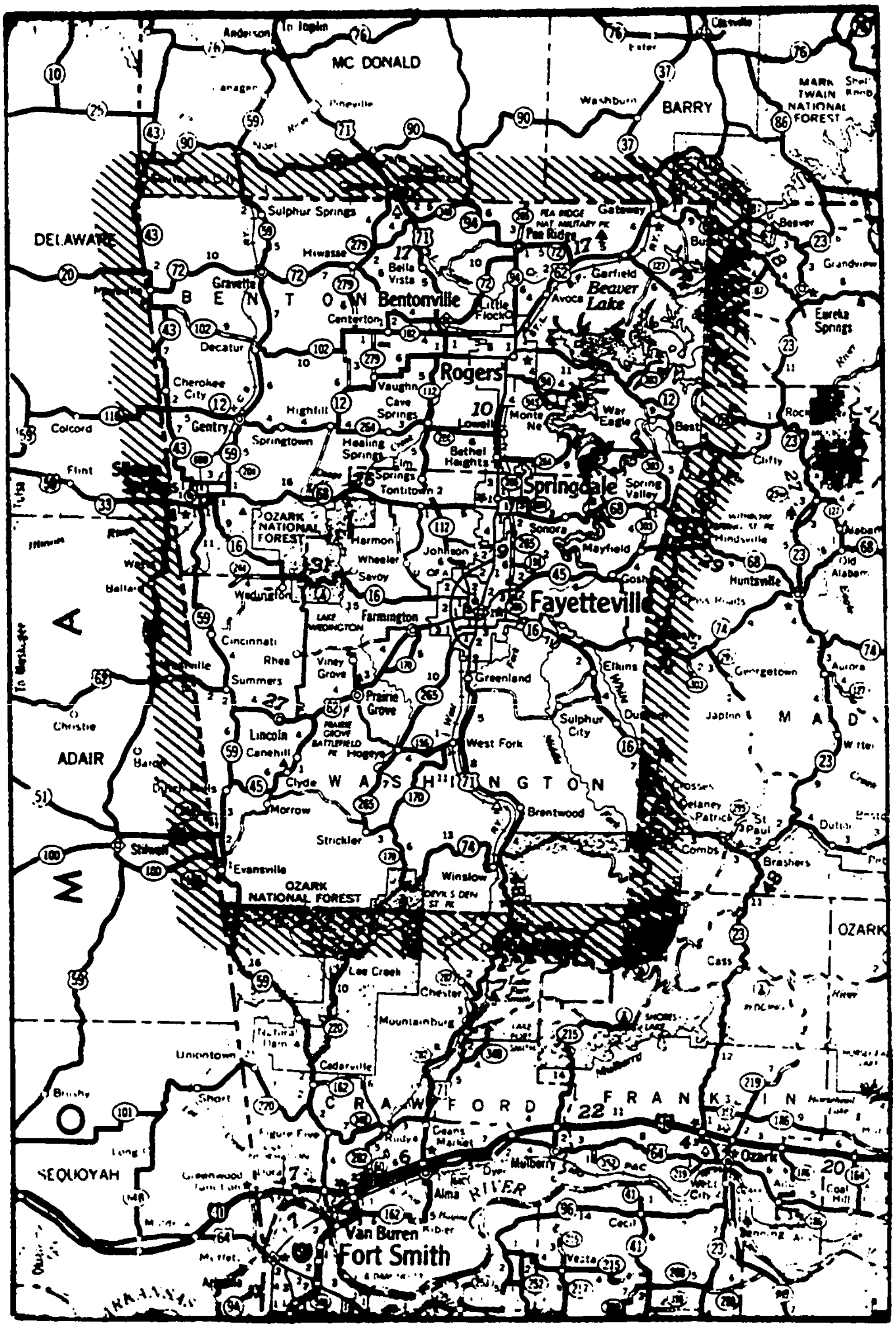


Figure 3-1. Test Area

Population

1. What has the net migration been in the past 5 years for persons:

5 - 14 ______________

15 - 19 ______________

20 - 24 ______________

25 - 29 ______________

30 - 34 ______________

35 - 39 ______________

40 - 44 ______________

45 - 54 ______________

55 - 64 ______________

65 - 99 ______________

2. What will the net migration be in the next 10 years for persons:

5 - 14 ______________

15 - 19 ______________

20 - 24 ______________

25 - 29 ______________

30 - 34 ______________

35 - 39 ______________

40 - 44 ______________

45 - 54 ______________

55 - 64 ______________

65 - 99 ______________

Figure 3-2. Population Delphi Questionnaire

Housing

1. What percent of the households have an income of:

   less than $6,000 ______________

   6,000 - $12,000 ______________

   More than $12,000 ______________

2. What percent of the houses are:

   single family ______________

   multi- family ______________

   mobile ______________

3. What percent of single family homes are renter occupied?

   ____

4. What percent of single-family owner-occupied homes have a value of:

   less than $15,000 ______________

   $15,000 - $25,000 ______________

   More than $25,000 ______________

5. What percent of single-family renter-occupied homes have a rent of:

   less than $100 ______________

   $100 - $200 ______________

   More than $200 ______________

6. What percent of multi family homes have a rent of:

   less than $100 ______________

   $100 - $200 ______________

   More than $200 ______________

Figure 3-3. Housing Delphi Questionnaire used in the INCOG studies--changed where necessary as a result of the Delphi.

Following the running of the population and housing models, another Delphi was constructed to determine what type of industries might be attracted to the area (Figure 3-4). Due to the limited amount of time available for the course, this and succeeding Delphi's were abbreviated to make possible the summing of the complete system. Because of the abbreviated Delphi, the results were altered where they deviated appreciably from the predictions available from the Northwest Arkansas Regional Planning Commission.

The land use model was then run. The first step in this model was a Delphi on potential residential areas and industrial sites in the two-county region. Here, a short cut was taken from the method described in detail in the chapter on the land use model for the handling of spatial responses. Each person made an overlay map for a response on tracing paper. By superimposing these overlays it was possible to quickly approximate the quasi-statistic associated with the graphical responses.

The second step in the land use model was a game. For this game, the seventeen participants were divided into three major groups: developer-oriented, government-oriented, and citizen-oriented. The development-oriented group consisted of two individuals concerned with industrial development, one concerned with commercial development, and three concerned with residential development. The government-oriented group consisted of five individuals representing one each from the following.
The regional planning group, the cities of Fayetteville and Springdale, the cities of Rogers and Bentonville, the remaining towns in Washington County, and the remaining towns in Benton County. The citizen-oriented

Industrial

Rate the following manufacturing groups as to their likelihood of coming to the area in the next 10 years.

	very unlikely 0.	1.	2.	3.	4.	very likely 5.	
Food and Kindred products							______
Tobacco Manufactures							______
Textile mill products							______
Apparel and other finished products made from fabrics and similar materials							______
Lumber and wood products, except furniture							______
Furniture and fixtures							______
Paper and allied products							______
Printing, publishing, and allied industries							______
Chemicals and allied products							______
Petroleum refining and related industries							______
Rubber and miscellaneous plastics products							______
Leather and leather products							______
Stone, clay, glass and concrete products							______
Primary metal industries							______
Fabricated metal products, except machinery and transportation equipment							______
Machinery, except electrical							______
Electrical and electronic machinery, equipment, and supplies							______
Transportation equipment							______
Measuring, analyzing and controlling instruments; photographic, medical and optical goods; watches and clocks							______
Miscellaneous manufacturing industries							______

Figure 3-4. Industrial Delphi Questionnaire

group consisted of six participants representing land owner groups and ecologically involved groups.

To start the game, each individual or small group was given an assignment. The developers assignment was to locate where the preferable sites of development were for their area of interest. In doing so they had to account for the projections from the previous sections of the models. The players having the roles of governmental bodies were given the assignment of producing plans and guidelines for development. The citizens were given the task of identifying important factors of the area which might have an effect of development. This group ultimately made their own plan for development.

After the first task was complete, the developers presented their desired development plans. If, for example, the residential developers proposed the development of an area in rural Benton County, they would present their proposed development before the regional planning agency and the county representative. One or more citizens would attend this presentation to express their views. Once the major arguments had been made, the group decided on the events most likely to occur.

Normally, before progressing to the next stage in the system of models, there would have to be a decision as to the acceptability of the land use results. This could mean that all or part of the model would be repeated. In the test case, the results were accepted but modified slightly where the game operator felt a change in the forecast was warranted.

In the next step of the system of models, the students were divided into three groups for the purpose of working with three of the technical sub-models. The three models chosen were the water supply, sewage, and solid waste models. Each group was asked to formulate a plan (water supply, sewage, or solid waste) to meet forecasted demand in 1985. In formulating this plan, each group determined the demand from information from earlier phases of the model system, then formulated at least two alternatives and evaluated them.

3.3 VALIDATION OF THE MODEL

The idea of producing reasonable results is basic to model validity but has often been the sole criteria used in validation. Yet, this one criteria indicates nothing about the usefulness of the model in question, and usefulness should also be a necessary criteria for validity. Some administrators would argue that it is the only necessary criteria. Thus, in this study, in addition to the requirement of producing reasonable results, a valid model is one judged useful to those for whom the model was intended. Though this requirement is "above and beyond" that normally required for a model to be deemed valid, it is necessary to ensure that the system of models can be used in day-to-day planning situations. Therefore, the definition of validity was extended to include a declaration of usefulness.

The results of the final test, involving the entire system of operating models, were of two types: numerical results involving the model outputs and statistical analysis and, most importantly, a subjective result concerning the usefulness of the approach. Looking at the results in sequential order, the first results were from the Delphi concerning population and housing attributes in Washington and Benton Counties, Arkansas are shown in Tables 3-1 and 3-2 (population and housing results respectively).

Table 3-1. Population Delphi Results

Net Migration 1965-1970

Age Group, Year	Median Response, No.
5 - 14	+2,000
15 - 10	+2,000
20 - 24	+2,000
25 - 29	+500
30 - 34	+750
35 - 39	+500
40 - 44	+500
45 - 54	+1,000
55 - 64	+1,900
65 - over	+800

Net Migration in the Next 10 Years

Age Group, Year	Median Response, No.
5 - 14	+3,000
15 - 19	+3,000
20 - 24	+4,600
25 - 29	+2,000
30 - 34	+1,600
35 - 39	+1,200
40 - 44	+1,200
45 - 54	+2,500
55 - 64	+2,900
65 - over	+1,500

Table 3-2. Housing Delphi Results

Household Income

Income	Median Response, %
Less than $6,000	26
$6,000-$12,000	45
More than $12,000	25

Single-Family Owner-Occupied House

Value	Median Response, %
Less than $15,000	30
$15,000-$25,000	45
More than $25,000	25

Housing Type

Type	Median Response, %
Single family	65
Multi-family	25
Mobile	10

Single-Family Owner-Occupied House

Rent	Median Response, %
Less than $100	20
$100-$200	60
More than $200	20

Occupancy

Occupancy	Median Response, %
Renter	30

Multi-Family Renter-Occupied

Rent	Median Response, %
Less than $100	20
$100-$200	65
More than $200	20

The results of the Delphi, which were of a historical nature and which could be compared to census data, are again shown in Table 3-3 with that census data. The Delphi result of the population portion of the Delphi, which consisted of historic migration estimation, was in obvious error concerning the age groups of college students and retired persons. The explanation for this discrepancy probably stems largely from two sources. The error, relative to other groups, concerned the age group of most college students due to the confusion on the part of some of the participants as to whether they should include the student body of the University of Arkansas in their estimates. Many did not include these students which resulted in an underestimation of in-migration of the 15-19 age group and likewise an underestimation of the out-migration of the 20-29 age group. The error in the retirement age group was probably due, in some degree, to the use of 1965-70 as the test period. During 1970-75, there was a large growth in retirement communities in the area, which probably biased the estimate. The results of the housing portion of the Delphi were more consistent with respect to census data. The ability of the Delphi to produce accurate estimates was tested by means of the binominal distribution. With 15 out of 20 means approaching the true values, the null hypothesis that the response means approached the true values due to chance (H_0: $p=p_0$; $p_0=1/2$), could be rejected at a significant level of approximately $\alpha = 0.1$.

Using the results of the population-housing Delphi on migration and housing trends, the population-housing model program was run to project future population levels and housing requirements. A summarization of the result is shown in Table 3-4. Following this, another Delphi was

Table 3-3. Delphi and Census Estimates

Net Migration 1965 - 1970

Age Group, Yr.	Delphi Estimate, No.	1970 Census Estimate, No.
5 - 14	+ 2,000	+ 1,864
15 - 19	+ 2,000	+ 3,533
20 - 24	+ 2,000	+ 3,073
25 - 29	+ 500	- 371
30 - 34	+ 750	307
35 - 39	+ 500	570
40 - 44	+ 500	578
45 - 54	+ 1,000	1,272
55 - 64	+ 1,900	1,370
65 - over	+ 800	913

Household Income

Income	Delphi Estimate, %	1969 Census Estimate, No. (Adjusted to 1974)
Less than $6,000	26	28
$6,000-$12,000	45	45
More than $12,000	25	27

Housing Type

Type	Delphi Estimate, %	1970 Census Estimate, No.
Single-family	65	80
Multi-family	25	14
Mobile	10	6

Occupancy

Occupancy	Delphi Estimate, %	1970 Census Estimate, %
Renter	30	35

Single-Family Owner-Occupied Homes

Value	Delphi Estimate, %	1970 Census Estimate, % (Adjusted to 1975)
Less than $15,000	30	34
$15,000-$25,000	45	54
More than $25,000	25	21

Table 3-4. Housing Model Results

	Forecasted Additional Housing Units Required	
Type	1985	1995
Single-low	1,718	1,826
Multi-low	495	525
Single-med.	3.712	4,535
Multi-med.	1,070	1,307
Single-high	1,133	1,428
Mobile	88	94

conducted to determine what type of industries might be attracted to the area. Due to the limited amount of time available, this Delphi was not carried to completion and was not analyzed statistically. The prediction of the Delphi and the analysis of possible future industrial development in the area conducted by the Northwest Arkansas Regional Planning Commission were used to arrive at figures to be used in the remainder of the modeling process (Table 3-5). Next, the land use trends for the area were predicted by means of an additional Delphi. Again, due to the limited time, the Delphi was not carried as far as it might have been, yet the results seemed to coincide reasonably well with the studies done by the Northwest Arkansas Regional Planning Commission. For comparison, the summary for future industrial land use resulting from the Delphi and that supplied by the Regional Planning Commission are shown in Figures 3-5 and 3-6 respectively. Again, due to the abbreviated Delphi, no statistical analysis was conducted.

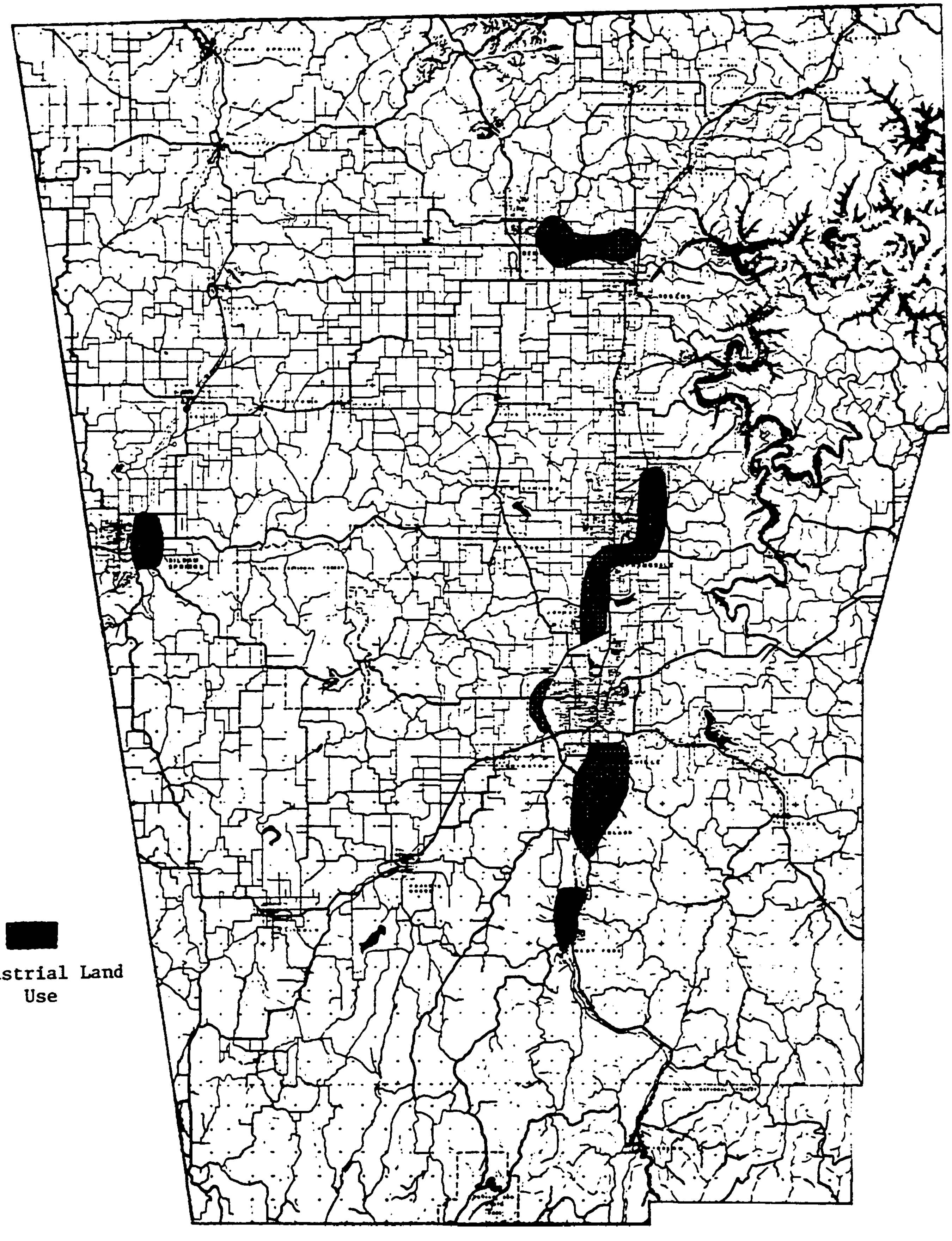
Using this data, the land use game was then played. The results of the game were somewhat mixed in the level of disaggregation obtained in different areas. Here again, the element of time was a limiting factor. While those participants playing the parts of citizen groups and governmental agencies were able to formulate fairly detailed plans and policies, those taking the parts of developers had trouble deciding on the types and distribution of industrial development by SIC codes and industrial sites. Based on observation of the participant play, the reason seemed to be that while the participants playing the parts of citizen groups and participants playing the parts of governmental agencies were able to work together easily, the development group lacked central leadership

Table 3-5. Industrial Delphi Results

SIC	MANUFACTURING GROUP	MEDIAN RESPONSE*
20	Food and Kindred products	5
21	Tobacco Manufactures	0
22	Textile mill products	2
23	Apparel and other finished products made from fabrics and similar materials	2½
24	Lumber and wood products, except furniture	3
25	Furniture and fixtures	3
26	Paper and allied products	2
27	Printing, publishing and allied industries	3
28	Chemicals and allied products	1
29	Petroleum refining and related industries	0
30	Rubber and miscellaneous plastics products	½
31	Leather and leather products	2
32	Stone, clay, glass and concrete products	3½
33	Primary metal industries	0
34	Fabricated metal products, except machinery and transportation equipment	3
35	Machinery, except electrical	2
36	Electrical and electronic machinery, equipment, and supplies	3
37	Transportation equipment	1
38	Measuring, analyzing and controlling instruments; photgraphic, mecical and optical goods, watches and clocks	3
39	Miscellaneous manufacturing industries	3

* likelyhood of coming to area in next 10 years

very unlikely					very likely
0.	1.	2.	3.	4.	5.



Industrial Land Use

Figure 3-5. Industrial Land Use (Delphi)

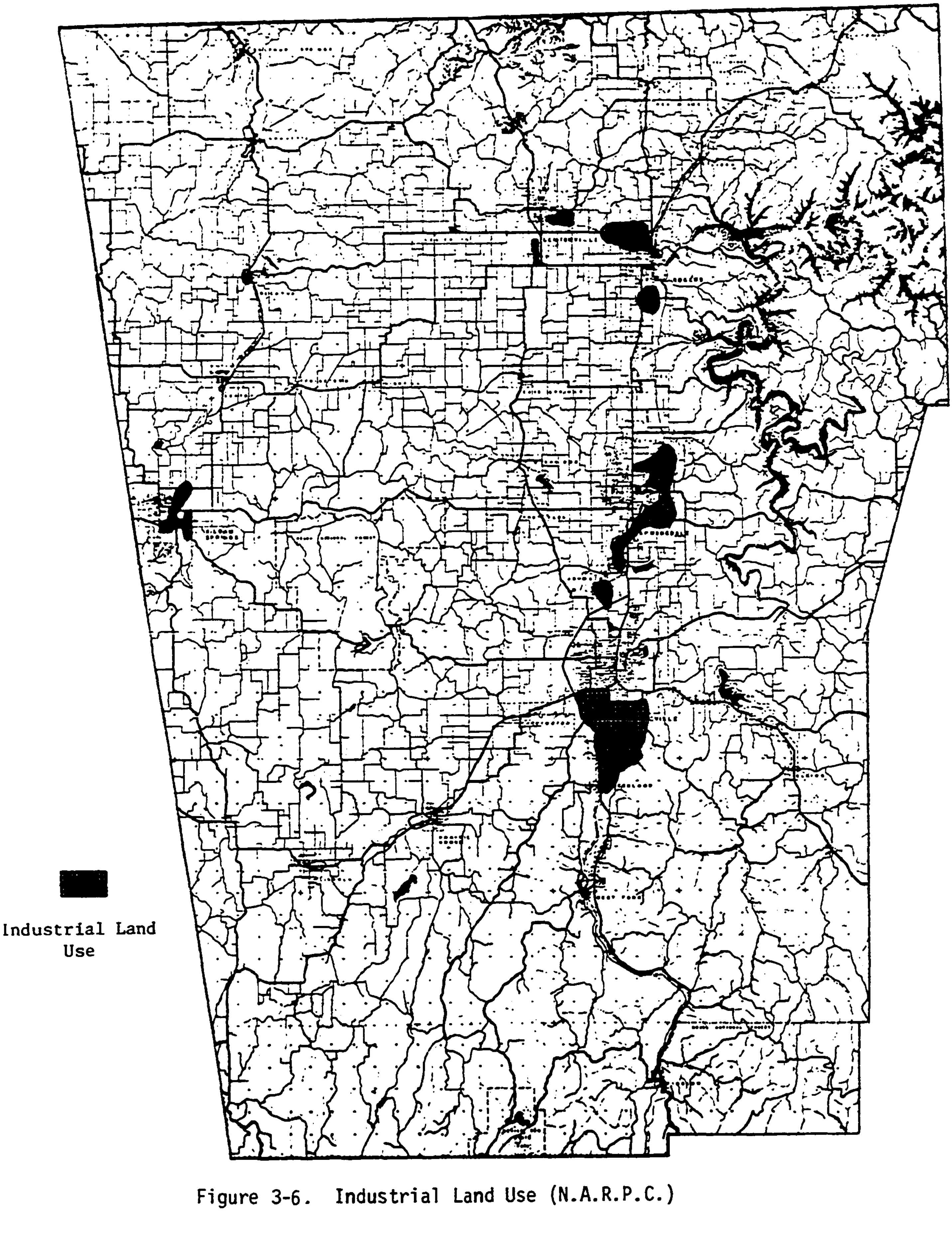


Figure 3-6. Industrial Land Use (N.A.R.P.C.)

among those concerned with industrial, residential, and commercial development. The residential and commercial developers working independently were able to arrive at their result, but the industrial developers were late getting started and ran out of time to complete their decisions. Unfortunately, the time schedule did not allow for an extension of time. To obtain data on which the succeeding model, the industrial developers and those managing the models completed the projection in a post-hoc meeting. The numerical results on the game are summarized in Tables 3-6 through 3-8 . The three technical sub-models used in this test, the water supply, sewage, and solid waste models, were then used by the participants to forecast demand/generation for the years 1985 and 1995. Based on these projections, each cf the three groups started to formulate and evaluate various alternatives. These groups were able to predict water demand and sewage generation using this computer model and solid waste using the land use model supplied. Further, at least one alternative in each area was formulated and costs were calculated. Though a complete analysis was not possible due to time constraints, enough was done to verify that these models were able to function effectively within the system.

Table 3-6. Future Population (Game)

Predicted Population for Major Towns

Town \ Year	1985	1995
Fayetteville	48,000	68,000
Springdale	30,000	40,000
Rogers	17,000	22,000
Siloam Springs	10,000	13,000
Bentonville	8,000	10,000

Table 3-7. Future Commerce (Game)

Acres of Commercial Development
Required for Major Towns

Town \ Year	1975 (existing)	1985	1995
Fayetteville	384	500	700
Springdale	352	500	700
Rogers	113	150	200
Siloam Springs	139	200	250
Bentonville	90	120	150

Table 3-8. Future Industry (Game)

Industrial Employment by 1985

Town \ SIC	20	23	24	25	27	32	34	36	38	39
Fayetteville	200	--	--	--	200	200	500	--	300	300
Springdale	1800	1000	--	300	700	400	1000	1100	800	800
Rogers	300	--	--	--	--	300	--	--	--	300
Siloam Springs	1500	--	275	75	300	500	600	--	1000	700
Bentonville	250	--	--	--	200	200	--	--	200	700
All Others	700	200	100	--	200	500	--	1000	200	--

CHAPTER 4

THE LAND USE MODEL

4.1 INTRODUCTION

The land use model might more appropriately be called the spatial structure model. Its purpose is to do more than forecast future land uses; it forecasts peripheral attributes as well. As a land use model, per se, it bridges the gap between the population-housing level of the system of models which is concerned with the aggregrated metropolitan area and the consequence models, or the technical level of the system, which looks at disaggregated areas. The population and housing models forecast future housing, industrial, and commercial conditions for the area as a whole. The land use model then allocates the totals to specific areas within the whole. In addition to land use, the model has been used to forecast data for input to the transportation model and future environmental attributes. The model, which is wholly heuristic, was orginally intended to be used in conjunction with an erudite mathematical model where possible.

In this role, its main purpose was to evaluate and modify, where necessary, the results of the mathematical model so that the ultimate solution to the problem being investigated would become more sensitive to human factors which cannot easily be cast in terms of explicit mathematical functions. This would not be an ad hoc embellishment to a final solution but an integral part of the solution process. The test area, Tulsa City INCOG, serves as an excellent illustration of how the model would be used to advantage in this role. If one looks at the recent residential development in Tulsa, one would immediately be struck by the fact that, by far, the greatest development has been in the area southeast of the city. This development has extended a considerable distance from Tulsa's center while the area to the north of the city has remained largely undeveloped despite the fact that there is a great deal of prime undeveloped land relatively close to the central business district. An erudite mathematical model which gave strong consideration to trends would probably predict continued growth to the southeast while one which was essentially a gravity model would probably predict growth in the northern area. The truth is that the northern area has not been developing because there is a stigma to the north side of Tulsa, but the city planners there are trying to induce growth in the north. These facts need to be considered during the solution process of a model, where their impact can most easily be put in perspective, not in evaluating the final solution. Besides making subjective arguments an integral part of the solution process, in this role, the heuristic model can strengthen the mathematical model by suggesting modifications to parameters, while the mathematical model strengthens the heuristic model by providing a firm guideline for subjective insights.

Due to the limited scope of this study it was not possible to develop an erudite mathematical model in addition to the other models. As noted earlier, such model typically cost over a million dollars and require manpower not available for this study. For this reason, the use of the model in this role was not chosen as a way of demonstrating the usefulness of the heuristic element in the system of models.

The constraint just mentioned illuminates a most important point in determing the method's usefulness. The situation encountered in the course of this study is not unlike that often faced by a planning agency: the lack of money, time and manpower to develop and run complex models like the system suggested above. Those planning agencies who have been actively involved in urban model building can testify that erudite urban models quickly become quite large (almost unmanageable), very expensive to run, and give results that are difficult to interpret or apply. Also, with the present state of the art, we do not have the necessary theory to support a comprehensive mathematical model. Even if we did have the necessary theory, we do not presently have an adequate data base to realistically simulate an entire urban system with an erudite model.

These convictions were responsible for an extension of the concept of the role of the model from a somewhat secondary role. The original concept was expanded into two areas: an efficient replacement of the mathematical land use model and powerful information gathering techniques. The heuristic model used in this study may not completely bridge these gaps in knowledge, but it circumvents many of the limitations created by the hungriness for mathematical relationships and excessive data encounteres with other urban models. There is an assumption that does have to be made though: that the users of the model can elicit and manage the knowledge that is available to them through this heuristic process. This doesn't seem to be an unreasonable assumption. Actually, the method was not changed; the change was in concept.

4.2 DESCRIPTION OF THE MODEL

The general structure of the model used in demonstrating the heuristic method is quite simple. It consists of three elements: information gathering, individual evaluating, and group evaluating. These elements are designed to interact with one another and with the total system of models. While it is necessary that the elements interact with one another and desirable that they interact with the total system of models, the spatial model can be used by itself if assumptions are made which replace the surrounding models. In some cases, this ability would be highly desirable. These would be cases which required a timely preliminary evaluation of an urban problem. Whether the spatial model is used as part of a larger system or not, its structure is constant.

The spatial model uses an embedded iterative process to acheive an answer to the question(s) under consideration. As indicated in the schematic shown in Figure 4-1, the sequence used to achieve a solution starts with an information element. This informational element consists of both "hard" information which is provided to the respondents being queried by the model users and whatever information, whether "hard" or "soft" that the respondent has acquired previously. The information which the respondents have previous to participating in the running of the model is the key to the model's success. This information and the outcome of the model is indirectly, but very definitely, affected by the choice of respondents. It is therefore extremely important that great care be taken when selecting the respondents for use in the model if valid results are to be obtained. The information provided the respondents is directly controlled by the operators of the model, but its impact on the respondents is somewhat

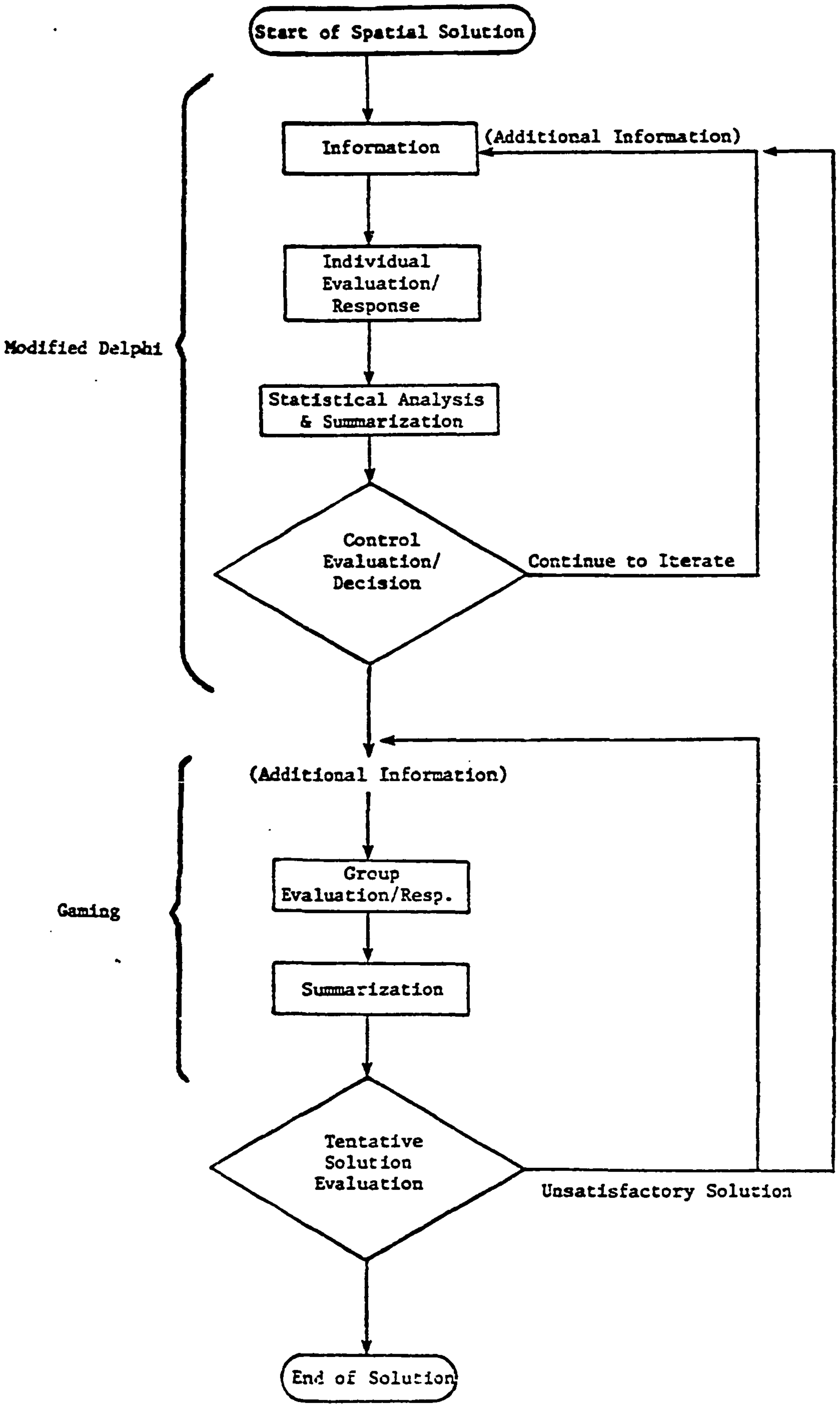


Figure 4-1. Schematic of Spatial Model

"sloppy". So, again, it is important to choose respondents who have the motivation for investing the time necessary for synthesizing the information provided to them. Equally important is the degree of comprehensiveness of the information supplied and format in which the information is presented. Since this element is part of an iterative process, the information provided to the respondents will change each iteration. Some of the change in information will be due to additional information reflecting what transpired in the previous iteration.

The second element encountered, categorized as individual evaluating, consists of the respondents individually evaluating whatever information is available to them and making a response. The evaluating-response procedure is structured by means of a questionnaire. This questionnaire consists of questions whose answers can be summarized statistically, questions whose answers can be presented graphically, space for the appropriate responses, and space for whatever comments the respondent might wish to make. The questions can concern one or more topics or be generally related. As with the information presented to the respondents, it is important to guard against biasing the outcome of the model by the choice of questions. In this respect traditional theories of surveys and questionnaires are helpful, but is must be remembered that this exercise is not designed as a traditional short answer questionnaire and the respondent group is not to be a random sample designed to reflect the population as a whole. The respondent group is small, certainly not random, and in some respects not representative of the general population. The thrust of the entire procedure is to involve the respondents, not only in thinking deeply about the questions asked but also in exploring the system of interactions which are at work in an urban system. The questionnaire is meant to be a stimulus and an organizing factor. Generally, the respondent will have these options with respect to any particular question being asked:

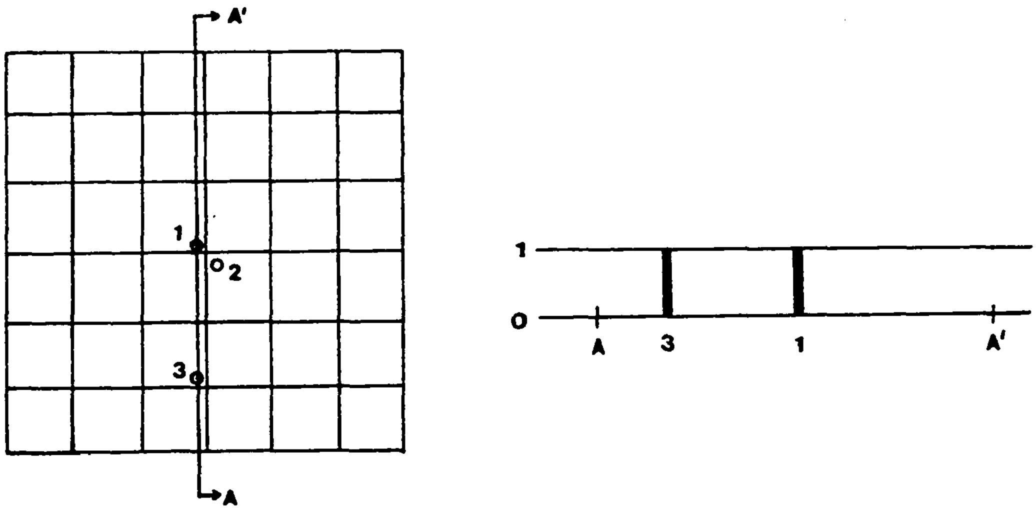
1. He may choose not to answer a specific question if he feels that he could not make a sound judgement on the topic. In this case he is encouraged to make a comment which would indicate what information might help in making the particular judgement.

2. He may simply answer the question.

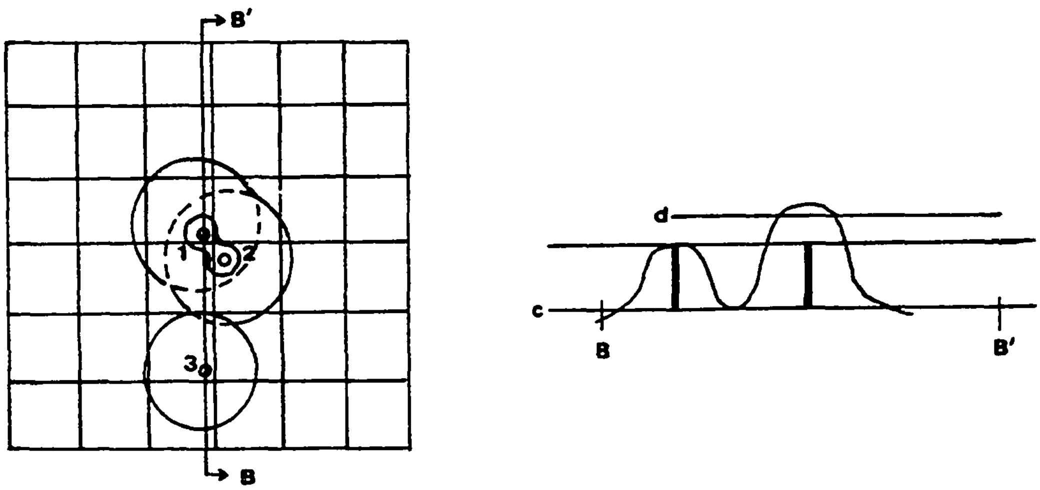
3. He may answer the question and either add or suggest as to additional questions which might clarify an issue or illuminate an area of interest, make a comment expressing a short argument on any judgement about which he feels strongly.

The questionnaires, with their responses, are coded so that hopefully the respondents will be more inclined to express their true opinion about controversial topics. This also would make it easier for a respondent to back down from a position without losing face. Although this does not guarantee the most honest response, it does eliminate some of the blocks to truthful responses. Having made a response, the respondent keeps a copy for his future references and returns one copy to the model operators.

The responses are then analyzed and summarized in the next element of the iterative process. Those questions which can be analyzed statistically are first ranked and displayed graphically to determine whether there is a tendency towards a single mode or two modes. The median and quantiles for each such question is then determined. The questions which do not lend themselves to the above type of analysis will be those questions which will ask for locations on a response map. In this case an improvised statistical analysis was made which, while not of any mathematical significance, was found to be helpful. This simple technique is illustrated in Figure 4-2.



Plan A: Binary Representation



Plan B: Smoothed Representation

Figure 4-2. Quasi-Statistic for Two Dimensions

If, for example three responses were made to a question involving the location of a particular entity, the location might be indicated as shown in Plan A. This point location can be thought of as a binary representation and have a cross-section as shown in section A-A'. If, instead of point locations, the responses are considered to be the point of maximum frequency of some distribution or if the points are smoothed by some process and the results are added, the representation might look like Plan B. The corresponding cross-section to A'-A might then look like B'-B. In this case, some threshold value might be termed "c" as shown in cross-section B'-B versus zero in the binary representation, and some convenient value "d" might take the place of 1. If the locus of points having the values "c" and "d" are plotted in plan B the result is a contour map indicating areas of reasonable probability and areas of greatest probability for location. Although this type of representation is not exactly analogous to the quadrille statistic, it conveys a similar concept which should be helpful in summarizing the results of the questionnaires. Once the responses are summarized, the model proceeds to the next step in the solution process.

Referring back to Figure 4-1, the fourth element in the iterative sequence of the model is a logical element for the individual responses. This is the last element in what is part of the modified Delphi. At this point the users of the model must evaluate the current set of responses and determine whether there will be another iteration of individual questioning or whether there has been sufficient consensus or stabilization to proceed to the next form of question-gaming. If the decision is to make another iteration, the summary of the previous iteration's responses, permanent comments from the previous iteration, and additonal questions as required are prepared so that they can be given back to the respondents on the next iteration. The additional questions may come from suggestions by the respondents themselves for highlighting some aspect of a question which they feel is important or they might come from the model operators for highlighting the reasons for any polarization of views which might occur. In the case of a polarization of views, the degree to which the majority-minority type of polarization is explored will be more a function of the arguments or comments made than of the actual number of individuals taking a particular view. If, in the opinion of the model operators, a sufficient closure has been reached, the sequence continues to the next element, a group response element.

The next element in the sequence of the spatial model is a different form of questioning. This time the question is presented to the entire group of respondents at the same time and is answered by means of a combination of a game response and a written response. The questions proposed to the group in the game are different than those in the previous questionnaires used in the model while the written responses are the same. The difference in this element lies in the type of group interaction which influences the responses. In the game, the respondents do not answer the questions directly but simulate what might occur in the original system. In a sense, the players actually become the active fraction of the model through role playing the elements of the system. The answer to the question which is the game response, is the final state of the game. The rules and structure of the game are quite flexible and can be manipulated to suit the objective of each session. This is accomplished simply by varying the emphasis on each of the aspects of the game.

Four forms of the game were investigated in this study although there are a great number of possible forms. The game could be used as an educational tool by adding a more sophisticated structure and emphasizing a pay-off or reward (as was done in one form of the game that has been used), but this was not the primary purpose foreseen for the technique. The purpose of the study was to develop a tool for gathering information and for helping to solve urban problems. The game was to serve mainly as a stimulus to the flow of information and ideas.

The general procedures for achieving the flow of information and ideas were to present the sum of the information collected in the modified Delphi stages of investigation, to create a stimulus for the respondents to express their viewpoints, and to collect this new information. This is where the elements of the game come into play: the game board, the game pieces, the competition, and the resolution of conflict. The game board is used as a focus point around which the activities of the game take place. This board is in the form of a large map, in the first cases a simplified map of the city and county of Tulsa, Oklahoma, and the other parts of the Indian Nations Council of Governments, INCOG, which would be considered to have a direct effect on and be directly affected by Tulsa. The map portrayed the main streets and roads in the area, the main river, political boundaries, and other features which were felt to give the respondents reference and information. A grid was superimposed over the area both to maintain scale and to be used as a geographic reference. The grid spacings in this study were square-mile areas which closely followed the Oklahoma grid system of townships, ranges, and sections. In the early stages of the development of the gaming procedures, a simple paper drawing mounted on corrugated cardboard was used. Once the scale and grid system were fixed, a more permanent matallic board was made to give the board more flexibility during the game. (See Figure 4-3). In the final test, the game board was a map of the second test area, the two-county area (Washington and Benton Counties) in northwest Arkansas. (See Figure 3-6).

An attractive, well organized board was considered to be the most important physical element of the game. Also of great importance were the game pieces, map pins and colored magnetic pieces. Everyone is inclined to like games, and the purposes of these two elements are to take advantage of that affinity for a game and to generate interest in participating and volunteering information which might not otherwise come out as in a conference situation.

The volunteering of information is also greatly encouraged by the competition in the game. The competition will also have the effect of stimulating interest as will the resolution of conflict; everyone likes to be a winner. The resolution of conflict can take various forms, as suits the game, but it will basically be by means of a democratic decision, with varying degrees of chance. As small as the degree of chance might be, it is nonetheless important for there is something in human nature that causes man to be stimulated by the occurrence of chance. Whatever the degree of chance involved, the resolution of this conflict is the game result.

The game result is important, but perhaps a more important benefit of the game is the collection of information, ideas, social indicators, feelings, and prejudices. For this purpose, in the games conducted, the interaction between members was recorded on magnetic tape.

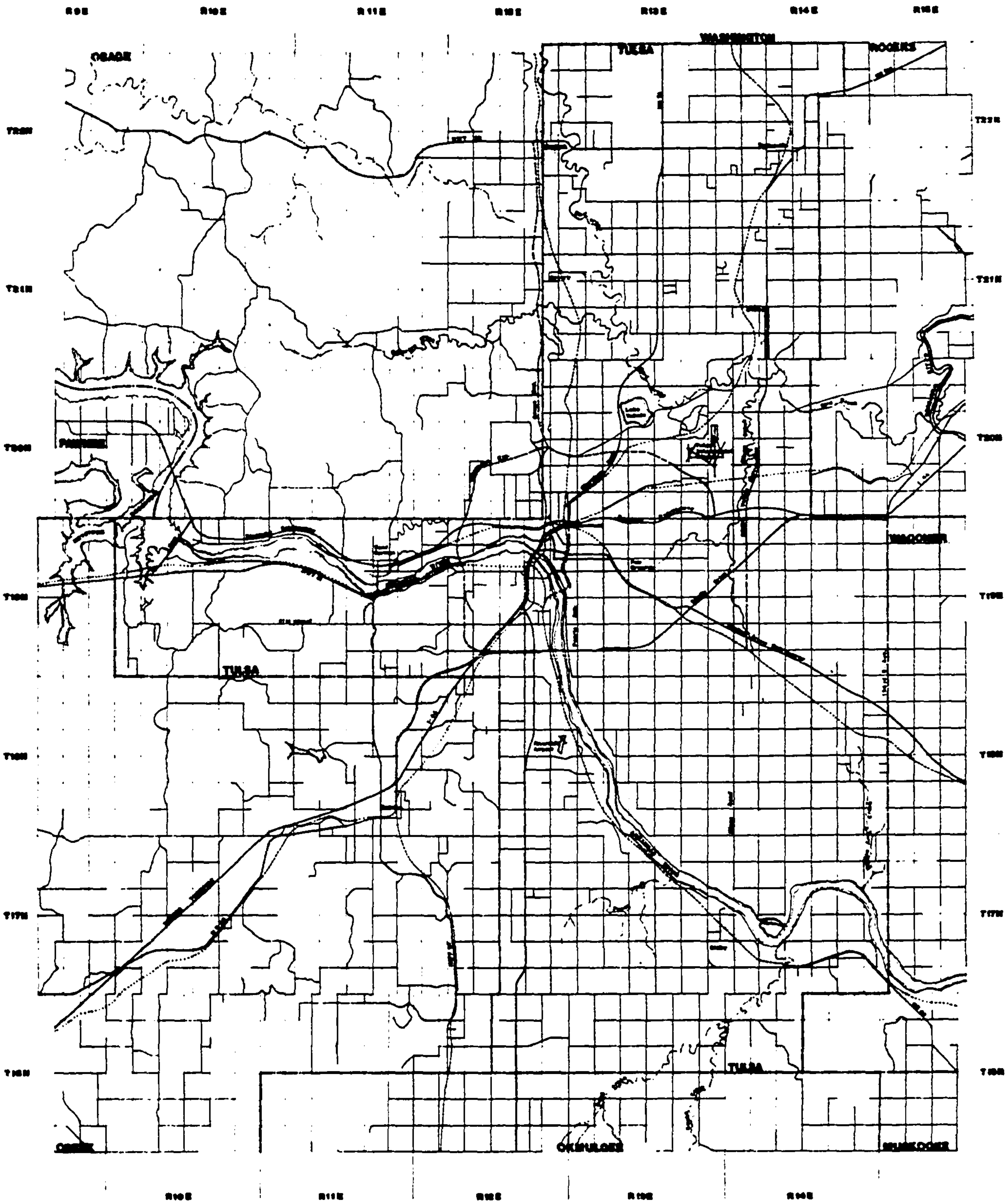


Figure 4-3. Game Board for INCOG

After completion of the game proper, the participants are queried again, independently to quantify any differences of opinion which might remain. The game is designed with the objective of stimulating maximum interaction among participants with the purposes of bringing to light as much information as possible for examination. In doing so, the possibility of introducing bias in the results is increased by personality factors and differing levels of gamesmanship exhibited by the participants. By having the additional written response, an estimate of the amount of influence exerted on the gamed results can be obtained. One should not get the ideas that the introduction of bias on the results of the game is necessarily bad; in fact, the introduction of this bias is a valuable asset to the model. It must be remembered that those who are intended to play the game in a planning situation are those persons who are making decisions and directly influencing the real system. To try to eliminate this bias entirely would detract from the validity of the model. The written response here will be in the same form as the written responses elsewhere in the spatial model. The main difference is that in the other responses, there was a highly controlled interaction among participants while here, the interaction is only minimally controlled.

Part of the next element in the spatial model, the summarization, is the same as in the previous summaries. All the analysis and summarization done before is done again while a summary of whatever additional information that came out of the game is added. The additional information will be of two types, factual and subjective. The factual information will either be presented as a list or on a map as might be appropriate. The subjective information will be in the form of a scenario.

The last element in the spatial model is the evaluation of the tentative solution. At this point, the model users must synthesize the model results from the modified Delphi, the game, and the additional written response, and make an evaluation. Three things can now happen:

1. The model users can bring the spatial model to its conclusion and proceed to the next model in the system of models.

2. The users could decide that additional gaming is required.

3. They could decide that the whole process should be repeated.

In most cases, alternative (1) would be the choice or one additional clarifying written response would be necessary. In choosing alternative (3) and going through the modified Delphi again, the Delphi process is changed somewhat since there has been a face-to-face confrontation. As mentioned earlier this does not necessarily degrade the procedure. In any case, once having gone through the entire process there should already be sufficient data created for continuation to the next model in the system if the process was well designed in the first place.

4.3 INFORMATION FLOW

The information transmitted by the links between the spatial model and the surrounding models are at two levels of aggregation: regional and small unit area. As the system cycles through a five-year period, the bulk of the information going into the spatial model is on the regional level while the bulk of the information produced by the model is on a unit level (Figure 4-4). Additional information used in inventory accounting and for comparison is also on the unit level.

Of the information supplied to the spatial model, the most significant comes from the population model, the housing model, the landbank model, and the model participants themselves (Figure 4-4). The information from the population and housing models, used in the system, consist of the regional level data shown below:

1. Population by age, sex, income, occupation, and employment cohorts.

2. Change in population by income, occupation, and employment cohorts.

3. Number of households by age of head of household and income cohorts.

4. Change in number of households by head of household and income cohorts.

5. Number of houses by tenure, value, and structure cohorts.

6. Change in number of houses by tenure, value, and structure cohorts.

Tables 4-1 and 4-2 show this data in greater detail. The information supplied to the spatial model by the landbank model consists of the following unit level data:

1. Current land use by percent of total and acres.

2. Land available by land use and acres.

3. Attractiveness by land use, degree, and acres.

4. Value by estimated cost.

5. Special information.

Table 4-3 shows this data in greater detail. Unlike the information supplied by the population and housing models, that supplied by the landbank model is not new information which requires a response from the participants to the spatial model but is inventory-type information for their use. Perhaps the most significant information source of all, the information

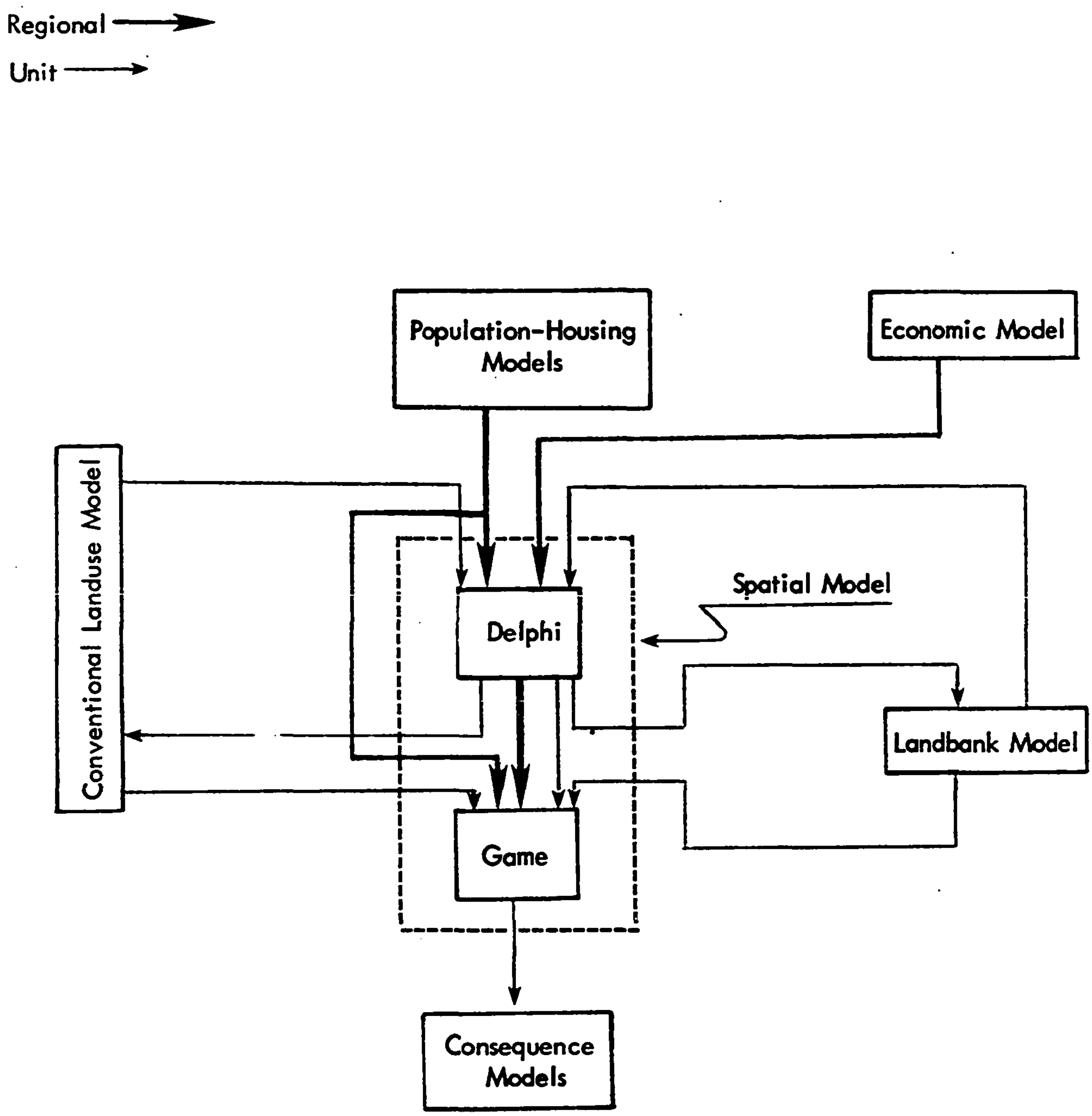


Figure 4-4. Information Flow (Information from participants not shown)

Table 4-1. Population Model Output

Population Model Output

Cohort	
Age	0–4, 5–9, ..., 85 and over
Sex	Male – Female
Income	$0 - $999; $1,000 - $1,999; ...; $50,000 - over
Occupation	Professional Managers Clerical Sales Farmers Farm Laborer Skilled Laborer Operators Household Workers Service Workers Laborers Unemployed Not Employable Armed Forces
Employment	Agriculture Mining Construction Manufacturing Transportation Trade Finance Services Government

Table 4-2. Housing Model Output

Cohort	Housing Model Output
Age of Head of Household	0-24, 25-29, ..., 65-over
Household Income	0 - $5,000; $5,000 - $12,000; $12,000 - over
Tenure of House	Owner Occupied, Renter Occupied
Value of House	Owner Occupied: 0-$15,000; $15,000-$25,000; $25,000-over
	Renter Occupied: 0-$100/mo., $100/mo.-$150/mo., $150/mo.-over
Structure of House	Single- Family, Multi-Family, Mobile

Table 4-3. Landbank Information

Category	Type of Data
Demographic	Population Densities Mobility
Economic	Income characteristics Commercial development Industrial development
Political	Political jurisdiction Zoning or alternative Special consideration
Social	Housing preference Racial characteristics Special characteristics
Geographical	Slopes Soil conditions Flood potential
Ecological	Agricultural development Type of vegetation Wildlife habitat

from the participants minds, cannot be listed in a table but will include some information of the type listed above, plus a myriad of other information.

Additional information is also available to the spatial model from the economic model and a conventional land use model. The information supplied by the economic model is on a regional level and consists of a budget of those monies available for operation and capital expenditures in the public sector. No conventional land use model has been specified for use in the system, but it is suggested that a model such as PLUM would be appropriate. The useful output of such a model should consist of data such as shown in Table 4-3 for the landbank model. The degree to which the participants in the spatial model must rely on such a model for quidance or comparison will determine the depth of information transferred.

Although all the information transmitted to the spatial model is transmitted to both the Delphi and game stages, the information at the start of the game is not necessarily the same as at the start of the Delphi. Since the Delphi is complete before the game starts, it is entirely appropriate to augment, to alter, or possibly to correct information based on the results of the Delphi as indicated in Figure 4-3. The Delphi results especially should have an impact on the landbank and conventional land use models.

4.4 VALIDATION

The early testing of the land use model served the purpose of allowing the formation of a subjective opinion about the relative validity of different forms of the game and the Delphi. These first tests used one undergraduate civil engineering class and two undergraduate sociology classes at the University of Oklahoma as test subjects. In all these cases, the INCOG planning region was used for testing.

The required data for operation was gathered from sources exogenous to the system of models. In addition, guidelines for development supplied by the Tulsa Metropolitan Area Planning Commission (TMAPC, part of INCOG) were imposed on the systems. The TMAPC had recently accepted a study by a private consultant which forecasts further development in five sectors of the area based on a "balanced growth" principal. Not wanting these forecasts to be compromised by differing forecasts from other sources, they asked that their forecast of development by five sectors be adhered to. This was easily done. Such ease in accommodating previous work as considered to be a major point in favor of the model's validity as a practical planning tool.

The civil engineering class was used in the first test. These students were divided into three groups, and each student was given the general assignment of indicating, on a map, where he or she thought development in the area would occur. The first group was given the responsibility for industrial development and told to take the viewpoint of industrial developers in making their decisions. The second and third groups were told to take the viewpoints of industrial-commercial developers and the regional planning agency respectively, each having the appropriate forecasting responsibilities.

After the individual forecasts were made, each group presented its forecast and point of view of development. The method for doing this was as follows. The two groups representing developers, in turn, presented their forecasts and a brief summary of their reasons for making that forecast for one sector of the area. In doing so they made use of the map (game board) and color-coded map pins representing different housing types, industry, and commercial land use. Following this, the group representing the planning group presented its view and a general discussion followed. This process was repeated for each of the other four sectors. As an output for this model, each of the students was asked to fill out an individual map similar to the game board. This data was then capable of being compiled and anlyzed for the remainder of the models.

From this test, four things seemed to be in evidence. First, despite a minimum of instruction or guidelines concerning the conduct of the game, the students became avid about their roles within a few minutes. The developers behaved as entrepreneurs; the planners supported the "public". Second, there did not seem to be any way to "direct" the model without disturbing the role-playing in process. Third, a great deal of information was produced during the course of discussion. Fourth, the number of developers seemed to be too great, overshadowing the planners and stifling information from them.

The two tests involving the two sociology classes used the same form of the game (model) which was more structured than the previous game. Here the students were divided into three main groups: developers, planners, and citizens. This game contained more of the elements of a conventional game. There were rules of play, money, and the element of drama involved. Also differing was the output; here, it was the results on the game board.

Within the three major groups of players were the elements and subgroups described below. The developers included those responsible for residential housing and for industrial and commercial development. The planner group consisted of a chief planner and his staff. The citizen group consisted of the city council and citizen groups concerned with the environment, residential preservation, and cultural-recreational committees.

Succinctly, the order of play progressed in five-year rounds, starting with an assignment for each player and ending with an evaluation of the period. At the start of a typical round, the developers were given money to invest (in the assignment). The city council was given money to spend, the industrial developers were told of new industry, the citizens of problems in the city, and the planners given a planning assignment. Twenty minutes were then taken for the players to digest the new information, make plans, and discuss matters with other groups. At the end of that time, the developers placed their development plan on the game board. The actual required development was then disclosed, and the success or failure of development determined by allocation or the required development according to chance based on probability determined by the results of a vote. The city planners presented their plans and the city council accepted, rejected, or did not act on them. At this point, the chief planner could be fired. Following this, the citizens voted on whether the city council should be retained or not. The state of the game at this point formed the output of the model.

In this second form of the game, it was easy to direct the attention of the group to certain questions or issues. In comparison to the previous game, the information produced seemed to be more balanced, but the quality of information seemed lacking. This result might partially be due to the difference in sophistication of the players, but it was felt that the main reason was that the emphasis from a serious effort to recreation.

Based on the first three tests, the final form of the model described earlier was developed. This last form of the model was an attempt to incorporate the best features of the previous games. The test of this form of the model was designed to produce results suitable for statistical analysis for a scientific evaluation. Here, a graduate engineering class on urban systems was used for testing. This class had the advantage of being knowledgable of the principals and general issues but lacking in knowledge of the test area. By not knowing the test area, the information on which the subjects based their decisions on was somewhat controllable. In this test, it became meaningful to evaluate the Delphi also. The results produced by the model described before are presented below.

The results of the Delphi-game, though based on "manufactured" information, are revealing because they indicate the form of results which should be expected and offer insight into the processes underlying the Delphi and game. One set of responses was selected as representing a typical response from the group and is shown in Figures 4-5 through 4-8. Figure 4-5 is a reproduction of one of four pages for the first response in the Delphi exercise preceding the playing of the game. Those questions, which concern the location of attributes, are answered by means of an accompanying map (Figure 4-6).

Figures 4-7 and 4-8 show the summarized information, generated in the first response, that was given back to the participants with the second questionnaire. A summary of the comments generated through the questionnaires would normally be typed and distributed with this information. The comment information was not supplied in this test to simplify the test. Succeeding responses and feedback summaries are not shown: they were similar to those in Figures 4-5 and 4-6.

What is the possibility that the bus service will be discontinued?

very likely 0 . . . . . . 5 very unlikely

13. Locate on your reply map where you think the most likely site for a large industry might be in area "H."

14. Locate on your reply map where you think residential development is most likely to occur in area "I."

15. A local developer wants to build a medium and high income housing addition in area "F" on your map. The Planning Commission would like to see this development but is hesitant to commit themselves to the construction of the northwest section of the Gilcrease Espressway at this time as an access road to the residential area. What is the likelihood of the addition being built?

very likely 0 . . . . . . 5 very unlikely

16. Locate on your reply map where you think residential development is most likely to occur in area "J."

17. Locate on your reply map where you think a small shopping mall would probably locate in area "F."

18. What do you think the driving time is from point "N" to downtown at 8:00 a.m. on weekdays? ________________

19. Locate on your reply map where you think the most likely site for a large industry might be in area "O."

20. What do you think the driving time is from downtown to point "M" at 5:00 p.m. weekdays? ________________

21. Ponderosa Homes, Inc., wants to develop approximately two-thirds of a section at location "D." The Tulsa chapter of the Sierra Club of America opposes the development of this wooded area and wants it to be declared a wildlife refuge. What is the possibility of the development being built?

very likely 0 . . . . . . 5 very unlikely

Figure 4-5. Example Delphi Questionnaire/Response Sheet

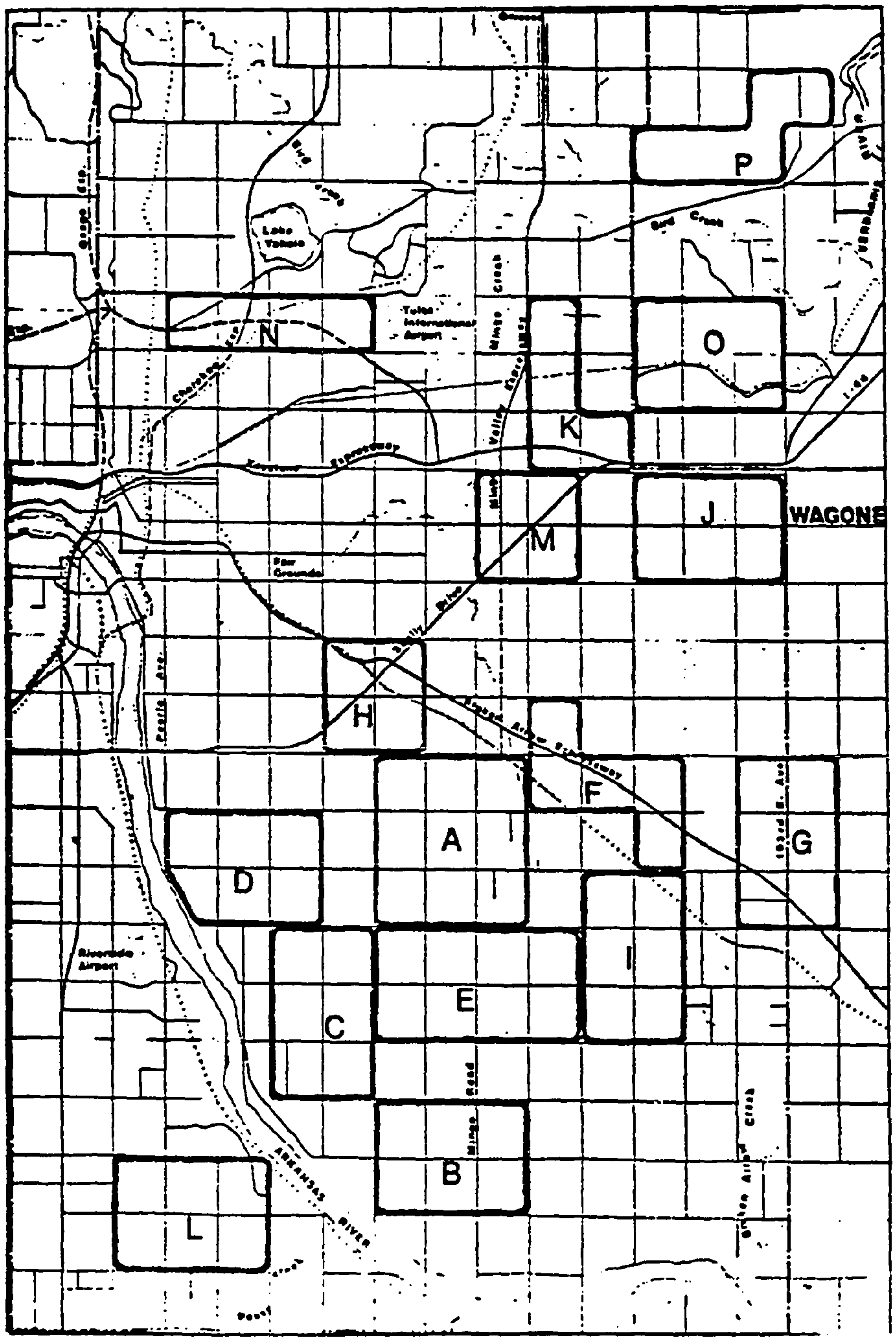


Figure 4-6. Delphi Map

Question	Q_1	Median	Q_3
1.		Map	
2.		Map	
3.	.5	2.25	4.25
4.	-	-	-
5.	$18	$20	$29
6.	-	-	-
7.		Map	
8.	-	-	-
9.	-	-	-
10.	-	-	-
11.	-	-	-
12.	-	-	-
13.		Map	
14.	-	-	-
15.	-	-	-
16.		Map	
17.		Map	
18.	-	-	-
19.		Map	
20.	25	35	42.5
21.	1.75	2	3.25
22.	0	1.25	3.75
23.	-	-	-
24.	-	-	-
25.	400	590	600
26.	-	-	-
27.	-	-	-
28.	550	950	1350
29.		Map	
30.	1.5	3.75	4.75
31.	-	-	-
32.	-	-	-

Figure 4-7. Delphi Feedback (First Round)

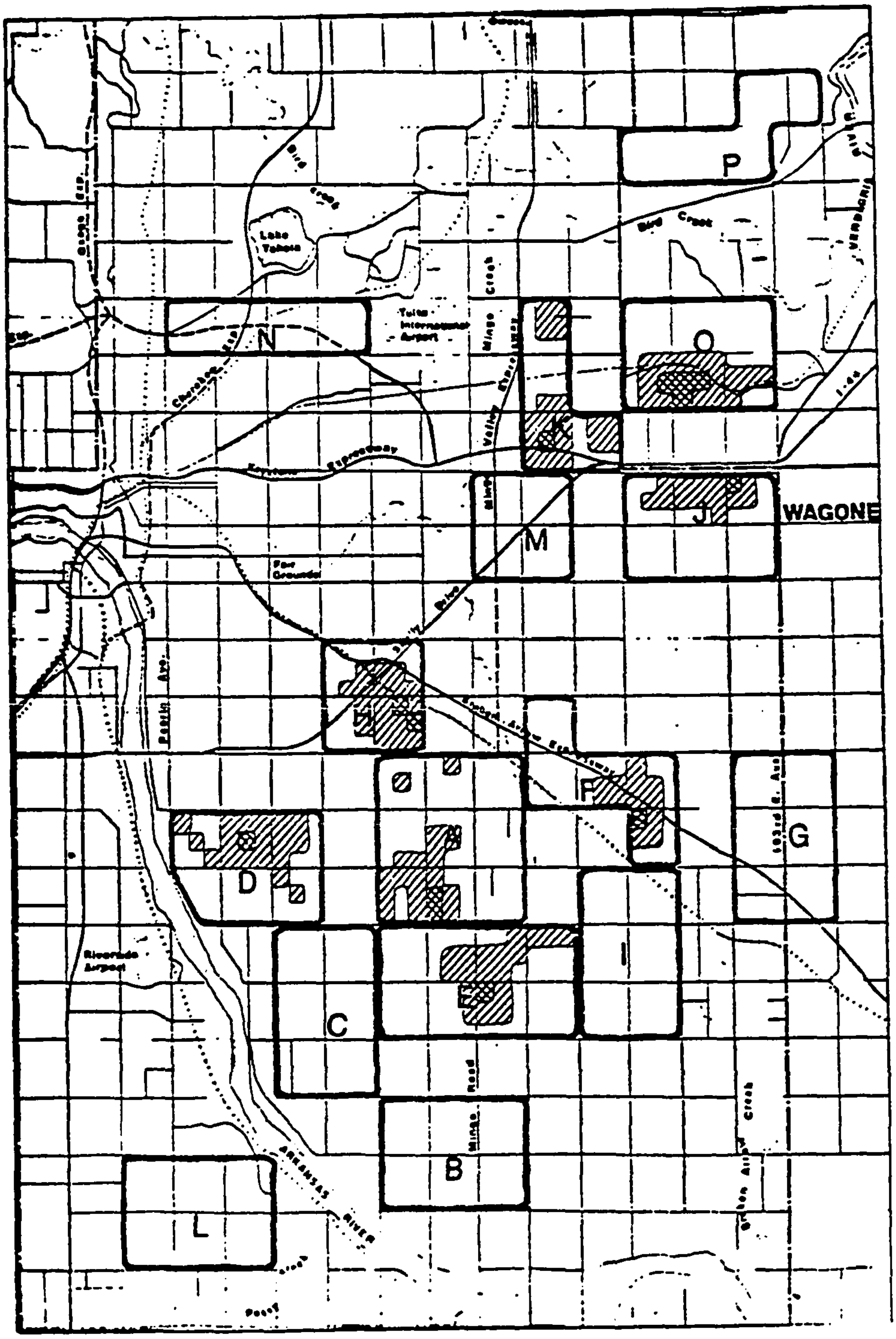


Figure 4-8. Graphic Delphi Feedback (First Round)

More detailed summaries of the responses by the first questionnaire and the final questionnaire are shown in Figures 4-9 through 4-12. The first figure, Figure 4-9, is a set of scatter diagrams for all of the written responses to the first questionnaire. Figure 4-10 is a scatter diagram of the accompanying maps. Figures 4-11 and 4-12 are the scatter diagrams from the final questionnaires. This information was not available to the respondents.

The Delphi exercise can be validated intuitively by observing the difference between the scatter of responses from the first questionnaire and the final questionnaire. The scatter shown in Figures 4- 11 and 4-12 (the final response) seems to be less than that in Figures 4-9 and 4-10 for those questions with feedback, relative to those without feedback. The results of the analysis of variance testing, summarized below, supports this intuitive analysis statistically. As expected, the null hypothesis that the difference in convergence to the median between the questions with and without feedback was due to chance (Ho: $M_1 = M_2$), can be rejected with 99.8-percent confidence.

The other results of the original experimental design were not significant. However, the effect of the amount of information given to individual respondents approached reasonable levels of significance (α = 0.20) while the "F" value for the factor concerning closeness of information to a priori median were much less than one--the reciprocal of the "F" values being highly significant (α = 0.20). Based on these results, the design was changed post priopi to a repeated measurements-hierarchial design where the main treatment of closeness of information to an a priori median was changed to closeness the previous response to the median of the

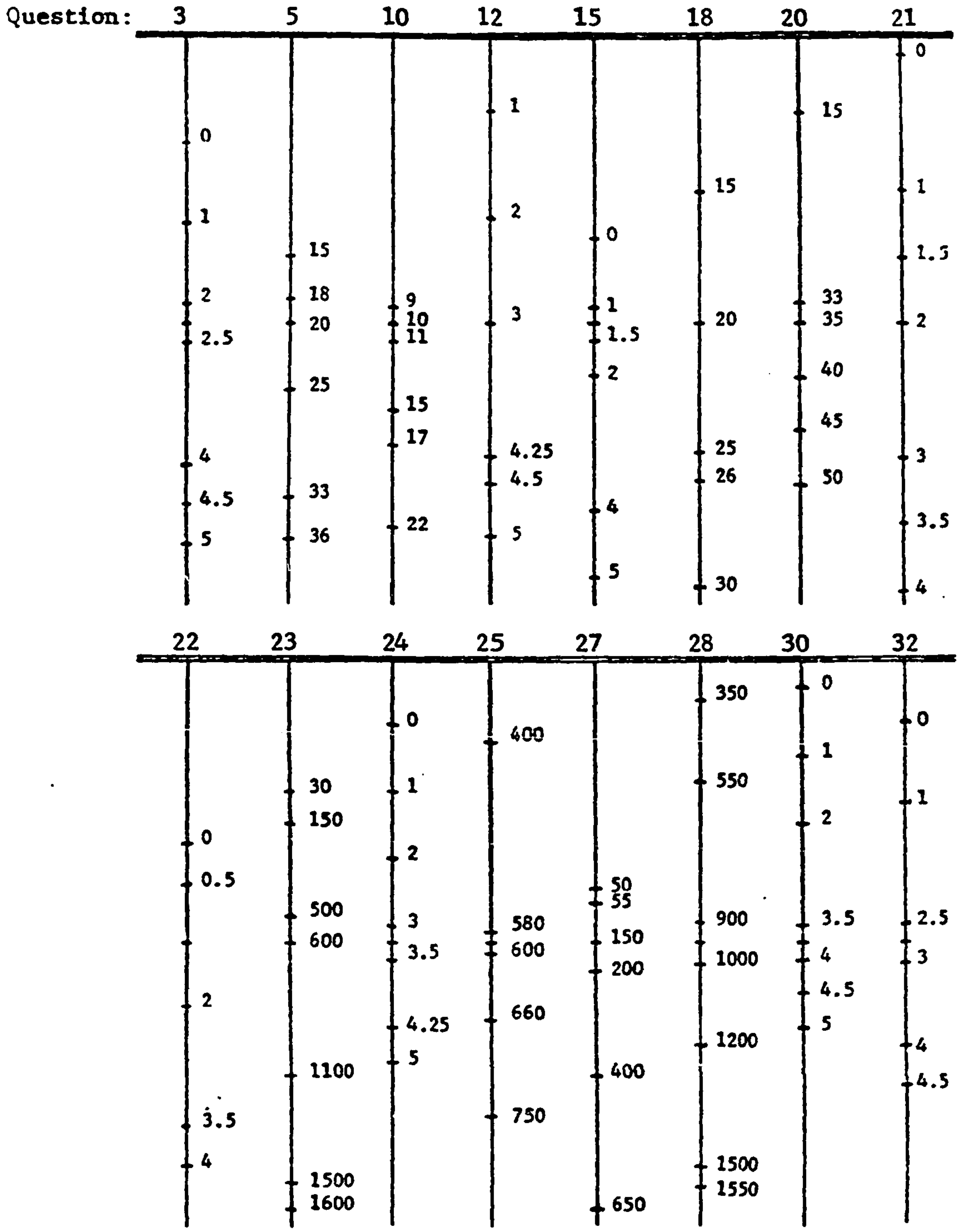


Figure 4-9. First Responses

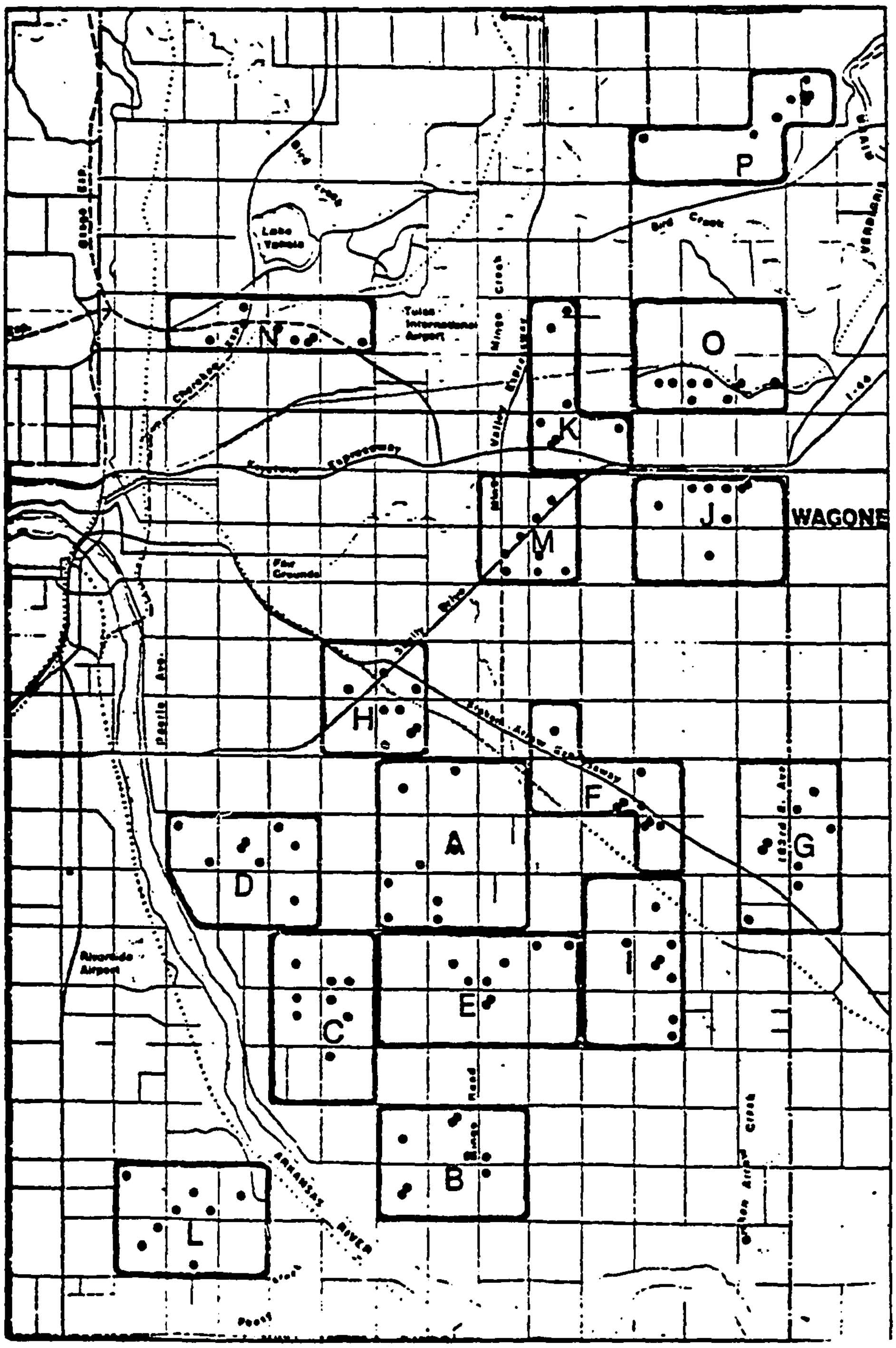


Figure 4-10. First Responses (Graphic)

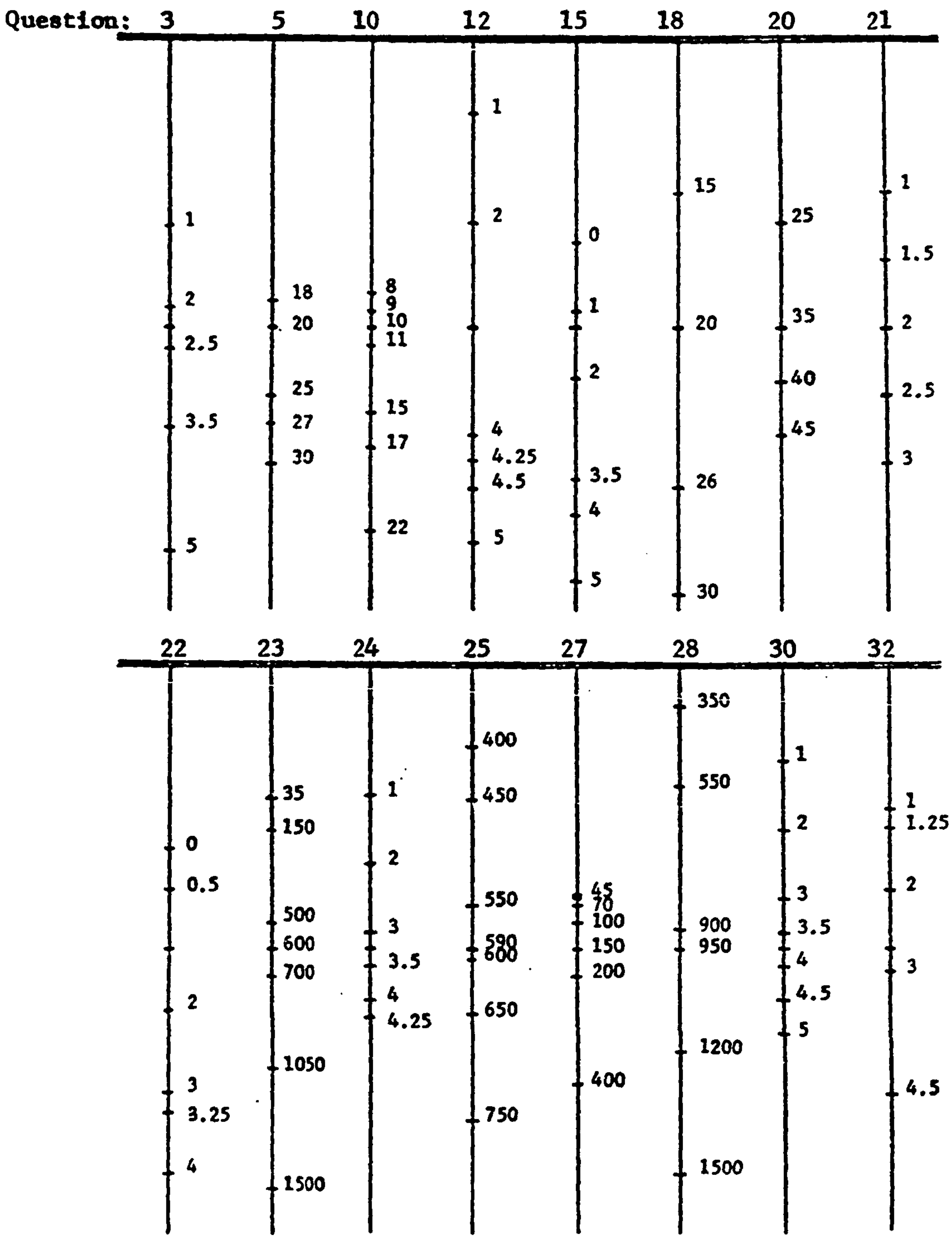


Figure 4-11. Final Responses

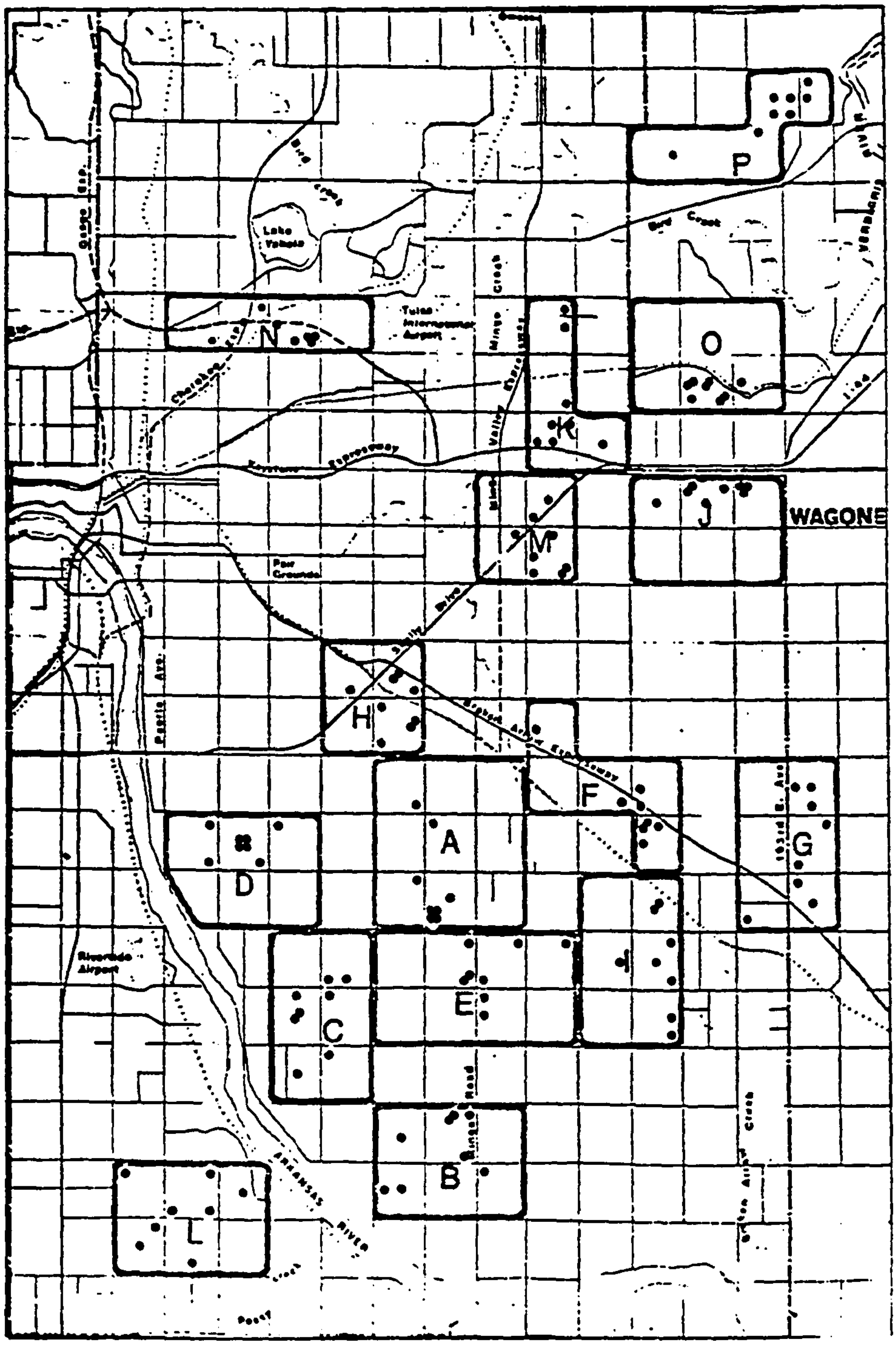


Figure 4-12. Final Responses (Graphic)

responses and, by eliminating the treatment of the information, was above or below the a priori median and the strength of information. Based on this analysis, the null hypothesis that differences in convergence to the median were not affected by the proximity of previous answers to the mean could be reflected with 95 percent confidence despite an inflation in error variance due to subject differences. Unfortunately, with changes dictated by switching experimental designs, it was not possible to clarify the ambiguity of the hypothesis concerning the effect of the amount of information supplied to the participants, but in view of the level of significance indicated in the original design, the rejection of this null hypothesis could reasonably be expected to reach significant levels in another experimental design.

The questions addressed during the game exercise were the same as those involving the placement of attributes during the Delphi exercise. The results are shown in Figure 4-13. The location of attributes on the map were not of significant interest in this phase of the testing however. The reason for testing the game was to ascertain the effect of the structure of the game on the illumination and collection of information.

In the opinion of the game director (who had only limited experience), this game structure did not generate as much information as previous games. However, the elements of a timed period of decision making and planning and the elements of chance added to the enthusiasm and seriousness of the game.

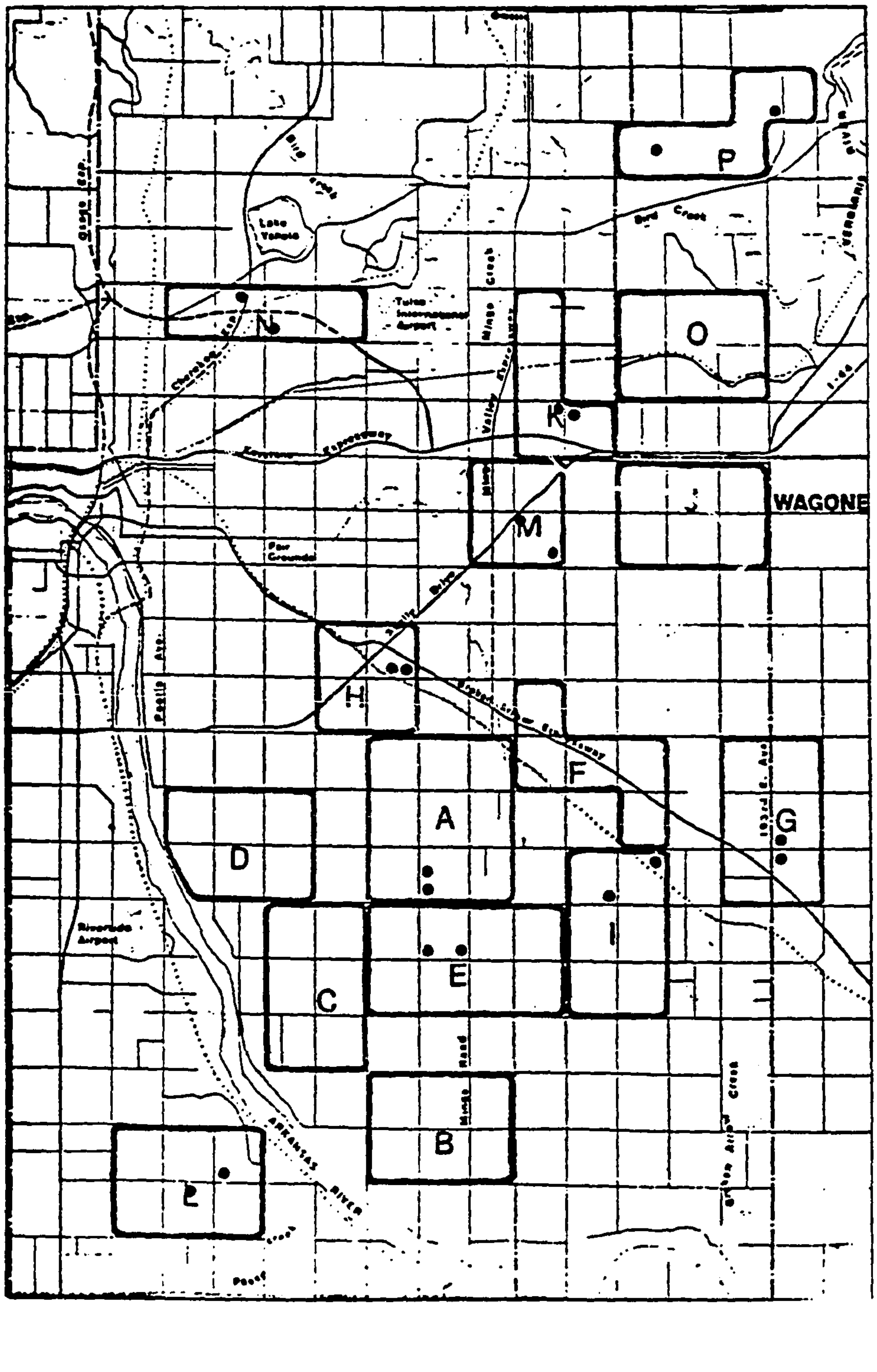


Figure 4-13. Game Responses

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 THE SYSTEM OF MODELS

The potential for the system's use by planning agencies seems quite good. At least those agencies which were used in developing this system would like to try parts of it. The creation of a simplified users manual, the idea of the system, and some of the models should be enthusiastically accepted. However, in most cases the entire system will not be adopted because each agency normally has some models to which they are committed. Therefore, only the submodels necessary to complete an agency's current system will probably be used. This flexibility is an inherent strength of the system.

Since each submodel of the system was developed by a separate group, there were a variety of approaches taken. The different degrees of success of the models suggest the following conclusions:

1. The model should be "transparent" in that model elements and their interactions should be readily apparent.

2. The models' inputs should be efficient, and the effort involved in changing the data or parameters should be minimal.

3. The structure of the model should be flexible in that the relationships and the level of aggregation should be easily changeable.

4. The model should be specific to an urban area and should retain an information residual from each use. If this

is done, the model will more nearly approximate the particular urban system with each succeeding run.

5. Within the system, each model's output should be "balanced" in terms of its importance to the particular objective.

Some conclusions concerning the individual submodels are given in the following sections.

5.2 POPULATION MODEL

The population model has been used in various forms for some time. In its present form, it is quite easy to use and requires little change in input data to investigate new propositions. The model's main virture is its simplicity and transparency. The model's most sensitive variable is in-migration, which is currently determined extraneously for computer input by means of a Delphi (conclusions concerning the Delphi are discussed later). While the Delphi has the advantage of allowing for human insight, it would be desirable to also have an objective mathematical model for comparison. Unfortunately, though a number of such models have been produced, none have achieved much in the way of convincing prediction capability, and no new developments are expected in this area. Given a reasonably accurate forecast of in-migration, the model is fairly robust and gives good results on a metropolitan level of aggregation. Further, it works well with the other models in the system.

5.3 HOUSING MODEL

The housing model seemed to give quite reasonable results in the opinion of the Indian Nation Council of Governments (INCOG) staff, who worked quite closely with the group testing that model. One minor criticism of the model is that while it seems to give good results (with the present computer programs) it is hard to modify parameters to investigate different propositions concerning the state of the housing market in the future. Thus, the computer program should be expanded to make projected changes in the housing market more easily inputted to the model by means of simplified input subroutine. This should only require a minor change in the computer program.

5.4 SPATIAL MODEL

The spatial model, composed of the Delphi on land use and the land-use game, are at the core of the system of models, and, while these models will operate individually, they are most effective when they are "hung" on the core. The rationale for this conclusion is that during the running of this model decisions must be made by an individual or group of individuals. If the Delphi and/or game are able to effect an informal consensus of expert opinion, then the result should be closer to the truth than individual estimates more than half the time. This assumption is based solely on the definition of median which the Delphi produces. The consensus effect alone should insure a greater degree of success than most current procedures, but if the process improves this 50 percent score significantly, then it must be designated a viable planning tool. Combined with the conclusions of the Delphi and the land-use game below, indications are that this type of model will be a valid and useful model for the majority of urban planning organizations. Based on the results of this research, the model was sufficiently successful to justify large-scale testing in an actual planning situation.

5.5 THE DELPHI

Based on the results of the Delphi conducted during this study, the following conclusions were reached. First, the Delphi model does effectively help form a consensus of opinion. Further, it produces this consensus relatively efficiently in terms of time and data base required -- an important feature to planners with schedule and budget limitations. Second the consensus reached approaches the "true" values, which has generally not occurred (or at least not been verifiable) in other studies. The reason for this close approximation is believed to be that the study was concerned with facts about which Delphi participants had some knowledge. In other such studies using the Delphi, almanac type questions were used about which the participants had almost no knowledge. Based on the results in this study, an even higher level of significance might be achieved in a practical situation. This should be tested further in an actual planning environment.

5.6 THE LAND-USE GAME

Based on the several forms of gaming used in this study, it was not possible to reach a firm conclusion as to the accuracy of gaming in forecasting land use. On the other hand, gaming seemed to be an ideal method of involving citizens in urban planning and of eliciting information concerning value judgements. These conclusions are based on observations of the game play and feedback from game participants. These games should be conducted using involved citizens in several counties, and attempts should be made to develop methods for quantifying the resulting influx of information. At worst, these games could serve as a welcome forum for planner-citizen interaction. However, they should also serve as an effective forum for discussion and prediction to be allied with a Delphi and used by the planning staff of an urban area. Both these avenues should be explored further and expanded to include the key personnel who guide the development of an area.

5.7 WATER SUPPLY, SEWAGE, AND SOLID WASTE MODELS

The water supply and sewage models have been very successful and have stimulated interest among planners who have seen them. The only model which needs work at this point is the solid waste model, which has not been fully developed. The results at the regional level are good, but the disaggregation to smaller areas is only in the formative stages. This formative model can be found in an appendix of this report. Since the solid waste model is similar to the water supply and sewage models, it should be equally successful once fully developed.

5.8 THE AIR POLLUTION MODEL

The air pollution model differed from the preceding models in that it was not intended to make forecasts below the metropolitan area level. Though quite simple, this model has produced excellent results and no additional development is recommended at this time.

5.9 RECOMMENDATIONS

The system should be tried in several actual planning situations, and the models should not be developed further until that time. In fact, any further model development should be in response to specific problems confronting specific agencies so that changes in the models will be directly responsive to specific concerns of planners.

The important problems at the moment are to put the modeling of urban systems into the proper perspective as a tool and to make these tools available to decision-makers. The type of systems analysis proposed here makes possible the interplay of the professional in this frame of reference. The obvious next step is to determine if the process developed here can be put in a format easily understood by planning staffs who can then use this method as one of their decision criteria. To do this, a users' manual should be created, disseminated to selective urban planning groups, revised on the basis of their experience, and then distributed widely across the United States.

Subject to the responses from planning staffs using the method, several recommendations for expantions and/or revisions to the models can be based on this work. The population model would be strengthened if a sub-model capable of giving a reasonably accurate forecast of in-migration were developed. The water supply and sewage models might be enhanced if they were made simpler. This would make it possible to investigate more alternative or to balance available man-power among all models. Another air pollution model which is more responsive to localized conditions might be tried in the system. The current model produces excellent results but is not responsive to things which a planner has control over.

Two models, the solid waste model and the transportation model, are exceptions to the above recommendations. The solid waste model should be developed to the level of the sewage model before use. This would only require some regression analysis of available data and validation. The transportation model tried in this study should be dropped for the time being. It is too far away from complete development. Instead a transportation model already in use should be used.