THE MICRO-COMPUTER AS A PLANNING TOOL
- AN ILLUSTRATIVE STUDY OF THE APPLICATION OF MICRO-COMPUTER TECHNOLOGY IN INFORMATION GENERATION AND DECISION-MAKING PROCESS IN PLANNING -

by

David Tam

A Thesis
Submitted to the Faculty of Graduate Studies
in Partial Fulfillment of the Requirements
for the Degree of

MASTER OF CITY PLANNING

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To

Mom, Dad, and Lu

ABSTRACT

The proliferation of micro-computers in the last decade has revolutionized the ways that we work, live, and possibly think. The purpose of this thesis is to explore the meaning and the applications of the micro-computer technology in city planning.

To accomplish the goal of the thesis, the research was carried out through three channels. First, a conceptual framework was explored with which the technology of micro-computer can best be implemented. Second, how such a system works within this framework on the computer was demonstrated, and thirdly, a system approach to implement the micro-computer technology was developed.

Housing planning was used as our reference for developing the system that serves as a guideline for implementing the micro-computer technology. A micro-computer and software programmes like MathCAD and Extend were used to demonstrate how this system works. The micro-computer may be shaping up a new paradigm for planning. The use of micro-computers to do optimizational planning, however, was ruled out. Instead, a gradual adjustment method informed and guided by the micro-computers was proposed.

ACKNOWLEDGEMENTS

I would like to express my most sincere gratitude to Professor Basil Rotoff for his guidance and support throughout this project. Professor Rotoff has been teaching in the planning field for over twenty years. However, he is informed and sensitive in new developments in planning, and he shows keen interest in the application of micro-computer technology to planning. With Professor Rotoff's close involvement and tolerance, the project proceeded with a sense of exploration and adventure. When the project has finally reached its conclusion, I looked back and was amazed by the diversity of subject matters that this project has covered. Without Professor Rotoff's guidance, this research would have gone off-track and its purpose would have been lost. Again, for all these, I thank Professor Rotoff.

I would also like to show my gratitude to Professor Richard Perron for his advice. Professor Perron's concerns about the specific planning purposes that this project is supposed to fulfill gave me a sense of bearing when I dashed into the dazzling sea of the ever-changing computer world. Professor Perron, with his expertise and interest in micro-computers, set a high standard for computer usage in the project. The high quality of the outcome of this project is a testimony to this high demand and unyielding standard.

I also want to thank Mr. Peter Mah for his contribution in this project. As a practitioner Mr. Mah's offered very helpful professional advice during the research. His presence in the thesis committee was a constant reminder of the practicality of the thesis.

I would also like to thank other faculty members of the Department of City Planning for their roles in educating me in the programme. Professor Mario Calvalho, Professor Geoff Bargh, and Professor Kent Gerecke all taught me different aspects of planning. I will miss them all after I have left the Department. I stayed in the Department too long to be tolerated, and yet I am leaving it too early to enjoy Professor Christine Mckee's leadership and contribution to the Department. I did, however, have lectures from her in the Housing course, and the lessons from the role-play in one of the lectures is still vivid in my mind. For that I have to thank her.

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PREFACE

I took a computer usage course in 1986 when I was an undergraduate. I entered the course with a simple belief that I might need to use computers in the future. The course turned out to be one of the most important courses that I ever took. Among other things, it earned me the job of a computer sales consultant on the university campus. This job gave me full exposure to the micro-computer technology, and demanded me to stay at the edge as the micro-computer world quickly evolved.

At the same time, I was growing in the discipline of City Planning. Planning theories, urban design studios, area characterization studies, housing issues, urban finance, etc. were boiling in my mind, seemingly unrelated, unsettled. Planning, then, occupied half of my world, and micro-computers took over the other. When I was deciding on which of thesis topic I was going to write, I proposed and tried a couple others, and finally I decided to address computer application in planning as an attempt to bring the two halves of my world together. Therefore, this thesis can be regarded as a personal project, one that is meant to stop me from becoming a schizophrenic.

It was not until half way into the project when I realized how illusive a topic that I have picked up. The difficulty is two-fold: First, there is not one dominant trend of planning theory to which I can make an easy reference. Second, there is not one dominant form of micro-computer technology that I can casually adopt. The first problem is perhaps rooted in the persisting question: What is planning? The second problem, however, is a strong sense of uncertainty with the fast pace of change in the capability of micro-computers.

In literature review I came across terms like 'modeling' and 'forecasting' as tasks that planners do. I then started to look into modeling and forecasting in planning. I was not prepared but I was greeted by stacks of books and journal articles on modeling, all bearing implications to planning. Topics like transportation modeling, shopping modeling, facility location modeling, recreation modeling, and housing modeling overwhelmed me, and the mathematical language in which they are expressed looked as if they did not mean to be for this world. I bought some mathematical texts, learnt the language, and searched for the right software programme to handle them. I tried some models on the computer. They seemed to work, and seemed to be very informative. This is the background to Chapter Five: Mathematical Modeling in Planning.

The research process never seems to trod on a straight, clean, nicely preconceived path. While I was working on quantitative modeling, I was sent a brochure by a software company on products relating to computer simulation. There is this package called Extend, and is described to be a simulation tool for 'performance modeling for decision support.' In its demonstration copy there is a file called City Planning. I opened it, and it was a simulation on land supply and demand. Although the structure of the simulation is totally nonsensical from the view of planning, it gives some hints on how simulation tools like Extend can contribute to planning. I ordered the software, and I began digging into texts relating to simulation.

I found that simulation is a topic well-known in the business management field. There they talk about simulation in the context of system analysis and operational research. The concept of system especially impressed me, and I started to think about a system approach to my application of computer technology in planning. This line of thinking is presented in Chapter Three: An Integrated Planning System. With some fundamental concepts sorted out, I entered into the realm of computer simulation with Extend, and it proved to be fascinating.

Deeper reflections always emerged along the whole process of research. I kept asking myself what these new techniques and tools mean to planning. I recalled Thomas S. Kuhn paradigmic theory to knowledge. I asked: Is the micro-computer technology shaping up a new paradigm for planning? Chronologically, since this reflection happens after the exercise, it seems to be logical to discuss it in the last chapter. However, it would only be clear in the presentation of the illustrative study after the paradigmic theory is presented. Chapter One, therefore, deals with the topic: The Micro-computer Technology and a New Paradigm for Planning.

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CHAPTER ONE
INTRODUCTION

The purpose of this thesis is to explore the possibility of a new paradigm being created in planning as a result of the use of micro-computer in planning. Such an exploration is undertaken through three aspects of discussions: First, the possibility of a new paradigm for planning with the advent of the micro-computer technology.; second, a general discussion of the use of micro-computer in planning; and third, an example that illustrates micro-computer usage in one specific planning task: housing demand projection.

1.1 BACKGROUND

The discussion of using computers to enhance planning process started since computers were invented and applied to some specialized research fields in the fifties. As early as then there were numerous concepts put forward as to how computers could fit into the planning process, and what specific tasks to which computers could be assigned. These concepts were further elaborated as computer technology advanced. Throughout the sixties, full scale geographical information system was suggested, and detailed integrated quantitative modeling was spelled out. It seemed as if a stage was prepared for the computer to perform, and the audience was waiting. The computer, however, failed to perform, and the interest in 'computer-aided planning' dissipated.

The failure of the initial attempt to apply computers in planning can perhaps be explained by the following factors. First, the comprehensive rational approach to planning that dominated the profession in the sixties was too inclusive.[1] Horizontally the approach was trying to take into consideration all phases of life that bore impacts to planning, and vertically it was intending to put out results valid throughout a substantial length of time, sometimes ten years, sometimes twenty years. In his book *Contemporary Urban Planning*, John M. Levy comments[2]:

> The laying out and studying of a number of alternatives [in the rational approach] is often simply not possible as a matter of time or resources. In many cases the planner(s) arrives at a very short list of alternatives very quickly and then focuses on the matter of implementation. The sort of global look-at-everything-so-as-to-make-the-optimum-choice approach simply is not possible.

The comprehensive rational approach to planning also overwhelmed the capability of the computers then, and it will, as the latter part of the thesis will show, go on over-demanding from the computer technology for a long time to come. Second, the cost of the mainframe computers, which was virtually the

1 For a description of the comprehensive rational planning see "Supplement: Note on Conceptual Scheme,," Politics, Planning and the Public Interest, Martin Meyerson and Edward C. Banfield, New York, 1955, p.314 and following.

2 John M. Levy, *Contemporary Urban Planning*. New Jersey, Prentice Hall, 1988, p.289.

only kind available in the sixties and in the early part of seventies, was very expensive. Not many planning agencies can afford the money to acquire one. A technology unaffordable is not an available technology. Therefore, the discussion of applying computers to city planning remained academic. Third, the mainframe computers were very difficult to use. The user has little control of them, and he has to learn some difficult computer or programme languages to interact with them. Often an operator is needed to translate the intent of the user into the computer or programme codes. This adds to the frustration and cost. Fourth, the computer technology changes very fast. Computer models become outdated very rapidly as new models with more power and lower cost become available. Many planning agencies held a 'wait-and-see' attitude. Before they were certain of sustained substantial returns in investing on a computer, they would not adopt the technology. With the computer less used, the application of computers in planning went on very slowly.

With the advent of micro-computers in the eighties, the 'computer revolution' of this century moved into another phase. It was, however, too much to expect the first generation of micro-computers to contribute to planning. They were simply too low on power. The first micro-computers that came out to the market in the early eighties carried only 128K in Random Access Memory[3], and the storage[4]

3 The amount of Ramdom Access Memory (RAM) on the computer is a good indictor telling how big a work load the computer can compute at one time. The units are either 'K' or 'MB'. 'K' stands for kilobyte, and 'MB' stands megabyte.

4 The storage memory of a computer is a different type of memory from what we mentioned earlier, the RAM. Where RAM is totally for operation of the moment and therefore, is temporary, storage memory is, comparatively, permanent. The computer retrives information

was totally dependent on the low capacity floppy disks. Soon after the 128K machines were out, 256K, 512K, and later 640K with 8086 microprocessor[5] appeared. In 1989, 80286 machines became the standard, with 80386 machines as the higher end models. In Spring of 1991, 80286 machines gives way to 80386-SX 16 MHz machines as the low-end model, and the high end is dominated by a model with a speed of computing that surprise computer users - the 80486 45MHz models. Yet many surprises were interwoven with the computer revolution of the eighties. What does this mean for planning?

Computer technology is a tool so widely applicable that discussing micro-computers and planning appears to be as indefinite a topic as "paper and human civilization." Indefinite as the topic may sound, it is not meaningless. Indeed there are books on the significance of paper on human civilization, and books on computers and human thinking. To tackle these significant and yet illusive topics, one possible approach is to undertake a case study. The case chosen, however, cannot be trivial, and has to be significant enough to bring out the theme of the study. In this thesis, the case chosen is a housing quantity

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from storage, and puts new information back to it for future use. Memory can be stored in floppy diskettes, or in hard disks, which can usually hold hundreds times more than the floppy.

5 The microprocessor of the computer is the engine of a computer. There are, in genral, four basic kinds being used in the IBM or IBM compatible computers. These are 8086, 80286, 80386, and 80486. The higher the model number given to a micro-processor, the later a product it is, and the faster it computes the data. The product model of a computer, and therefore the heirarchy of models in the porduct line, is usually defined by the type of microprocessor the computer uses. IBM-type computers, of course, are not the only computers in the market, and therefore these microporcessors are not the only kinds that operate today's micro-computers. We choose this type only for illustration purpose.

planning system with which new information is generated and decision-making is supported.

Given the distinct functions and versatility of micro-computers, this thesis treats them as a separate tool from mainframe computers. In our discussion of paradigms and micro-computers, this distinction is vital, for the 'tool', or the apparatus, is an important notion in the paradigmic notion in epistemology.

1.3 A NEW PARADIGM

Thomas S. Kuhn reminds us that often what the tools determines the thinking. In his book *The Structure of Scientific Revolutions*, Kuhn proposes the concept of paradigm as the overall determinant of scientific development.[6] A paradigm includes not only the dominant worldview of the day, but also physical details such as laboratory apparatus. **The implication of his paradigmic notion to the thesis is that a shift of thinking of what planning is when micro-computers are more widely used in planning needs to be observed. This concept is an important framework within which the explorations of the role of micro-computers take place, and is therefore to be dealt with in Chapter Two of the thesis.**

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6 Kuhn, Thomas S. The structure of scientific revolutions, Chicago, University of Chicago Press, 1970

1.4 OUTLINE

This thesis proceeds according to the following outline. The second chapter is divided into two parts: First, an account on the rise and fall of implementing the micro-computer technology in the positivistic approach to planning is given. After that, a new paradigm of planning with micro-computer as a tool is introduced. In the third chapter, a particular system in which different areas of computer usage can be integrated will be discussed. Chapter Four presents the first component of this system, geographical information, and illustrates how a map-based database can generate information for planning research activities. Chapter Five presents the second component of this particular system: mathematical modeling, and its basic methodology. A hypothetical employment level study is used to demonstrate how it takes information generated on the map-based database, processes it, and exports results for the next stage of the system to handle. The sixth chapter discusses computer simulation, its basic concepts, and how it is to be implemented. This part of the system would take the information sent out by the mathematical models of the previous stage and simulates the housing demands of the community in a twenty-year period. This technique would also be used to simulate housing supply, and combine the demand and supply into a full housing simulation model. In the last chapter, a conclusion is drawn to the study, and some directions are pointed out in which further studies can be undertaken.

It needs to be emphasized that although the thesis would venture into some technical elements of computer usage, it does not intend to address all the technical aspects of the use of micro-computers. There is no intention in this thesis to argue that the system adopted is better than other possible systems formed by other combinations of software and hardware. For the purpose of bringing out the main theme of the thesis, the set of software and hardware adopted is only one possible form of computer usage, and it is used to illustrate the fundamental argument: that micro-computers is a distinct tool, and it may help to shape a new paradigm of planning, one that is different from producing the rational comprehensive planning.

CHAPTER TWO
THE MICRO-COMPUTER TECHNOLOGY AND A NEW PARADIGM FOR PLANNING

This chapter seeks to explore the meaning or implication that the micro-computer technology could bring to the meaning and theory of planning. A conceptual framework can perhaps be achieved through this discussion for the later experiment to follow. In exploring the topic of this chapter the paradigmic theory to knowledge outlined by Thomas S. Kuhn will be used as a guiding principle in exploring the topic of this chapter. Two of the major views of planning will be examined: Planning as an optimizational activity, and disjointed incrementalism. One can argue that the computer technology is not delivering anything new to the planning theory. This may be the case, but it may reinforce one camp of thought and denies another. The paradigmic view of knowledge does not require the tool to always offer a whole new set of thinking. Rather, it proposes that dominant thinkings are often supported by the technology and worldviews of the day. The invention of the telescope by Galileo is an often cited example. The solar-centric view of the world was not invented by observations of the telescope, but was confirmed after it was put forward by Copernicus almost one hundred years ago. First, the optimizational theory, an attempt to seek for the absolute plan is discussed.

2.1 A PARADIGM OF THE ABSOLUTE PLAN

It had been a common belief that science advanced through new discoveries of truths. The truths were given, either by God (for the theists) or were embedded in Nature (for the atheists). They were part of Him/It, and were always valid. The perception of scientific activities had been, then, to weed out the False, and get closer to the Truth. It was then, a linear process with a purpose and a single direction. The way of getting to The Truth, perceived by religion, was revelation, and perceived by science, was logical positivism.

What influenced scientific thinkings also influenced other facets of human life, such as planning. Like scientists pursuing The Truth, planners pursued The Plan, the so-called master plan for the cities for which they work. They did not seek for The Plan from revelation, but from knowledge gained through logical positivistic studies.

Logical positivism, in revolt against romanticism, asserts rigid logical thinkings in the earning of knowledge. A logical positivist would hesitate to come to any concluding statement if the logical path from observations and assumptions to conclusion is not clear and smooth. He is a sceptic of human intuition and wisdom, and likes to ask what they are. He believes that if it is agreed that A is identical to C, it first has to be established A is identical to B, and C also is identical to B. Typically, logical positivism is atomistic in its approach to knowledge. It would not allow any statement about the forest if each single tree in it is not examined. If only a sample of the trees can be observed, the arguments to statements about the forest have to include assumptions on the sampling method. Observations and assumptions, in the positivistic approach in research, have to be necessary and sufficient to establish a concluding statement.

There are many problems to logical positivism, especially applied to human and community affairs like planning. First, statements and observations themselves almost are impossible to be established in the rigid positivistic way. For establishing observations as innocent as 'there are 345 people in the community who are at the age or over the age 65,' one has to argue first in a *positivistic* way why age segregation is needed, and why segregating people in such and such a way. Explanations offered for questions like this would only invite even more questions, and more positivistic explanations are needed. The logical statement list can go on and on without ending. One can take assumptions to avoid unending arguments, but that also opens up a series of 'why' questions on the values and grounds of assumptions. Second, given the reason mentioned above, the positivistic approach to research never delivers conclusions that a positivist would feel final and complete. That means, it can never be made certain what is being missed. Third, in the discipline of epistemology, it is not clear how logical positivism could lead to new knowledge. Given a positivist spends his efforts almost exclusively in clearing up language and statements, how he can earn knowledge outside the parameter of the known statements is not clear. If he is solely a discoverer of knowledge buried in the things known, how he comes to recognize the significance and meaning of knowledge that he digs out from the jungle of known statements is to be explained. A typical positivist, then, is forever condemned in the cocoon of words and statements.

2.2 COMPUTER AND THE ABSOLUTE PLAN

It does not require one to stretch imagination too much to find the possible relationship between the computer technology and logical positivism. Logical positivism demands logical and numeric calculations, and computers are good in doing that. However, can the computer technology deliver the capability to carry out a logical positivistic approach to planning? This is what needs to be examined.

One manifestation of the positivistic approach to computer usage in planning is perhaps in the idea of optimizing plans. To find the linkage between positivism and plan optimization, the value of cost-efficiency needs to be examined. Cost-efficiency as a value penetrates almost all aspects of urban life. This value is maintained for economic reasons (to be competitive as a city), political reasons (to avoid high taxes), and conservation reasons (to avoid waste). Given planning as an optimum-seeking activity, quantification and calculations are the basic mechanism to seek a good plan. Mathematical arguments are needed to establish an optimal plan. To the author, mathematical argumentation is one form of logical argumentations. Mathematical arguments, however, tend to be expressed in their own specialized language and symbolism. Logical arguments also have their own symbolism, but they tend to be more verbally descriptive. For example, mathematically it is stated that:

Given $a = 2$, *and* $b = 7$, *and* $c = a \times b$
$c = 14.$

Logically, it is stated that:

If the statements 'a is 4', 'b is 7', and 'c is the multiplication of a and b' are true,
then 'c is 14' is true.

To approach an optimized plan in terms of cost-effectiveness, then, mathematical and positivistical methods are followed. All necessary and sufficient (relevant) variables and arguments are brought in, and the computer is used to generate an optimized plan. The question is: does it work? If it could, optimization can be very useful in certain subsystems in the metropolitan region. For example, a dynamic programming algorithm is used to find the shortest paths in a transport network, providing a capability that has become absolutely fundamental in locational analysis. Other optimizing methods can simulate retail trade location and housing choice, but various difficult problems always arise in their use and interpretation.

The problems with logical positivism that is mentioned above also, as can be expected, find their way into using computer to do optimization planning. The number of variables, assumptions, and possibilities/probabilities can easily suffocate mainframe computers, let alone the micro-computers. The severity of the problem can perhaps be illustrated by the "travelling salesman" problem. This suspicion was finally crystallized through the definition by Cook [7] of a class of problems that he called "NP-complete." This discovery requires a brief exploration.

NP-complete problems have an enormous number of possible solutions: for example, there are more than 2,400,000,000,000,000,000 (2.4E+18) possible sequences in which 20 city blocks can be redeveloped, one at a time. Under certain circumstances, the evaluation of such a very large number of possibilities in a reasonable period of time requires a "nondeterministic Turing machine" (N), a fictional device that has unlimited potential computing power. This is required even through the evaluation of any one solution requires time that is only "polynomial" (P) in the problem size - not unduly large. Any "NP" type of problem is defined to be "NP-complete" if it corresponds exactly, in a sense well specified by Cook, with the logical problem of "satisfiability," which, as he showed, demands an exhaustive enumeration of all possible alternatives for its solution.

Experience and analysis have shown that most large planning problems are NP-complete, and cannot be solved optimally in a reasonable period of time with any

7 Schlaifer, Robert., *Probability and statistics for business decisions; a introduction to managerial economics under uncertainty.* New York, McGraw-Hill, 1971, p.64.

foreseeably available computer power. The fundamental structure that leads to these difficulties has virtually nothing to do with the ambition of the planners or the supposed complexity of computer models. Even every simple problems display this quality. It appears whenever a large number of decisions have to be made, and the value of every decision is strongly affected by other decisions. In economics, this difficulty leads to the defeat of automatic economic optimality whenever there are externalities, indivisibilities, and decreasing cost industries - but these are the precise characteristics of urban planning problems, so that neither competitive economics nor computer optimizing can solve them.

The principal and ultimate objection to the use of standard optimizing methods for city planning is that as a practical matter they cannot work.

2.3 A PARADIGM FOR A RELATIVE, ADJUSTABLE PLAN

God, the Nature, and Idealism served as parts of the paradigm for the absolute. Rigid tools such as pens and paper served as other parts of the same paradigm. The Twentieth Century offers a new thrust of thinking. The relativity concept and quantum theory in physics find their way slowly but surely into the realm of metaphysics, and have created a new worldview. In planning, they allow for concepts like incrementalism, muddling-through theory, mixed-scanning, and phenomenology. These concepts may not be direct descendants of relativity or quantum physics, but the overall worldview or framework allow non-absolute thinkings to emerge, and thrive. Also, flexible tools like the micro-computers, as part of this new paradigm, make thinkings about probabilities, alternatives and simulations easier.

2.4 COMPUTER AND A RELATIVE, ADJUSTABLE PLAN

An embarrassing dilemma is presented to us in the previous discussion: in professional planning activity, the planner wants to produce the best plan possible, yet optimization is impossible. It then has to be concluded that, if standard methods will not work, then surely there must be a way to proceed without them. Indeed, the principal and ultimate solution to this difficulty is the use of an active and well-considered method of planning design - one that allows the planner, with the assistance of the computer, to take advantage of the knowledge gained through the study of optimization. The paradigmic theory allows us to conceive the conceptual framework with what tools have promised us. In the latter part of the thesis, such an attempt will be launched. The housing simulation model as a finished planning tool, combined with computer and modeling, system and simulation concepts is used. It can be discovered that there is one planning theory that best serves as a theoretical framework for that simulation model, and it is the disjointed incrementalism.

2.5 MICRO-COMPUTERS AND INCREMENTALISM

Disjointed incrementalism is presented as the typical decision-making process of pluralistic societies, as contrasted with the master planning of totalitarian societies. Influenced by the free competition model of economics, incrementalists reject the notion that policies can be guided in terms of central institutions of a society expressing the collective "good." Policies, rather, are the outcome of a give-and-take among numerous societal "partisans." The measure of a good decision is the decision-makers' agreement about it. Poor decisions are those which exclude actors capable of affecting the projected course of action; decisions of this type tend to be blocked or modified later.

Partisan "mutual-adjustment" is held to provide for a measure of coordination of decisions among a multiplicity of decision-makers and, in effect, to compensate on the societal level for the inadequacies of the individual incremental decision-maker and for the society's inability to make decisions effectively from one centre. Incremental decision-making is claimed to be both a realistic account of how the North American polity and other modern democracies decide and the most effective approach to societal decision-making, i.e., both a descriptive and a normative model.

Therefore, disjointed incrementalism seeks to adapt decision-making strategies to the limited cognitive capacities of the decision-makers and to reduce the scope and cost of information collection and computation. Charles E. Lindblom outlined the strategy of "disjointed incrementalism" in six points:[8]

1. Rather than attempting a comprehensive survey and evaluation of all alternatives the decision-maker focuses only on the policies which differ incrementally from existing policies.

2. Only a relatively small number of policy alternatives are considered.

3. For each policy alternative, only a restricted number of "important" consequences are evaluated.

4. The problem confronting the decision-maker is continually redefined: Incrementalism allows for countless ends-means and means-ends adjustments which, in effect, make the problem more manageable.

5. Thus, there is no one decision or "right" solution but a "never-ending series of attacks" on the issues at hand through serial analyses and evaluation.

6. As such, incremental decision-making is described as remedial, geared more to the alleviation of present, concrete social imperfections than to the promotion of future social goals.

The experimental housing policy simulation that is presented in the following chapter of the thesis fits very well into this conceptual framework.

8 Lindblom, Charles Edward, Politics and markets : the world's political economic systems. New York : Basic Books, c1977

Corresponding to Linblom's first and second points, the housing simulation focuses only on three policies that 'differ incrementally from existing policies': new housing, restoring old housing, and tolerating units deteriorate. On the third point, the 'restricted number of "important" consequences' in the simulation model are: the surplus or deficit of the housing units. On the fourth, the housing problem simulated is continually redefined. It can be an excess surplus problem, or a supply insufficiency problem. The means could be higher rates on new housing, or higher rates on restoring downtown older stocks. With less new housing as means, restoration becomes a goal. With less restoration, new housing is then the goal. On the fifth point, the housing simulation does not attempt to offer a single answer to the housing problem. It allows the problem to be tackled with different means and at different times. The means and the timing, in turn, are to respond to the political forces of the day. Finally, on Linblom's sixth point, since the housing simulation policies are to respond to the housing needs of the day, they are not meant to lay out a twenty-year housing plan, but to remedy the housing problem of the day.

CHAPTER THREE
AN INTEGRATED PLANNING SYSTEM - AN APPLICATION TO HOUSING

In this chapter, a particular system in which different areas of computer usage can be integrated is discussed. A system approach, in the author's opinion, is needed if these tasks are to be performed on the computer in an efficient and integrated way. Before present one such system, it is pertinent to ask the fundamental question: what is a system?

3.1 DEFINITION OF A SYSTEM

The term system is used in such a wide variety of ways that it is difficult to produce a definition broad enough to cover the many uses and, at the same time, concise enough to serve a useful purpose. A *system* is defined as an aggregation or assemblage of objects joined in some regular interaction or inter-dependence.[9] While this definition is broad enough to include static systems,

9 Chorafas, D. N., *Systems and Simulation,* New York: Academic Press, Inc., 1965.
Klir, George J., *An Approach to General Systems Theory,* New York: Van Nostrand Reinhold Co., 1969.
Zeigler, Bernard P., *Theory of Modelling and Simulation,* New York: John Wiley & Sons, Inc., 1976.

the principal interest will be in dynamic systems where the interactions cause changes over time. In the following, a particular system used in some planning researches: housing demand and supply analysis is presented. This particular system is chosen because of its simplicity that lends itself rather easily to be modelled and applied in computer.

3.2 INTEGRATED HOUSING PLANNING SYSTEM

The modeling system being presented consists of the following subsystems: employment data from map-based database, employment level projection, population projection, housing demand, housing supply, and policy performance. The housing planning is taken in this thesis as one of the major planning activities and can serve well to be an example for an integrated planning system for computer implementation.

In brief, the system is composed of the following logic. The level and structure of population are important factors in the need or ability to attract employment and the requirements for housing. On the other hand, the growth of employment opportunities may be the main cause of in-migration, or the lack of employment may result in out-migration. Furthermore, lack of available housing may act as a constraint on in-migration to fill vacant jobs, or new house building may result in in-migration, either of these who work elsewhere or associated with employment growth. These interlinkages have led to the development of integrated forecasting systems. In this context the integration refers to the use of a set of common, compatible supply-and-demand assumptions for population, housing and employment, with explicit consideration of their relationships. This may be termed horizontal integration. There are, however, other aspects to integration, methodologies for which are little developed. These are[10]:

1. Vertical integration: to ensure the compatibility of forecasts for large areas and long terms with those for smaller areas and shorter terms.

2. Organizational integration - these are not based on techniques but on ensuring that different arts of an organization use consistent forecasts.

There is no standard method of horizontal integration of forecasts. Several versions have been developed by particular local planning agencies to suit their own needs. Attempts to move to a more standardized approach are not well advanced. The thesis, however, will adopt the Gloucestershire method, which is outlined in (Breheny and Roberts, 1978).[11]

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10 Cockhead and Maters, 1984

11 Breheny and Roberts, 1978

3.3 THE GLOUCESTERSHIRE METHOD[12]

The Gloucestershire approach provides a basic integrated forecasting model which examined the supply-demand relationships within and between population, employment and housing. Activity levels are related through the supply-demand relationships. Determination of actual levels cannot occur until supply and demand are mutually adjusted. One activity level is held constant and the others are adjusted to produce an equilibrium. In reality, of course, there is no starting point and so it is necessary to 'break in' to the loop and to identify the prime mover activity from which to start. As such it is similar to the linear-deductive approach.

The basic features of this model are:

1. The activity levels are determined by the relationships between supply and demand.
2. The supply and demand factors are influenced by, and influence, the levels of other activities.
3. The prime mover in the system is the one placing the strongest constraints on the others - once found, other activities have to be made consistent.
4. The basic activities considered are employment, population, households and housing.
5. The system produced has an equilibrium static approach. It does not model the dynamic and possibly continual imbalance of reality.
6. It is not a model of the causal relationships between component modules, but merely an accounting device to ensure compatibility.

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12 Ibid.

From the outset a distinction is made between outcomes over which policy could exert control and those over which it could not. The procedure is in three stages:

1. Forecasts are made for individual activities without the constraining effects of other activities. This represents the unconstrained potential for change.
2. Forecasts are made with the mutually constraining effects. This produces the integrated forecast.
3. The effects of policy constraints on the integrated forecast are tested. These can produce the basis for a forecast which combines planned and unplanned changes.

From the basic structure shown in Appendix I more specific linkages can be derived, which is constructed on the assumption that:

(a) Employment tends to be the prime mover which determines general demand levels.

(b) Housing tends to be prime determinant of supply levels.

The steps taken are summarized in Appendix II and are as follows:

1. Forecast the unconstrained employment-labour demand.
2. Multiply employment-labour demand by the inverse participation rate (persons per job). This produces a constrained forecast of resident population. (It may be used to forecast migration.)
3. Apply headship rates to the population to produce a constrained housing demand forecast (note this is not economic demand.)

1-3 above produce an initial set of demand-based forecasts.

4. Forecast the housing supply to establish unconstrained housing supply .

5. Compare housing supply and demand forecasts. If supply is greater than demand, then there are no housing constraints and calculation stops.

6. If housing demand is greater than supply, assumptions concerning rates of building new housing units and restoring the substandard units can be adjusted to compensate.

7. The process is repeated until labour supply and demand match.

In reality adjustments are dynamic and an equilibrium may never be reached. However, to produce a static equilibrium in the model, assumptions must be made if supply and demand do not match, that is:

(a) If and how marginal adjustments might occur to ensure equilibrium.

(b) Which should take primacy if demand and supply are incompatible even after adjustments?

Answers are required when demand and supply for housing (Step 6) and for labour (step 8) are compared. Only when adjustments have been made beyond a level of tolerance does supply or demand have to take primacy and act as a constraint. If supply exceeds demand no adjustments are necessary.

In this chapter a conceptual system along which an integrated micro-computer tool can be designed is presented. The whole system, however, has to start with some raw information. In this case, the first piece of information is the employment levels of the town in the base years. The next chapter, explores the fundamental concept of a computer map-database, and explore the feasibility of building such a database for cities on a micro-computer.

CHAPTER FOUR
A COMPUTER GEOGRAPHICAL INFORMATION SYSTEM

4.1 GEOGRAPHICAL INFORMATION SYSTEM (GIS)

A geographical information system is a computer map-database for a municipality or a region. While some GIS's are designed to handle one particular subject, most GIS's are comprehensive database that include information relating the physical and legal features of the municipality, such as infrastructures (water, drainage, sewerage), environment (creeks, contours, environmentally sensitive areas), transportation (classification of roads, lanes) identity of land parcels (civic address, legal descriptions). Theoretically, human and social information can be added to a comprehensive GIS as well, although this would require a more powerful computer to operate. Given the right software and hardware, a comprehensive GIS can make use of raw data stored in them to provide new information. However, a GIS for an average-sized city with these functions can easily overwhelmed the capacity of a micro-computer.

The main thrust of this thesis is to choose a certain computer usage to illustrate the paradigmic theory of planning discussed in Chapter One. This particular computer usage is confined in the realm of micro-computers, with microprocessor 486 machines typically marking its top power level. This range of computer power is not arbitrally chosen, for micro-computers can be regarded as possessing an identity different than main-computers, and can therefore be regarded as a different tool than the mainframe computers in the paradigmic theory. With the hardware chosen, it is therefore reasonable to avoid a full discussion of a comprehensive GIS that designed to provide a wide range of new information. Implementing such a system is beyond the capacity of our tool, the micro-computers, and discussion on its technical aspects is beyond the purpose and scope of this thesis.

In this thesis, a GIS takes on the limited function of displays of map-oriented information on the micro-computers. Analysis of its raw information is handled by other specialized software. A GIS, narrowly defined, provides the planners with the capacity to map (or at least to locate within, say, blocks) land parcels and to follow events in the development process. Thus it has multiple uses in the management and control of urban affairs. It is essential to note not only that all these administrative uses can be pursued quickly, efficiently, and accurately in a computerized system, but also that the information can be organized and displayed geographically, using charts and maps. A typical GIS will connect a mapped representation of the city or other jurisdiction with a database consisting of individual and aggregated observations about the land and the events and uses located on it. The mapped representation of the city is a particular type of data base in itself, and may in fact consist of many different maps dealing with different human activities, such as land ownership, population, economic activity, and public safety, and with different natural characteristics, such as slope, elevation, soil types, and so on. Changing a mapped representation in various ways can affect the data base, and manipulation of the database can generate new maps or mappable characteristics.

Many difficult technical problems arise in designing a GIS, particularly in relating different databases through overlays and in locating points within areas. Many planners are visually oriented, and the information most useful in planning and administration involve spatial distributions and their interrelationships, as defined in part by the coincidence, contiguity, and propinquity of different activities, events, and conditions. Therefore the mapping and display characteristics of a GIS, despite their costs, are of enormous psychological and operational importance.

Given the limitation of the power that today's micro-computers have, it is not quite possible yet, in the author's opinion, to build a full-scale map-database for an average-size city on the micro-computer. Such a system would have to be parcel-based, each parcel carrying lines, dimensions and orientations for the lot. Often a parcel does not correspond to a property, causing a new layer to be drawn, and each property again has its demarcation lines, dimensions, and orientation. Further, a full-scale system should have information not only above ground, but also underground as well. This would mean the vertical elevation profile of the land in terms of contour, soil type, depth of bedrock, etc.

Underground information would also have to include infrastructure such as sewage system, water, hydro lines, telephone lines, natural gas, etc. Each of this information should have a layer of its own. A medium size city has thousands of land parcels, and a good size city like Toronto and Vancouver has tens of thousands of these units. Is it realistic to have all the Toronto's information outlined briefly here to be presented on a powerful micro-computer screen all at once? Yes, *perhaps*, but it is going to be so slow that it renders operations on it impossible. One can argue that if less layers are to be opened at any one time, and only portions of the city are displayed, the load for the computer is lighter, and therefore working on it and using it becomes easier. However, at the same time, the extent to which this database is used is compromised. One cannot, for example, cross reference easily the above ground features with the underground features by a simple clicking. Given the present limitation on the power of micro-computers. The likelihood of seeing a full-scale information system for a city on a micro-computer is rather remote.

4.2 THE PLANNER AND THE MAP-BASED DATABASE

Planners working for a municipality often find themselves in a position to co-ordinate projects required by Council. For example, if the municipality is under pressure to make available more suburban lands to be developed for urban uses, it is the planners that co-ordinate efforts from other municipal departments to arrive at a desirable plan. Planners, therefore, often have a comprehensive view of the municipality that engineers, surveyors or by-law building inspectors do not process. It is, therefore, appropriate to have planners to be the co-ordinator in establishing a computer system as comprehensive as the geographical information system This is not to say, however, that the planners should be expected to build the system technically, for the technical matters are best to be left handled by technicians with computer and survey training. In order to serve effectively as co-ordinators in a GIS project, planners should be well-informed about the theories, fundamental concepts, issues, and limitations of geographical information systems.

In some broader definitions of GIS, the map-database itself is programmed with modeling functions to generate new information. In this thesis, however, the GIS is defined as an electronic map-based database that keeps the raw data, or at the most some basic compilation of data. New information functions, in this thesis, are attributed to other specialized types of software, examples of which will be given in the following chapters.

The next chapter examines the concepts of mathematical modeling. The way to use software programmes like MathCAD to project employment levels for the future is illustrated.

CHAPTER FIVE
MATHEMATICAL MODELING IN PLANNING

With the GIS as the source for raw data, the next phase of the system would be a way to generate new information. New information can be collected or generated basically in two ways: intuition and logic. Since computer functions on logic, not intuition, and modelling is an essential way to express logical relationships between entities of information. This chapter will discuss mathematical modeling. Modelling and its functions will be defined. More specifically, the Shift-and-Share Analysis model of employment forecast will be presented, with an explanation of how this modeling method, computed with the software program MathCAD, can generate new employment level information. However, some basic concepts in mathematical modeling, such as the term 'model.' would have to be clarified.

5.1 WHAT IS A MODEL?

A model is simply a way of representing reality in which real-world objects and relationships are expressed, either physically or in the abstract, in some way relevant to their characteristics.[13] Their value lies in improving understanding of reality where it is not possible to construct an experiment in the real world. Physical models can be created by replicating the original at a different scale, for example an architectural model of a proposed development, or by analogy, for example a map or plan. By contrast, abstract models represent the relevant characteristics of the original in a language, which might be expressed verbally using words and syntax or mathematically using symbols and equations. Mathematical models lend themselves to easy manipulation by avoiding many of the problems of the other variants, such as the ambiguity that often characterizes verbal conceptual models or the inflexibility of the physical model. This facilitates their use in the making of forecasts. But perhaps, most important of all, they provide the opportunity for computation.

Almost all operational urban models rely on a computer for their effective use. This is simply because models of the urban system (or parts of it) are likely to be fairly complex, and require large amounts of repetitive calculation. The main characteristic of computers is that they are capable of performing calculations at high speed and with high degrees of accuracy. It therefore seems sensible to utilize this capacity as a tool in the construction of urban models.

Essentially, therefore, computers represent a means of making models operational, especially where the model is a large and complex one. Older

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13 Hester, J. (1970). *Systems Models of Urban Growth and Development.* Urban Systems Laboratory, M.I.T.

computer technology, however, required the mathematical formulation of the model to be re-expressed, first as an algorithm and then as a computer program. Now, with the advent of powerful microcomputers and mathematical software, mathematical formulation simply needs to be typed in or drawn on the screen. Results of the formulation would then be displayed either in numbers or with graphs. The ability to execute the calculation process and to program the computer is no longer a pre-requisite to build and test mathematical models. What is still to be needed is the knowledge of what the substance of modeling is: namely the concepts of the formulation, and the understanding of the mathematical language to express these concepts.

An urban region is a highly complex system of interconnected activities which, for ease of understanding, can be divided into subsystems. When building a planning model it is necessary to try to understand and describe the mechanisms which govern the behaviour of a given subsystem, and then translate what is often a verbal description into the language of mathematics. But the real-world subsystems are themselves very complex, so in order to make models workable, they are going to be considerably simplified representations of our phenomenon of interest. Nevertheless, if properly constructed, they can provide a good structure for problem solving and evaluating planning policies generally.

5.2 EMPLOYMENT MODELING

The following discussion is largely based on Krueckeberg, D.A. and Silvers, A.L.'s work.[14] In their view, an appreciation and understanding of local economic activity provides an essential underpinning to much of the planner's work. For example, employment opportunities influence population levels, mainly through migration and, therefore, impact on housing requirements. Planners have an interest in three broad aspects of economic activity: local economic prospects and the consequent scale and character of development; personal incomes and the effect on demand for services such as shopping; and requirements for land, buildings and infrastructure. There are various approaches to the analysis of such activity, most having been developed within the field of regional science. One of these approaches is the Shift-and-Share Analysis method.

Shift-and-share analysis is a relatively uncomplicated technique that attempts to identify some of the factors that underlie the differences in the growth and hence employment performance of different regions or local areas. In recognizing that different areas will grow at different rates, the approach simply asks why this should be the case.

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14 Source: Krueckeberg, D.A. and Silvers, A.L. (1974), "Regional Income and Employment Analysis", Chapter 12 in Urban Planning Analysis: Methods and Models, John Wiley, New York.

5.2.2 THE COMPETITIVE AND INDUSTRY-MIX EFFECTS

There are two main reasons why a region or local area may grow at a slower or faster rate than the national average. First, different areas possess different attractions to and conditions for industrial development and hence it would be expected that there would be different growth rates in similar industries. The second component recognizes that, within particular areas, the mix of industries might be strong weighted towards the slow or fast growth type - for example, areas within high concentrations of industries with a strong propensity to grow would be expected to grow faster than other areas within the national or macro-regional space economy. Clearly, it would be very useful if planners could isolate these two effects, known as the competitive effects and the industry-mix effect, from the national growth trend, and to identify and quantify the extent to which each is responsible for a given study area's growth performance. This procedure of separating the total shift into its two major components is the shift-and-share analysis.

5.2.3 THE SHIFT-AND-SHARE METHOD (REF. APPENDIX I)

The actual operationalization of the technique is based, as suggested above, on a comparison of the growth performance of a given local area or region with the expected growth in a larger area (macro-region or nation) of which the study area is just one of many. National or macro-regional and study area data - measured either in terms of output, value-added, or employment - are thus required for two periods in order to proceed with estimation as follows.

Assume that employment data is being used and that $E_{ij(t)}$ is the level of employment in sector *i* and in region or local area *j* at time *t*. If there are *m* industries and *l* regions or local areas, the regional or local area employment change in each industry is then

$$\Delta E_{ij} = E_{ij(t+n)} - E_{ij(t)} \tag{1}$$

where ΔE_{ij} = change in employment between time periods *t* and *t* + *n*.
n = the number of years between the two periods.

At the national or macro-regional scale, employment change in each industry, ΔE_{iN}, is

$$\Delta E_{iN} = \sum_{j=1}^{l} \Delta E_{ij} \tag{2}$$

While national or macro-regional employment change in all activities, ΔE_N is

$$\Delta E_N = \sum_{i=1}^{m} \sum_{j=1}^{l} \Delta E_{ij} \tag{3}$$

Now if it is assumed that all regions or local areas grow at the national or macro-regional rate, then the industry's hypothetical growth is $(\Delta E_N / E_{N(t)})E_{ij(t)}$.

Subtracting this from the growth that actually occurred, ΔE_{ij}, a measure is obtained that can be called the industry's total shift, S_{ij}, that is

$$S_{ij} = \Delta E_{ij} - \left[\frac{\Delta E_N}{E_{N(t)}} \right] E_{ij(t)} \tag{4}$$

where S_{ij} = the net shift in industry *i* and in region *j* of the *l* region space economy.

There is now a need to determine the magnitude of the major forces contributing to this net shift. As stated earlier, the first component is a competitive effect commonly known as the differential shift, and measures the study area's locational advantages. If this is defined as D_{ij}, then

$$D_{ij} = \left[\frac{\Delta E_{ij}}{E_{ij(t)}} - \frac{\Delta E_{iN}}{E_{iN(t)}} \right] E_{ij(t)} \tag{5}$$

As can be seen, the size of the different shift depends on the difference between the industry's regional and local area growth rate and its national or macro-regional growth rate. It measure the extent to which forces operating on industry at the regional level (e.g. labour supply advantages) contributed to the magnitude of the net total shift. It is possible, therefore, for equation (5) to be either positive or negative, the former indicating that the study area has a competitive advantage, the latter otherwise.

The second component of the total net shift focuses on industry composition and measures the effect of the study area's industry mix. This is commonly known as the proportionality shift and, if this is defined as P_{ij}, then

$$P_{ij} = \left[\frac{\Delta E_{iN}}{E_{iN(t)}} - \frac{\Delta E_{N}}{E_{N(t)}}\right] E_{ij(t)} \tag{6}$$

The size of the proportionality shift depends on the difference between the total national growth rate and the industry's national growth rate. It therefore measures the extent to which forces operating on the industry at the national level (e.g. changes in national demand patterns) contributed to the magnitude of the total net shift. If the proportionality shift is positive, it means that the study area has a favourable industry-mix biassed towards rapid growth industries.

That the differential shift and the proportionality shift together equal the total shift is easily verified by simply adding them, that is:

$$\begin{aligned} D_{ij} + P_{ij} &= \left[\frac{\Delta E_{ij}}{E_{ij(t)}} - \frac{\Delta E_{iN}}{E_{iN(t)}}\right] E_{ij(t)} + \left[\frac{\Delta E_{iN}}{E_{iN(t)}} - \frac{\Delta E_{N}}{E_{N(t)}}\right] E_{ij(t)} \\ &= \left[\frac{\Delta E_{ij}}{E_{ij(t)}} - \frac{\Delta E_{N}}{E_{N(t)}}\right] E_{ij(t)} \\ &= \Delta E_{ij} - \left[\frac{\Delta E_{N}}{E_{N(t)}}\right] \\ &= S_{ij} \end{aligned} \tag{7}$$

The approach as described above, which is illustrated schematically in Appendix II, can be adapted for predictive purposes by assuming that regional shifts remain constant and incorporating a differential growth rate - this is so called constant shift method. Beginning with equation (5) which expresses D_{ij} in terms of differential rates of growth it is possible to proceed as follows:

Given:

$$D_{ij} = \left[\frac{\Delta E_{ij}}{E_{ij(t)}} - \frac{\Delta E_{iN}}{E_{iN(t)}}\right] E_{ij(t)} \qquad (5)$$

then

$$\frac{D_{ij}}{E_{ij(t)}} = \frac{\Delta E_{ij}}{E_{ij(t)}} - \frac{\Delta E_{iN}}{E_{iN(t)}} \qquad (8)$$

This gives the differential growth rate that industry *i* experienced in study area *j*, i.e. it is the difference between industry *i*'s recent study area and national or macro-regional growth rates. Equation (6) may be written for ΔE_{ij} as

$$\Delta E_{ij} = \left[\frac{\Delta E_{iN}}{E_{iN(t)}} + \frac{\Delta D_{ij}}{E_{ij(t)}}\right] E_{ij(t)} \qquad (9)$$

Equation (4) is the projection equation under the constant shift assumption. As can be seen, the national growth-rate term has been relocated to the same side as the differential growth-rate term, and the technique therefore takes account of the possibility that regional shares may shift and that such changes may be important. For example, if it is found from **hypothetical** historic data, say the last five years, that the study area's manufacturing sector had a growth rate that exceeded the national (or macro-regional) growth rate for manufacturing by 2.3% and, assuming that there is a five-year national (or macro-regional) growth rate projection for manufacturing of 2.7%, then the study area's recent differential growth rate is added to the national/macro-regional growth rate projection to obtain the projected study area growth rate, i.e., 2.3% + 2.7% = 5%. This result can now be applied to the study area's current manufacturing output, value added or employment levels (depending on which units being worked in) to obtain our five-year growth projection.

5.3 EMPLOYMENT MODEL WITH MATHCAD

MathCAD on the Macintosh is very easy to use.[15] Besides the standard user-friendly features like the pull-down menus, cut and paste, mouse dragging, etc., its basic environment is as simple as a scratchpad. When the window (work area) is displayed on the screen, variables and equations can be typed on the window quite freely. To enter a definition or an equation, simply click and type. Mathematics is a logically sequential exercise. Therefore, MathCAD has to work according to some sequence. It calculates from top down. Therefore, variables at the bottom should have been assigned values in the above lines. The mathematical language used by MathCAD is almost identical to that expressed by pens and paper. Models often are comprised of many submodels and components of equations. Working with these models often would mean pages of tedious step-by-step calculations. With an electronic scratchpad like MathCAD, the variables are first defined, then the full model is typed in, and the results come out instantly. The results can also be presented in graphical format, either as line graph, or bar graph, or scatter plot, etc.

The employment model with MathCAD is included in the file 'Employment Model' of Disk Two of the thesis. To open the file, the programme MathCAD version 2.06 or higher, and a Macintosh computer equipped with a hard disk and with RAM at least 1MB is needed. The details about how MathCAD is used are

15 **MathCAD, MathSoft, Inc. Massachusetts, U.S.A., 1989.**

not included in this thesis. The manual of the program should be relied on for that purpose. The layout of the model in the file, however, warrants some description.

The model is about the employment level changes in a hypothetical regional-economic area called Stone. There are two cities in Stone: Stoney Mountain and Stonewall. The goal of the model is to find out given the present performances of Stonewall's industries in the region, and assuming the trend of economic development holds for a number of years, what are the employment levels of the city in the next twenty years. The base years are 1981 and 1986.

The employment information of the base years, 1981 and 1986, for Stonwall is presumably imported from the map-database of Stonwall. The first part of the model, then, is to import this information from a file called 'Stonewall Employment' that contains this downloaded information. A READ command is used to accomplish the task. The Stoney Mountain's data could also be imported the same way from a map-database for the city. In this model, hypothetical data for Stoney Mountain is typed in.

The second part of the model is to calculate the employment level changes for individual industries in both cities. These changes are then summed up to produce the total employment level change between the years 1981 and 1986 for the whole macro-economic region. With this information obtained, the differential shift of the employment level of Stonwall can be calculated.

Assuming a constant shift over a number of years, Stonewall's employment levels for twenty years from the base year 1981 is produced. The results would then all be written into a file called 'fromMath.' This information is used in a housing demand simulation, a topic discussed in the next chapter.

CHAPTER SIX
COMPUTER SIMULATION

The last chapter discusses how mathematical modeling can be done with the micro-computer. The purpose of mathematical modeling in a computer planning system is simply to process raw information to information needed. The raw information imported is presumed to be real, and therefore information generated is also presumed to be real assuming all things being equal. Chapter Five moves beyond simple information processing to policy simulation. Policy simulation is a process to 'visualize' different scenarios.

6.1 DEFINITION OF SIMULATION

In general usage, simulation is defined as an act or process that gives the appearance or effect of some part of reality.[16] Maisel has suggested that the purpose of simulation is "to attain the essence without the reality." Such definitions are too broad. A more operational definition is given by Naylr et al.: "simulation is a numerical technique for conducting experiments on a computer,

16 Herbert Maisel, *Simulation of Discrete Stochastic Systems*. Toronto: Science Research Associates, Inc., 1972, p.111

which involves certain types of mathematical and logical models that describe the behavior of a business or economic system (or some component thereof) over extended periods of time."[17] Except for the restriction to business or economic systems and the specification of "extended" periods of time, it is a good working definition for our purposes.

Mathematical modeling and simulation are similar to the extent that simulation sometimes use mathematical argumentations, such as addition, subtraction, multiplication and so on. However, mathematical modeling and simulation are different in many ways. First, whereas the purpose of mathematical modeling is to take in real data and to produce the required information, simulation modeling is to test out different hypothetical scenarios. Second, as implied in the first point, the input data for mathematical modeling is real, whereas that for simulation modeling is hypothetical, and often is expressed in a range of values. **Third, mathematical modeling in this thesis is totally expressed in mathematical language. For simulation modeling, although mathematics is part of it, the basic components are blocks and lines that express logical relationships.** Lastly, whereas a mathematical model is an expression of a theory, a simulation model is an expression of a process - a process of how events interact.

17 Pidd, Michael, *Computer simulation in management science.* Chichester ; New York : Wiley, c1984

6.2 ADVANTAGES OF THE SIMULATION METHODS

The major advantage of a simulation is that it permits study of the real system without actual modification of that system in any way. For many real systems, major experimentation involves very high risks. Changes of policy in housing planning, for example, may lead to very desirable results, or they may lead to catastrophe. How is the planner to know which changes can be attempted? He can look to past experience; he can call upon expert opinion; he can implement changes on a limited basis. All of these things have been and will continue to be done. But if the system is simulated on a computer, the results of various modifications can be observed in the simulation without modifying the real system in any way. Alternative modifications can be tried and their consequences studied in a systematic and controlled way. Of course, other kinds of models also can be used to make predictions about the behavior of real systems. But for complex systems of the kinds relating to planning, the simulation on a computer is unequalled in its ability to provide realistic models of system behavior at a reasonable investment of time and money.

Simulation has other advantages. As a process is studied in preparation for a simulation, previously unrecognized relationships or deficiencies often are revealed. These discoveries may lead to immediate alternations and improvements in the process. Simulations also have many uses as training tools, and a number of simulations have been developed for this specific purpose.

Finally, computer simulations permit the study of a broad range of problems and the asking of complex questions. The computer can manipulate elaborate descriptive and mathematical models that consider a great number of factors, provide for complex interrelationships, and deal simultaneously with a large number of individual units.

6.3 PRINCIPLES USED IN SIMULATION

It is not possible to provide rules by which simulation models are built, but a number of guiding principles can be stated. They do not describe distinct steps carried out in building a model. They describe different viewpoints from which to judge the information to be included in the model. The next section introduces the software program "Extend," which is designed to allow these principles to be implemented.

The Manual for Extend has a full explanation of how the program works, and what the blocks are. The following is a brief description of the basic components of the program. The Manual, however, should be relied on for details. First, the description of the system should be organized in a series of graphical symbols called *blocks*.[18]

18 Extend - Performance Modeling for Decision Support, Imagine That, Inc., San Jose, CA.

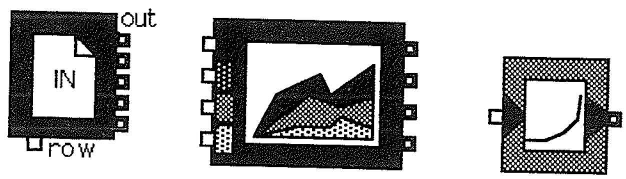

Diagram 1. Blocks as functional components used in Extend.

The aim in constructing the blocks is to simplify the specification of the interactions within the system. Each block describes a part of the system that depends upon a few, preferably one, input variables and results in a few output variables. The system as a whole can then be described in terms of the interconnections between the blocks. Correspondingly, the system can be represented graphically as a simple block diagram.

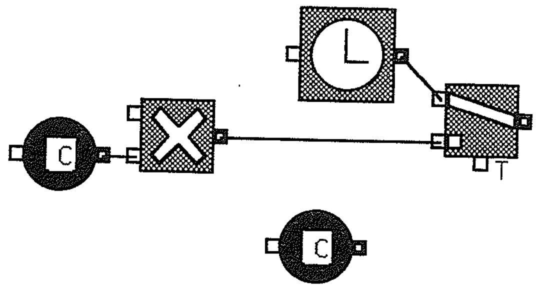

Diagram 2. A block diagram.

Second, the model should only include those aspects of the system that are relevant to the study objectives. While irrelevant information in the model may not do any harm, it should be excluded because it increases the complexity of the model and causes more work in solving in the model.

Third, the information gathered for the model should have a high level of accuracy and integrity. Without true information, simulations would serve no purpose.

Fourth, a further factor to be considered is the extent to which the number of individual entities can be grouped together into larger entities. It is sometimes important, for example, to know the housing adequacy and availability for individual income groups. For some more general studies, however, total figures on these aspects of housing would suffice.

6.4 SUBSYSTEM

In Chapter Three, a simple definition of a system as a set of interacting objects was discussed. The objects might be considered the basic entities of the system, but, usually, the description of a system can be made at many levels of detail. It is customary to describe a system as consisting of interacting subsystems. Any subsystem might, itself, be considered a system consisting of subsystems at a still lower level of detail, and so on. A system study must begin by deciding on the level of subsystem detail to be used.[19]

The block-building principle, mentioned earlier in this chapter, helps organize a system description by isolating subsystems and identifying their inputs and outputs. Each subsystem at a given level of detail is described as a block, giving relationships between the inputs and outputs. The relationships should be such that they are sufficient to determine the outputs from the inputs when the subsystem stands by itself; that is to say, there should be no need to use an endogenous variable (i.e., external factors that bear impact to the model) within the block. The term "black box," borrowed from the engineering field, is often used to describe an element of this nature which gives an output in response to an input without any need, or ability, to know how the transformation is made.

Each subsystem has its own inputs and outputs and, standing by itself, its response can be derived from the relationship that defines the subsystem. The interactions that occur in a system arise from the fact that the outputs of some subsystems become the inputs of others: they become endogenous variables of the system.

In the same way that a system breaks down into subsystems, so also a model of a system breaks into submodels. When describing systems in terms of blocks, the term *block, subsystem, or submodel* tend to used interchangeably, as will

19 Mihram, G. Arthur, "The Modelling Process," *IEEE Trans. System. Man Cybern.*, vol. SMC-2, no. 5 (1972), 621-629.

occur in the subsequent discussion. In fact, when concentrating on a particular part of a system or its model, the prefix "sub," is often dropped and talk about a part of a system or model as being, itself, a system or model. The context should make it quite clear what is intended.

6.5 EXTEND (PLEASE REFER TO APPENDIX II FOR ILLUSTRATION)

Simulation modeling, long the domain of mainframe computers, has gradually filtered down to the personal computer arena, with improved results. Extend, a dynamic model generator from Imagine That!, uses graphic representations of the building blocks of systems as well as graphic output. That is a far cry from traditional mainframe programming language input and tabular output.

Time- or frequency-dependent models can be used to simulate the behaviour of almost any system, such as manufacturing processes, inventory and cost control procedures or hospital patient flows. Results of such simulations can validate ideas, maximize performance or cost ratios, and diagnose potential design problems.

Models created in Extend consist of interconnected blocks representing basic system functions. The connections, which may be multiple and complex, represent inputs and outputs to the blocks. Each building block is driven by its inputs to produce its outputs. Extend models operate in an object-oriented fashion: Each block "does its thing" as the model is run, receiving "signals" from other blocks at its inputs and transmitting "signals" to other blocks via its outputs.

To avoid complex web-like paths on the model sheet, output signal paths may also terminate in a name, which can then appear elsewhere on the sheet as the source for an input path. In addition to user-specified signals between blocks, system messages are generated to inform each block of the state of the simulation.

There are three levels of Extend use. The first consists of taking an existing model and varying its parameters for system tuning or analysis. The second involves assembling a model from Extend's extensive library of supplied blocks. Finally, the user can build blocks from scratch, using Extend's C-like MODL language.

Two windows are used in block construction. One is for designing the block's parameter dialog box, while the second is used to design the block's structure, including its icons, variables, help text and equations.

When the user clicks on a model block, a dialog window opens to permit parameter definition. These block dialogs are customized during design of the block and can include edit fields, push buttons, radio buttons and check boxes. Dialog windows can also perform calculations, handle tables, and take parameter and text input.

A variety of output blocks are available, including graphs and tables. Different colors or line characteristics may be selected for each variable to be displayed in a graph. A table of numerical values of the variables is also provided, and when the user moves the cursor to any point on the graph, such as a minimum or maximum, the values at that point are shown.

More than one "case" may be run during a particular model session. Cases appear as separate pages that can be flipped through. Graph axes can be changed, and plots can be expanded and compressed for additional viewing flexibility.

The MODL simulation is a C-like structured object-oriented language. Using MODL, block designs specify what to do with input signals and what to provide at outputs. These scripts are embedded in 11 message handlers, such as ON Simulate. On DialogOpen and On CheckData, give the model its object-oriented, asynchronous power.

The handler On OK is particularly powerful; it can be used to produce calculations or actions within a dialog window itself, independent of running the simulation. For example, the supplied lease/purchase simulation includes a button that produces an amortization table.

The MODL language includes and extensive set of error messages, operator and control statements, and more than 150 built-in math and statistics functions. User-defined functions can also be created.

A powerful and highly user-friendly library system keeps track of the extensive collection of pre-defined blocks supplied by Imagine That! with Extend, as well as user-defined blocks. Block definitions are stored in the library system and transparently invoked by the work sheet on opening.

Extend includes a clear tutorial that uses as examples models of a lemonade stand and a home heating system. The manual is well-organized, and on-line help is provided. Technical support for registered users is a toll call, but a free quarterly newsletter is provided.

Constructing and editing models in Extend is easy with editing features for scripts, and good display and printing options are available. Extend can import and export data via the Clipboard or tab-delimited text files. The powerful block management library with automatic searching is very convenient for generating and maintaining systems of models. Models may be simulated in the background under MultiFinder, a very convenient feature for larger, more time-consuming models.

Despite its ease of use, Extend is not for beginners. Simulation model building requires careful thinking and analysis of the system to be modeled. Modeling is usually a subject for advanced undergraduate engineering and management science courses. It should also, in the writer's opinion, be integrated into the city planning course. The following parts of this chapter would present a housing planning simulation model. Before going to the actual setup on the computer, discussion of the concepts behind housing modeling is in order.

6.6 HOUSING PLANNING MODEL

The Housing Policy Simulation Model included in this thesis is composed of three major parts: Housing Demand model, Housing Supply model, and a policy simulation to test the performances of different housing policies. This simulation can only be taken as a prototype. In applying it to a real housing policy studies, it has to be adapted to specific local environment at that time.

6.6.1 HOUSING DEMAND

The simulation starts with importing data from the file 'fromMath.' This task is handled by a File Input Block on the extreme left side of the demand section of the simulation. (As indicated before, Extend models work from left to right) The Employment level projection is then divided by the work force participation rate of the population to generate a population forecast of the same duration of time. (In this case, from 1981 to 2001) The forecast population is then divided by the average household size to produce the number of households in the city. The results are processed by a Conversion Function Block to ensure them being integers, not real numbers. The numbers of household for different years are used as indications of how many housing units are needed, assuming one unit per household. This housing demand information then is to be compared with the housing supply information, which is controlled by some policy inputs. (See next paragraph) Also, the annual change of the housing demand is produced to be displayed on the graph for reference.

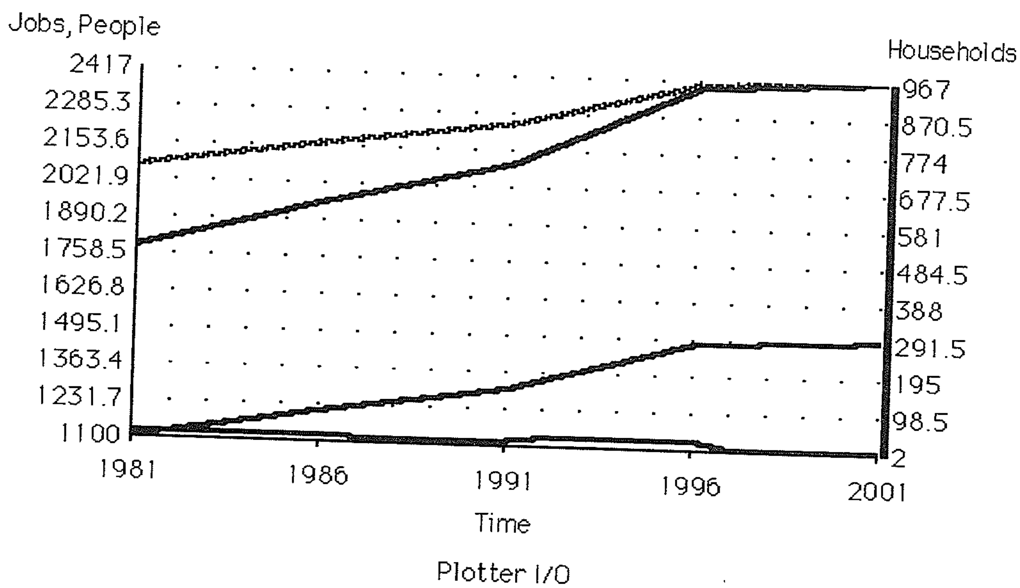

Diagram 3. An Output from the housing supply and demand model.

6.6.2 HOUSING SUPPLY

The supply side of the simulation starts with a System Variable Block.

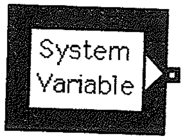

Diagram 4. A system variable block

The System Variable Block tells the simulation to prompt the user to enter rates for three housing planning policies: Building new housing units, restoring some substandard units, and allowing some housing units to go substandard. In the first step of the simulation, the number of units of the beginning year, 1981, is manually 'fed' into the simulation. This is accomplished by a File Input Block connected to a Select Input Block, which in turn is controlled by a mechanism telling the simulation to get information from the 1981 pre-set data in the beginning of the simulation. After the first step, however, the numbers of housing units available are produced by the multiplication process between the previous year's housing units and the three policy rates. The first two policy results (new units built and substandard units restored) are added up together, and the third policy result (units gone substandard) is subtracted. Each annual result is turned into an integer, and is compared with the same year's housing demand figure for understanding policy performance, and is 'looped' back into the multiplication part of housing supply to generate the next year's policy results.

6.6.3 HOUSING POLICY SIMULATION

The housing policy performance is a comparison of housing supply and demand year after year during the simulation period. The performance is largely observations drawn from the line graphs generated by the Plotter, I/O Block. The lines displayed are interpolated, i.e., they are adjusted to show not only true results of specific years in the simulation, but also estimated data between the beginnings of two adjacent years. Therefore, the lines are smoothed out, rather than stepped and 'jaggy.'

The X-axis of the graph displays the years. (Please refer to Diagram 3) There are two Y-axis. The one on the right displays values in the unit of households. The one on the left displays values in the unit of housing units. There are three lines shown on the graph, and therefore three 'stories' are told. First, there is the first line from the bottom displaying the annual changes of household numbers in the city. This line uses the second Y-axis on the right for reference on its values. The second line from the bottom indicates the housing units surplus. If the line is flat on the value 0, it means there is no housing surplus during that period of time. If the line is above 0 value, there is surplus. The surplus is increasing if the line goes up, and, of course, the surplus is decreasing if the line goes down. The same thing can be said about the thicker line, which indicates the housing unit deficit.

The **rates** that the user enters into the beginning part of the simulation control the results shown on the graph. The faster new housing units are to be built and old units restored, the easier are surpluses to identify. However, this is rather self-evident. What is important here is the capability to answer the 'by how much' and 'if' questions. By how much, for example, a surplus would be experienced in the real estate market in the year 1996 if housing units to be built at the rate of 2%, old units to be restored at the rate of 1%, and if old housing units are allowed to become substandard at the rate of 0.5%, and keep these policies from now all the way till then? Three different rates for new housing, three different rates for restoring are considered, and three different rates for tolerating old units becoming substandard, there are twenty-seven different scenarios. The duration of time in concern in this model is twenty years, or 240 months. That means, for different combinations of housing policy, 6480 (240 x 27) results are available for all the months in the period. With simulation model like this one, it is possible to estimate in a reliable way what the impact of new housing policies have on the existing housing supply and demand situation.

The housing increase/decrease rates do not have to be entered all at once, nor do that have to be entered once only. Different rates of the policies to go into the simulation can be scheduled. What needs to be done is some minor adjustment on the Prompt Blocks.

The rates chosen for different scenarios should be based on policies of the day. Policies, however, are determined not just by numbers and facts, but also by values and political choice. Values and political choice are not included in the simulation discused in this thesis. This omission is intentional, for although some may argue that these aspects of decision making can be indexed from 1 to 10 to represent their significance, and thereby processed by the simulation, modeling values and political choice is nevertheless an illusive undertaking, and does not carry strong convincing power. Computers, then, in this thesis, is limited to the role of facts, dissections and analysis of facts. The raw information as well as processed information are then served to the planners, who in turn would make their recommendation to Council on the basis of information from a larger planning process that includes simulation results as one of the inputs. There is no attempts in this thesis, therefore, to present the computers as a planning machine.

This chapter completes the exploration of a particular case of the use of micro-computers in planning. This case shows how different software and functions of the computer can generate new information, new knowledge, and decision-making support for housing demand and supply analysis. This chosen case by no means exemplifies all that planners do. It, for example, does not extend to the realm of land use planning regarding attributing different densities to different parts of the town or city. It certainly is silent on the urban designs and development management and by-law enforcement. All these are important aspects of city planning. What this thesis so far has illustrated, however, is how new information is generated in one particular case. The process described, taken conceptually, can be applied to other processes where new information and new knowledge are required. This is one of the most important processes in planning, and, as what the previous chapters have presented, the computer is impacting this process in a very significant way.

CHAPTER SEVEN
CONCLUSION

This thesis is to illustrate the use of micro-computers in planning with a particular case of information generation system: housing demand and supply. Specific software is used for such an exercise. While this particular case cannot be extrapolated to represent all that planners do, it is nevertheless a significant aspect of planning that causes us to reflect on the impact of computer technology on planning in its practice and theory.

As presented above, new information can be generated from raw data through a mathematical and simulation modeling structure. Once it is set up, the required new information can be generated very quickly. This versatility enhances the testing of different scenarios, and an ad hoc planning process. One point that needs to be emphasized is that new information is still information. It is meant to make a process intelligent, and not meant to replace the process itself. In planning, processes to come to conclusions in reports to Council are complicated. They involve much more than raw data or processed information. Public participation, for example, is an important element in the planning process, and yet it often produces conflicting information. A

community may state that they need industries in their area to provide employment base, and yet they do not want any industry to be located close to their residence. While humans resort to a political process to resolve contradictions, computers would usually flash ERROR messages on the screen, and stop to co-operate further. In using computers, therefore, the planner should put the information, however sophisticately produced, into perspective, and should not expect any simulation to command him what to do next.

The impact of computers on planning under the theoretical framework laid out in the paradigmic theory of knowledge has now been presented: that when the things in possession change, human thinking changes as well. It is not a matter of right or wrong with the previous or present thinkings; instead the worldview and the technology of the day often instill new approaches to problems, and thus new theories are formed. It can be extended by saying that the same thing happens to planning when micro-computers are adopted. The technology makes it possible for planning to deviate from the positivistic, absolute mentality. It makes implementing more relative concepts like incrementalism, or phenomenological planning possible. The housing policy simulation modeling is a good example of how this happens.

Micro-computers are providing more and more support to incremental and intuitive processes as they are made easier and easier to use. The housing model discussed above, for example, can readily provide new information under any given scenarios. Beyond information generation, given different software, the technology can allow urban designers to visualize concepts in a three-dimensional way at ease, and allow development control planners to organize and manage application processes in a non-linear fashion. Intuitively, they can relate different categories of information at different levels of a database according to how human minds function. The fast growing "hyper-media" technology, when fully developed and adopted by planners, would impact planning process in a significant way. Computer technology, then, is impacting planning practice in many ways. It is the author's opinion that the common theme that these different aspects of computer usage share is that incremental and intuitive approaches to various planning tasks are strengthened. The new paradigm, then, is one that celebrates planners as a person, not part of a logical mechanism.

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Appendix I: Employment Forecast for Stone

Source: Krueckeberg, D.A. and Silvers, A.L. (1974), "Regional Income and Employment Analysis", Chapter 12 in Urban Planning Analysis: Methods and Models, John Wiley, New York.

"ORIGIN = 1" specifies that the index of the first element in arrays is 1.
The variable "i" is a range variable.

$$\mathbf{ORIGIN} \equiv 1 \qquad i := 1 ..3 \qquad t := 1 ..5$$

EStwlBase : Employment figures in Stonewall by industry and by year. The columns stand for industry; the rows stand for the years 1981 and 1986.
EStmtBase : Employment figures in Stoney Mountain by industry and by year. The columns stand for industry; the rows stand for the years 1981 and 1986.

$$\mathbf{EStwlBase} := \begin{bmatrix} 300 & 350 & 450 \\ 305 & 400 & 500 \end{bmatrix} \qquad \mathbf{EStmtBase} := \begin{bmatrix} 250 & 250 & 480 \\ 230 & 300 & 500 \end{bmatrix}$$

ΔEStwlBase : Employment level change between the years 1981 and 1986 in Stonewall.
ΔEStmtBase : Employment level change between the years 1981 and 1986 in Stoney Mountain.

$$\Delta\mathbf{EStwlBase}_{i} := \mathbf{EStwlBase}_{2,i} - \mathbf{EStwlBase}_{1,i}$$

ENtlBase : the employment levels of macro-economic region that is comprised of Stonewall and Stoney Mountain

- for the base years 1981 to 1986.

ΔENtlBase : Employment level change between the years 1981 and 1986 in the whole region.

$$\mathbf{ENtlBase} := \mathbf{EStwlBase} + \mathbf{EStmtBase}$$

$$\Delta\mathbf{ENtlBase} := \Delta\mathbf{EStwlBase} + \Delta\mathbf{EStmtBase}$$

∑ΔENtl : the employment level change in this macro-economic region.

$$\Sigma\Delta\mathbf{ENtlBase} = 155$$

ΔStwl86' : the differential shift of the employment level of Stonewall in the macro-economic region.

$$\mathbf{DStwl86'}_{i} := \left[\frac{\Delta\mathbf{EStwlBase}_{i}}{\mathbf{EStwlBase}_{1,i}} - \frac{\Delta\mathbf{ENtlBase}_{i}}{\mathbf{ENtlBase}_{1,i}}\right] \cdot \mathbf{EStwlBase}_{1,2}$$

1986 FORECAST

FStwl86' - the projected employment increase for the year 1991 in Stonewall.

$$FStwl86'_i := \left[\frac{\Delta ENtlBase_i}{ENtlBase_{2,i}} + \frac{DStwl86'_i}{EStwlBase_{2,i}}\right] \cdot EStwlBase_{1,i}$$

EStwl91' - the projected employment level for Stonewall for the year 1991.

$$EStwl91'_i := EStwlBase_{2,i} + FStwl86'_i$$

ENtl91' : the total employment level in the region for the year 1991.

$$ENtl91' := EStwl91' + EStmt91'$$

DENtl91' : the employment level change between 1991 and 1986.

$$\Delta ENtl91'_i := ENtl91'_i - ENtlBase_{1,i}$$

1991 FORECAST

FStwl91' : the employment level forecast for Stonewall from the year 1991 and for the year 1996.

$$FStwl91'_i := \left[\frac{\Delta ENtl91'_i}{ENtl91'_i} + \frac{DStwl86'_i}{EStwl91'_i}\right] \cdot EStwl91'_i$$

$$EStwl96' := FStwl91' + EStwl91'$$

$$ENtl96' := EStwl91' + EStmt91'$$

$$\Delta Stwl96' := EStwl96' - EStwl91'$$

$$\Delta ENtl96' := ENtl96' - ENtl91'$$

1996 FORECAST

FStwl96' : the employment level forecast for Stonewall from the year 1996 and for the year 2001.

$$FStwl96'_i := \left[\frac{\Delta ENtl96'_i}{ENtl96'_i} + \frac{DStwl86'_i}{EStwl96'_i}\right] \cdot EStwl96'_i$$

$$EStwl2001 := FStwl96' + EStwl96'$$

$$ENtl2001 := EStwl96' + EStmt96'$$

$$\Delta Stwl2001 := EStwl2001 - EStwl96'$$

$$\Delta ENtl2001 := ENtl2001 - ENtl96'$$

$$PInd := \begin{bmatrix} EStwlBase_{1,1} & EStwlBase_{1,2} & EStwlBase_{1,3} \\ EStwlBase_{2,1} & EStwlBase_{2,2} & EStwlBase_{2,3} \\ EStwl91'_1 & EStwl91'_2 & EStwl91'_3 \\ EStwl96'_1 & EStwl96'_2 & EStwl96'_3 \\ EStwl2001_1 & EStwl2001_2 & EStwl2001_3 \end{bmatrix}$$

The forecast employment levels by industry for Stonewall is then written to a textfile named "fromMath".
The information on "fromMath" would in turn be processed by models created with Extend.

$$TTLStwl81 := \sum EStwl81'$$

$$TTLStwl86 := \sum EStwl86'$$

$$TTLStwl91 := \sum EStwl91'$$

$$TTLStwl96 := \sum EStwl96'$$

$$TTLStwl2001 := \sum EStwl2001$$

$$TTLStwl := \begin{bmatrix} TTLStwl81 \\ TTLStwl86 \\ TTLStwl91 \\ TTLStwl96 \\ TTLStwl2001 \end{bmatrix}$$

$$WRITEPRN(fromMath) := TTLStwl$$

Appendix II-Housing Simulation