THE DEVELOPMENT OF DISCOURSE:
A LANGUAGE FOR COMPUTER ASSISTED CITY DESIGN

by

William Lyman Porter
B.A. Yale University
(1955)
B. Arch. Yale School of Art and Architecture
(1957)

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Signature of Author...................................................
Department of Urban Studies and Planning, August 18, 1969

Certified by........................................
Thesis Supervisor

Accepted by........................................
Chairman, Departmental Committee
on Graduate Students
ABSTRACT

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Submitted to the Department of Urban Studies and Planning on August 18, 1969 in partial fulfillment of the requirement for the degree of Doctor of Philosophy in City and Regional Planning.

DISCOURSE is a language and computer system to assist the city designer in the process of the design of large scale physical environments. The system can accommodate large amounts of data describing the environment which can be readily changed, and new categories of the description as well as new data which can be added at any time.

DISCOURSE permits the designer to develop his own ways of working by having a data structure which is not committed to any particular set of environmental descriptors and yet which allows the designer to specify his own without extensive bookkeeping; and by having a large vocabulary of building-block manipulations out of which the designer can fashion his own special requests. The designer can alter the description directly or alter it subject to criteria which he specifies.

In Chapter II is the record of an experiment in the replication of a design which was fundamental to the development of the system. Chapter III attempts to analyse the process of city design in functional terms which will point toward the use of a computer system. It is argued that what designers do when they design can be thought of as "describing" (and further describing) the environment, "transforming" the description, and "testing" it. The language of DISCOURSE accommodates these three activities; its structure and manipulations are presented in Chapter IV. Chapter V contains an example of the use of DISCOURSE to simulate the use of recreational facilities in an urban environment.

The emphasis in system development to-date has been to build the capability of the computer system to handle internally the data and manipulations used by designers and to permit the designer to create and change both. Plans for the immediate future include improving the ease of entering large quantities of data, improving the quality of the display, and facilitating communication with other sources of data and systems for manipulation.

Thesis Supervisors: Aaron Fleisher
Professor of City and Regional Planning

Kevin A. Lynch
Professor of City and Regional Planning
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DISCOURSE is the product of the efforts and skills of many. My thanks to those who have been most involved is not meant to suggest that, by the support which they gave me, they were not making progress in their own right, progress which deserves reporting from their points of view, just as this dissertation reports from mine.

I would like to express my special thanks to Professor Aaron Fleisher whose insights and criticisms are an integral part of the thinking which underlies this work. I would like to thank Professor Kevin Lynch for his guidance particularly in the early phases of the work when the direction was hard to find. My thanks go also to Dr. John Boorn with whom much of the early thinking was done.

Many of my colleagues in the Departments of Urban Studies and Planning and of Architecture have contributed to the development of the ideas and have given me their support and patience as this document was being prepared. My thanks are to all of them.

The design of the first version of the DISCOURSE system was the work of Katherine J. Lloyd. She deserves much of the credit for bringing clarity and order to the idea of "DISCOURSE" at its inception.

Wren McMains is responsible for the development of the second and present version of DISCOURSE, and, beside bringing his ingenuity to the design of the system, he has been able to help generalize many particular ideas about design. Stanley Hoderowski has done able work on "mapping" and other features of the system; my thanks go to him and to others who have part of the development of the computer system.
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CHAPTER I
INTRODUCTION

This chapter is an introduction and background to the rest of the thesis. It describes: 1. what the writer means by "city design"; 2. describes the characteristics of city design problems and designers' problem solving behavior; 3. summarizes the criteria for the design of the DISCOURSE language; and 4. concludes with an outline of the following chapters.

DISCOURSE has to do with assisting the designer in generating and studying alternative configurations of the environment. These configurations may be the design, the implications of a set of policies which is heart of the design, or a representation of the environment which is useful in determining what the design problem is.

DISCOURSE is not a tool for data gathering though through its use the designer may get a better sense of what information he needs. Nor has it been developed to help in the communication of design ideas to people other than designers although in the future this might be one of its uses.

DISCOURSE has been conceived from the beginning as a system which should help the designer to achieve a sense of mastery over some of his material during the time he is generating design ideas. It is devoted to the designer's communication with himself.

The major difficulty in the development of a computer
language to assist the city designer is that what the designer does has not been well described. For in order to design a vocabulary and a grammar which can be implemented on a computer, one must have a clear idea of what the vocabulary and grammar of the city designer are; and, in order to design a computer system which responds appropriately to the designer's ways of working one must have a fairly clear idea of what they are. A second difficulty is that the dividing line between what the designer and what the computer does best, as well as the nature of the criteria by which that judgment is made, are not clear.

In the development of DISCOURSE we have tried to program what we could describe of what the designer does. (1.01) This still leaves both difficulties unresolved: first, one does not know how much of what the designer does remains to be described; and second, one does not know whether an activity, even though describable, may not better be performed by the designer than the computer. And to further complicate matters there will be a moving frontier between what is programmable and what is not.

If the system is rich enough to satisfy the demands of the subtle user, it will force him to think through design issues which, if he were to design in the traditional manner, he might not have to face. He may work more slowly, he will surely work in an unfamiliar way. Many techniques not presently being used by designers will suddenly become
available. The change in design aids will offer constraints and opportunities for working on problems which are different from those of the past and may change design behavior. The designer may become increasingly resourceful in the use of his own abilities as much of what he has customarily done is accomplished with the aid of the computer. (1.02) But it may be that design as we know it now and designers as they are presently trained are not adaptable to the new techniques. If so the goal which continues to govern the development of DISCOURSE, to augment the skills of the designer as we know him, will have been ill chosen.

I. CITY DESIGN

The city designer is concerned with the spatial form of cities over time as cause and as effect of what society does and feels; he is concerned with it as means to other goals; and he is concerned with it as an end in itself. He is particularly sensitive to the wide range of experiences the environment affords to himself and to others. His special skill is in the manipulation of the elements which affect that experience. His own normative contribution is usually that environments be of high quality and that they be life enhancing: responsive to present and future needs, and contributory to the development of the individuals and groups which make up the society. (1.03)

These norms have been further specified to include the safety, health, and comfort of people, adequacy of facilities
and of settings for the conduct of everyday life and business, a wide range of diversity of facilities and of settings and many others ranging from creature comfort to transcendental pleasure. (1.04)

The city designer may design not only the public spaces of towns and cities, but also the suburbs, arterials, left over spaces, industrial areas, parking areas, junk yards, and strip commerce, systems of movement, communications, public services and the other systems which affect the ecology of the total environment as well as key aspects of those systems; and the city's graphics, furniture, lighting and color. The designer may work at the location of activities and physical facilities, at the design of pieces of the environment or its systems, at the processes which result in environmental development or at the policies which would set the stage for better design.

The designer might address a problem of the design of a corridor for a new highway to be built through an already developed area. The goals he will have to contend with may be many: of the federal and state agencies to connect satisfactorily to other roads and to minimize the costs of land acquisition and site preparation; of the city to minimize the loss to its tax base and minimize the problems of relocation of residents and businesses which might be politically damaging; of the drivers on the road who need clarity in orientation, good lighting and well marked access
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points; of the residents who require freedom from nuisances generated by the use of the highway and minimum breaks in the residential pattern to allow free movement to adjacent areas; of the would-be politician who wants clear issues upon which to build his reputation and consolidate his constituency; and of the other professions and groups who are involved in the design of highways, utility systems and other components of the urban environment who have their own design criteria.

The designer engages in many activities during the course of his work: finding out what the physical characteristics of the area are, who lives in there, how they use and value the local environment, who changes the area, and what their plans are; trying alternative locations and designs of the corridor in detail where needed, studying the possibilities for pedestrian crossings, air rights developments, and regional road connections; predicting how the environment will change with and without the kinds of interventions which would result from his influence, imagining how people will perceive, use, and value the changed and changing environment, developing criteria for the institutional arrangements associated with the design ideas, spelling out the environmental implications of new institutional arrangements; and trying to state purposes clearly and to develop criteria by which the design alternatives may be evaluated.
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We face the typical situation in large-scale design: objectives numerous, poorly related, and possibly shifting, constraints imperfectly known and changing, the range of alternatives limitless and not occurring along a single continuum; even the potential variables not certain. (1.05)

To these observations must be added the necessity for the city designer to deal with spatial, temporal and experiential components: his problem area is usually large geographically, so large that it cannot be comprehended simultaneously from any point nor even in a short time; he is considering issues which may imply changes to that environment extending over a very long period of time; and he is at once concerned with the easily and the not so easily measured. (1.06)

II. CITY DESIGNING

City design problems fall into the category of complex and ill-defined problems. The designer is reaching for criteria, for what constitute satisfactory values for those criteria, and for design alternatives all at once. A problem is a condition in which apparently no fit exists between known alternative states of the environment and satisfactory values of the criteria. "Problem", therefore, includes at least implicitly, perceived solutions, and it is in part the inappropriateness of the solutions perceived which creates the problem.

As he nears the achievement of design alternatives the designer is usually able to demonstrate that his proposal overcomes major disadvantages of the existing environment plus
existing development trends, even though the precise
disadvantages which his design overcame may not have been
evident to him until very late in the design process. It is
as if the designer were engaged in a process of finding almost
simultaneously problem and solution. (1.07)

Ways of Working

Some designers may prefer to work from the formulation of
goals and tests by which the achievement of the goals may be
measured, to the inventing of policies and specifications
which would ensure their achievement; other designers may
prefer to work in other ways, for example, from particular
possibilities for action to goals which can reasonably be
achieved or from attempting to explore the environmental needs
of some particular group of people with those people in order
to develop both goals and appropriate actions. (1.08)

The designer may limit his area of inquiry by working on
a single goal, a single small geographic area, one activity
system such as the recreation or transportation system, trying
to improve the environment for a single group in the
population, or looking at the impact of a specific system of
environmental change or the constraints on it such as zoning.
(1.09)

As the city designer works he attends to different scales
of the environment in response to thinking about different
aspects of the problem. He may be interested in the design
character of certain points in the environment. At the larger
scale he may specify the qualities to be present at those points, at the smaller scale he may work out the character of the area in detail. Or, at the smaller scale, he might further specify the qualities to be satisfied by the designer of form, structure and materials.

At the early stages of design the designer will probably spend more time finding out about the environment and its related systems, and the standards by which the design is to be tested. As he proceeds the changes to the description may be very large and the design problem will begin to be formulated more clearly. Later, he will probably spend more time testing the various design alternatives he has developed; the changes to the description may be smaller. From the beginning to the end his major attention will probably shift from information gathering and the invention of designs and goals to trying to assemble them in some acceptable design alternative. (1.10)

Although sequences of activities during creative problem solving have been identified they may be no more useful than as a checklist of things to remember for any particular designer: the order in which any designer works may be very usefully his own. (1.11)

**Graphic Media**

Maps or spatial displays are fundamental to the designer's way of working. The visual representation of the design is the traditional focus of the designer's activities;
considerations of patterns makes him aware of many aspects of the design. (1.12)

The designer uses different ways of representing the environment: plan or map view, sections, perspectives, three dimensional models and simulations by means of movies, photographs and videotape, to mention a few.

But none of these which display motion through space or change over time permit design changes to be made readily. It is difficult also to record large amounts of data in map form. Several variables can be mapped on a single drawing with clarity, but particularly if the variables take many values, there cannot be many variables before the drawing is unclear. And a proliferation of symbols, keying location to specific information, is also difficult to read.

The designer may deal with his design in a loose or a tight fit with the real world. At one extreme his sketches may be only approximately placed on the land and may refer to categories of the description which are either scarcely or ambiguously defined. And, at the other extreme, the sketches or models may be intended as a precise scale representation of some piece of the real world or of some specific information about the world like road alignments. And there are combinations of loose drawings with detailed information, for example, traffic flow diagrams in which the width of the lines represents the exact volume of traffic, but the placement on the land is approximate.
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Large scale environmental design, like smaller scale design includes both visual and non-visual concepts. Either may, through translation, help the designer by means of providing new associations with what is symbolized in the new mode as well as increasing his understanding of the material because of having had to translate it. Certain kinds of information which the designer works with may better be displayed in tabular, graphic or diagrammatic form: for example, the distribution of population density against income, the growth of population or income for several population groups or the circulation pattern of an air terminal.

But where the idea is visual or spatial from its inception, the violence done it by translation into a visual symbol may be less than by translation into a verbal symbol. Ideas may need to be nurtured in their relatively untranslated states during part of their development.

The designer operates on the visual field in different ways than the verbal field: goodness of form, different geometries, symmetrical transformations, doodling and form play all yield new juxtapositions and other new relationships which enrich the vocabulary of possibilities for designing as well as for testing the design. And the scanning of a visual pattern yields information not always expected and problems which one may not be verbally aware of.

Just what accounts for the insights which a designer
CHAPTER I: INTRODUCTION

Gains from graphic displays and from visual manipulations is not at all clear. Nor is it clear how translation from one mode of representation to another is accomplished. What is clear is that the designer needs a wide variety of displays which can be readily manipulated as he works.

In summary, city designing involves the use of large amounts of visual and non-visual, geographic and non-geographic material, much of which is appended or changed during the course of the design. The designer requires vivid and manipulable displays easily translatable one to the other to see the consequences of design changes and to pre-experience the designed environment. The designer works in an unpredictable order on all or part of the problem, at large or small scale, and with a "tight" or "loose" fit with the real world.

III. THE DISCOURSE LANGUAGE

The DISCOURSE language has been designed as a high level problem oriented language in which the data structure would be transparent to the user and in which there would be most of the manipulations existing in any general purpose computer language. It affords the opportunity to program in the language, responds rapidly to answer user requests, and has a limited range of displays. Soon it should have a wide range of vivid displays, have ways of interfacing with other data sources and should have associated with it teaching programs which make it easier to learn and to use than at present.
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Approaches to the design of computer languages for assisting any user group range from those which are close to the user's own vernacular to those which are usable by many user groups. Those which are close to the user's own vernacular are sometimes called "problem oriented" languages and those at the other end of the range, "general purpose" languages. The terminology is somewhat misleading because, as indicated in figure (1.01), the whole spectrum of languages which is being discussed is already "problem oriented" in that the languages contained within it are designed to be used in scientific and commercial applications. (1.13)

Some higher level languages can be written in other (usually somewhat lower) higher level languages. They may either be translated into an object program or remain to be interpreted by the language in which they were written. The latter type of language is sometimes called an "interpreter". DISCOURSE is an "interpreter" written in the higher level language of AED. (1.14)

Languages at the top end of the spectrum tend to be closely tied to a particular problem or set of problems and it is in this sense that the label "problem oriented" is helpful. For example, STRUDL is a problem oriented language for structural engineers written in ICES using two subsystems of ICES: Command Definition Language (CDL) and ICETRAN which is the manipulations language, very much like FORTRAN. (1.15) Some typical lines typed by the engineer user in STRUDL might
be:

TYPE SPACE FRAME
UNITS INCHES KIPS
JOINT COORDINATES
X 0.0 Z 0.0 Y 0.0 SUPPORT

where SUPPORT, for example, is one of two options, the other of which is FREE indicating the degree of restraint at the joint. The computations which the engineer wishes to perform have been anticipated by the ICES system programmers; he need only use them after the appropriate data have been entered, and the computations will be performed.

Where many of the tasks to be performed are well defined, a problem oriented language at the STRUDL level may be very appropriate. Where the task is not as well defined, ICES offers the opportunity to the engineer-programmer to define his own new subsystem using the Command Definition Language and ICETRAN. Even though modification of subsystems is relatively easy the ICES system seems particularly appropriate for assisting in tasks which can be well defined at the outset.

The major justification of building higher level problem oriented languages is to relieve the user of the burden of having to deal with the complexities of the management of the data internal to the computer and the communication among different components of the computer system. What one brings to the user in terms of input, manipulations, and output facilities is another matter and depends upon the
characteristics of the user's problems and manner of problem solving. (1.16)

Unlike some other fields, city design does not have a set of well defined sub-problems for which facilities could be built. Therefore, DISCOURSE offers the possibility for the user to program in the language with a wide range of manipulations in order that he be able to modify it to suit himself and in order that designer-programmers can improve the system without having to rely entirely on the expert systems programmers who constructed the system in the first place.

The rapid response time of the system has been achieved by virtue of the time sharing systems at M.I.T. which give the user the appearance of having a large computer fully dedicated to his own use. The reason for the rapid response is to allow the user the opportunity to learn from the result of the question he has just posed without getting off the subject as he would if he had to submit a deck of cards and wait until the next day for the results.

Until recently work on the language has been concentrated on the development of the storage, retrieval and manipulations facilities. Now the stress in development will be placed on creating a wide range of displays, and on the input problems associated with getting data from other sources and with reading in complicated and large amounts of geographic data. And the results of the present phase will include an up-dated learner's primer plus examples of the use of the system.
This thesis reflects the fact that neither the language nor the process of design is well enough understood to make the design of the computer system obvious. The reflection can be seen in the roughly equal shares of time spent analysing design and describing the language to accommodate design.

Chapter II, "An Experiment in the Replication of a Design", is addressed to the issue of whether there is anything which the designer does which could even be approximated by a sequence of instructions so clear that a computer could carry them out. A sequence of instructions which can be carried out on some computer is an algorithm. The same issue restated asks if there is anything the designer does which can be replicated by means of an algorithm.

In Chapter II, a design which was favored by the designers near the end of the master planning for Ciudad Guayana, a fast growing city in southeastern Venezuela, was selected as a subject for the replication. (1.17) An algorithm was developed to substitute for the designers' thinking about the design; and, from a representation of how the environment was at the beginning of the planning phase, it generated a design not unlike that of the designers. The algorithm seemed to be capable of refinement to produce an even better approximation of the design, or of modification to produce some of the other designs for the same city which had
been considered by the designers at other times.

The components of the algorithm, then, took on a new luster: if they could, by being rearranged, generate more than one plausible design, might they be useful in a computer language for the designer? To write an algorithm, one needs to describe a function because an algorithm is a procedure which computes a function. Algorithms and functions, then, are closely allied. But there are functions for which no algorithm exists. (1.18)

Chapter Three, "Functional Analysis of City Design", is an effort to analyse city design in functional terms which are more independent of a particular problem situation than the Ciudad Guayana experiment. Several distinct "functions of design" emerged which seemed to be applicable to a wide range of design situations: these are "functions of further description", the derivation and inference of new data of the description, "functions of transformation", the alteration of the data of the description, and "functions of testing", the comparison of data of the description with norms.

The major achievement of the DISCOURSE language, explicated in Chapter IV, "The DISCOURSE Language", is that it can accommodate these functions. Although the data structure and manipulations of DISCOURSE are independent of empirical reference, the user can most easily think of the language as "places" and "descriptors of places": a grid of LOCATIONS; and ATTRIBUTES, names which specify or qualify what is at
LOCATIONS. Examples in Chapter IV serve to illustrate the basic features of the language for this interpretation.

Chapter V, "Simulation of Environmental Use", moves somewhat closer to how a designer might use the language. The experiment, which simulates people's use of recreational facilities, demonstrates the use of functions written in the language which correspond to two of the categories of functions developed in Chapter III: "Functions of Further Description", and "Functions of Measurement". In the chapter are discussed some of the issues which can be considered in the context of a highly explicit formulation of a design problem.

Chapter VI, "The Future Development of DISCOURSE", looks ahead - pointing out tactics for increasing its usefulness in the short run to city designers, discusses the elusive issues of "graphics and modes of representation", and raises some of the issues surrounding the need for a description of the environment richer than that easily afforded by DISCOURSE as it stands.

In the Appendix is the implementation of the algorithm developed in Chapter II, demonstrating how DISCOURSE can be used for some of the bookkeeping which the design analyst might want. Also included is an additional experiment with the same decision rules but with a minor change in the data which caused major changes in the results.
general purpose system building languages *---eg. LISP, PL-1, AED, ICES, FORTRAN

special purpose design languages +--------DISCOURSE

specific problem oriented languages *---eg. TRANSET

HIGHER LEVEL LANGUAGES
FOR SCIENTIFIC, COMMERCIAL AND RESEARCH APPLICATIONS

LOWER LEVEL LANGUAGES

assembler languages

machine languages

Figure (1.01) DISCOURSE occupies a range on the continuum within higher level languages offering to the user a language in which he can store, retrieve and manipulate data about his environment without having to do any of his own programming (represented by the top part of the line associated with DISCOURSE), and offering the facilities with which he can do his own programming to modify and adapt the system to his own special requirements. (1.19)
CHAPTER II

AN EXPERIMENT IN THE REPLICATION OF A DESIGN

Chapter II is the record of an experiment in the replication of a design, for in that experiment was the beginning of the thinking which underlies the DISCOURSE language and system. First, however, will be a short historical note to clarify the perspective within which the experiment was conceived.

This experiment grew out of a seminar on the city design process. (2.01) The seminar started as an effort to describe the skill of the city designer. The participants harbored two suspicions: first that designing could be rationalized, that is that the ways in which designers worked were, by and large, rational - even though they might not know it, and second that city design was largely conventional, that is, that the designer's ways of working were similar in project after project, and, possibly, small in number - the differences among designs arising mostly from local differences in topography, the kinds of activities to be accommodated, and individually favored visual (map) patterns. Behind the apparent variety there might be a kind of behavior which could be described, and, therefore, replicated.

Recording how the designer works, trying to determine the types of information he uses, his analytical procedures and his sketches, and asking him to keep as complete a record as
possible of what he was doing and thinking might have been one method of research. But that method would have taken an enormous amount of time, not only on the part of the analysts, but on the part of designers whose work was being analysed. There would have been problems of communication with the designer and of confidentiality, as well as the problem of recognizing how much the design was changing because of the research activity. Moreover, it would have been necessary to study many designers in order to be sure that the hypotheses being advanced were of more than parochial interest. And this approach would have resulted in hypotheses which could not easily have been tested.

A second approach might have been to have simulated the designer's behavior. This approach would have required a completely described substitute for every aspect of the designer's activity, the behavior called "city designing" would have to have been translated into algorithms. The test of success would have been, by means of programming the algorithms, to have reproduced the same record of drawings, sketches, and verbal comments which the designer would have done when faced with the same initial conditions. With success, it then might have been possible to have speculated about the similarity of the processes in the human mind to those which were programmed.(2.02)

The behavior which Newell and Simon were trying to simulate was in the context of a very well defined problem in
logic; when the ill-defined nature of city design problems was added to the apparently eccentric behavior of some designers, the simulation of design behavior seemed more distant then ever. Moreover, the drawings, sketches and verbal comments of a designer over the entire course of a design project were not readily available.

A third approach, and the one which we selected, was to create procedures however we could which would reproduce the product of the designer without regard for how well the procedures reflected the behavior of the designer. The by-product of an accurate protocol of design behavior during the design process was not required. Instead we were interested in the procedures because they might embody the conventions of design; we were looking for the logical equivalent of the designer. (2.03)

1. THE EXPERIMENT

The experiment was an attempt to replicate only one aspect of the favored design for Ciudad Guayana, a fast growing industrial city in southeastern Venezuela with which this writer was familiar. (2.04) The chosen aspect of the design was the plan for the use of the land at a very gross level of detail. The categories of "uses" (or "activities") were: industry, major city center, and urbanization - a residual category for developed land consisting principally of residence.

The "design" which was to be replicated was assumed to be
"the order of occurrence at various locations of these activities." The design commenced with the first departure from the environment as it was in 1961, the time of the formation of the development corporation charged with developing the region. (2.05) It was necessary, therefore, to describe an "initial state" of the environment including the three types of activities selected.

The next step was to pick the variables from the existing environment which would most influence the locations of the three activities. It seemed reasonable to start, at least, with some of the variables which had been central to the design discussions: slope of the land: 0-5 percent was most preferred by industry; 5-15 percent still buildable for both industrial and residential purposes; and more than 15 percent unacceptable land for any purpose; (2.06) the river: the Orinoco River had a deep sea channel to the ocean which was highly valued by industries exporting raw materials and large volume partly processed and finished products; and the existing activities in the three categories selected.

In order for the representation of the design and initial states of the environment to be unambiguous with respect to location, a grid was laid over the land which provided a set of squares within which the variables could be placed (or, differently stated, points at which the data falling within the limits of one square could be placed). The grid size selected was the maximum which would still retain the identity
CHAPTER II: REPLICATION

of the initial and design states. The sacrifice was of the accuracy of the description, but the gain was a description with fewer parts very much simpler to manipulate.

Figure (2.01), the existing environment in 1961 and the "initial state" for the replication was drawn with each grid square one mile on a side; and the variables were assigned to the squares by the arbitrary rule that if more than half the square was occupied by the variable in question it became true of the entire square.

The designer's "design state", figure (2.02), could then be drawn using the selected variables of the description and grid size plus the order and placement of the activities over time which were part of the design.

The problem of replication was, then, completely described: write the set of rules which would transform figure (2.01) into figure (2.02).

The transformation rules were developed by considering the quantity of activities, the order in which they would be assigned, and the relative importance of the environmental variables considered. For example, urbanization was to be located on flat land next to other urbanization and next to a river if possible. Flat land was thought by the designers to reduce the cost of urbanization, adjacency to existing urbanization could take advantage of the urban services which did exist; and land next to a river seemed desirable. Next in priority would be sloped land next to existing urbanization
and, if possible, next to a river. If land of neither category was available then urbanization would not be assigned.

The necessity for keeping the development "compact" rather than letting it run out the ends of the site became apparent only during the trial of different rules; in retrospect, "compactness" had been part of the designers' discussions of the form of the city. Proximity to the center of gravity of the existing activities proved to be a useful way of expressing "compactness". Thus a new variable of the description was created, one which, in counter distinction to the other variables of the description, depended for its presence in a location not on values to be found within that location but on a specific function, center of gravity, which operated on values found elsewhere. Also, in the rules, it can be seen that there were three other functions needed: at a location, next to a location, and nearest of one class of locations to some other location.

Finally, the quantities of new activities were taken from the design drawing, and the order freely interpreted from the design drawing and indirectly from the economists' projections for the city.
II. SUMMARY OF DESCRIPTORS AND TRANSFORMATION RULES

1. Description

1.1 Grid size: one mile squares

1.2 Variables and their values:
   1.21 slope 0-5 percent
   1.22 slope 5-15 percent
   1.23 unacceptable land (more than 15 percent or flooded)
   1.24 river
   1.25 deep sea channel
   1.26 industry
   1.27 urbanization
   1.28 major city center
   1.29 center of gravity of locations with industry, urbanization, or major city center

1.3 Functions needed for the description:
   1.31 variables occur at the location
   1.32 center of gravity

2. Rules

2.1 Quantitative measure of change required: 4 square miles of major city center; 24 square miles of urbanization; 24 square miles of industrial land.

2.2 Assignment orderings: 3 square miles of urbanization, 3 square miles of industry, 1 square mile of center, 3 square miles of urbanization, and 3 square miles of
industry four times in succession.

2.3 Transformation rules

The location of urbanization is a function of adjacency to other urbanization, location of flat or sloped land, adjacency to a river, and proximity to the center of gravity of activities.

The location of industry is a function of adjacency to deep sea channel, adjacency to other industry, and proximity to the center of gravity of all activities.

The location of the major center is a function of location on flat land, adjacency to other major center, and proximity to the center of gravity of all activities.

In figure (2.07) are the "decision trees", elaborations of 2.3, above, which, when coupled with the assignment orderings, generated figure (2.03).

2.4 Additional functions needed for the rules:

2.41 variable does not occur at a location
2.42 adjacency
2.43 nearest (of 2 variables or more) to a location

III. THE RESULTS

Figure (2.03) represents the result of the application of the rules to the "initial state". The chief differences between figures (2.02) and (2.03) are in the use of the sloped land. The differences can be further noted by examining figures (2.04), (2.05), and (2.06) which compare the patterns
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generated by the decision rules with the pattern generated by the designers for each of the three activities: urbanization, industry, and center.

The results raise some issues to be investigated further, issues which it would be practical to investigate only if the rules were implemented on a computer. Better "fit" with the design might have been achieved by varying the assignment orderings. (2.07) The generated design seems to be relatively insensitive to assignment orderings except in the later stages when the ability to predict events is not great. Clearly if all activities wanted the same variables at the location, that is, the transformation rules for each were the same, then the design configuration would depend only upon the distribution of the desired land and the assignment ordering. This phenomenon can be observed in assignments 15 to 25 of industry and urbanization. This extreme might be reached in a growing city where the supply of total land within the municipal boundaries was limited or in a metropolitan region where proximity to the regional core was highly valued.

The other extreme, when no activities compete for the same land, may be reached in design because designers often try to fit each particularity of the site to the appropriate activity. In this case, the transformation rules for different activities would have not similar branches and would determine the configurations; the assignment orderings would have no influence.
CHAPTER II: REPLICATION

Where assignment orderings do have an influence on the configurations, there may be other rules which can be formulated for the competition for land among activities which represent their monetary or political resources available for the purpose of land acquisition and construction of the appropriate facilities instead of the point in time of assignment.

The assignment orderings used in the experiment were very gross for the initial stages of development with respect to the designers' sense of what would happen; and they were overly detailed in the later stages, a fault which could easily be remedied by different assignment orderings.

Better "fit" with the designers' design might have been achieved by varying the transformation rules to give, for example, more weight to flat land for industry and more to sloped land for residence. The transformation rules might have been changed during the growth process in order to reflect the changing locational criteria of the various activities as the city grew in size. And, in order to reflect real changes in the activities themselves as the city grew, new activity types might be introduced with new transformation rules.

One could have varied the qualities attributed to the land, for example, changing "unacceptable" to "sloped" at location 7,13, a site favored by many of the designers for the major city center, and one where the original decision as to
which category to use in figure (2.01) for the "initial state", 6-15 percent or "unacceptable", was difficult to make. One could introduce new information, for example, that the land owned by Orinoco Mining Company, locations 5,11 6,9 6,10 6,11 7,9 7,10 7,11, would not be available for development for at least half the growth period and would be classed as "unacceptable" land during that time. And, the grid size might have been varied. For this design the one mile grid size was too large in some areas, but needlessly small in others.

If the differences between the generated design and the designers' design could not be reduced, the failure could be ascribed to the lack of ingenuity on the part of the experimenters, or to the designer: either his artistry or his error. More generally, if the differences between many designs generated by rules in different situations and the many designs done by designers in those situations could only be reduced by rules which were different in each case and seemingly arbitrary, then something of each designer's unique or creative contribution might have been indentified. "Creative", when used as above, can be thought of as local violations of a system of rules: the exageration of the height of one facade in relation to some important space; or the delay beyond the previous spacing (point of expectation) of the next opening in a wall of enclosure. Of course, the violations of one rule system may well be consistent with another. The element of surprise mixed with joyous curiosity
which carefully designed violations of regular movement through a sequence can yield may be consistent with a system of behavior in environments of which the designer is at least intuitively aware.

But creative ideas can also be thought of as those which violate conventional ideas in a global way with some new regularity strongly implied. The more "creative" an idea, in this sense, the more of observation is changed by it and the more wide ranging are its repercussions throughout the body of concepts making up the present theory of design. (2.08)

Conventional ideas are the habitually used rules of interpretation and thought. The creative ideas of today may become the conventional ideas of tomorrow after the readjustments in the body of knowledge have taken place. In hindsight, and without reference to factors external to both, creative and conventional ideas cannot be distinguished from each other. (2.09)

Suppose that the transformation rules have replicated the land use design with reasonable fidelity. By looking at the rule set alone it is impossible to infer that the rules are conventional or creative. Suppose that those rules have replicated many land use designs. The rules might then be called conventional for land use design and designs which adhered to them most closely conventional designs. If from some land use design a new set of rules were inferred which generated better land use designs than had been done
previously, then they might be termed "creative", and the design termed "creative" from which they were inferred. This brand of creativity might better be termed a very high level of competence.

IV. STRATEGY FOR REPLICATORS

Exploring the "conventional" and the "creative" implies a different kind of development from the experiment described above. Instead of working toward better"fit" with the designer's design, it implies working toward simplicity and the promise of general applicability. It should be observed that, even as they are, the rules which were utilized consisted in the main of an activity's adjacency to itself, the seeking of flat land, and the seeking of central position with respect to the whole development. It would be tempting to try various formulations of these rules to see how well they do on several land use designs, as well as to explore the kinds of rules which are involved in improving the fit with designers' designs from that point on. The goal in these experiments would be to find the simplest set of rules to account for the largest part of the design.

But, in working toward rules of greater generality one would expect some loss in the accuracy with which they might replicate any particular design. A balance will have to be struck between rules which are so specific as to have no application to other situations and those which do a very bad job of replication or generate foolish designs. (2.10)
There may be designs which are impossible to replicate with the land use design rules. Two explanations are suggested. First, the designer may have been working in another aspect of the design primarily (for example, generating his design from the point of view of how the environment is seen at ground level). The land use design may simply be the consequences of his work in that other realm, not understandable in its own terms. Of course, one could argue that a good design ought to satisfy criteria in many realms; but to what extent it should satisfy different criteria is not a question for the replicator of designs, but for the designers themselves. The rules governing the design may be derived primarily from a realm the replicator is not looking at, he may simply have been looking at the wrong variables.

The second explanation has to do with the difference between the representation of the design which is the object of the replication and the full intent of the designer. The representation may depend to a large extent upon the conventions of the field of city planning and design; a land use plan, often has the same legend which limits the choice of variables; it is course in detail; it represents one point in time only; and puts only one land use at one location. Thus, the replication may fall short of including the full design intent because the rules governing the design may not be expressed in the conventional media of design. The replicator
may fail because the rules governing the design were unrepresented or unrepresentable, perhaps not becoming evident until the design is realized.

V. THE SHIFT FROM REPLICATION TO DESIGN AID

There are two major reasons why, at least temporarily, the project shifted at this point from attempting to replicate designs to the building of a system to assist the city designer. The first has to do with the substance of design, and the second with the formal structure of the replications.

Substance

Substantively, the replication could be looked at as a way of obtaining the consequences in terms of environmental form of a set of rules about how that form should evolve. The Guayana rules, figure (2.07), could be interpreted as an effort to generate a "least cost" city form: "least cost" for construction because of the utilization of flat land; "least cost" to industry because of proximity to the deep sea channel; "least cost" of urban services, at least in the early stages, because of the possibility of extending existing services to adjacent development; and "least cost" of transportation because of keeping the development as compact as possible. It is not a challenge to this line of reasoning to observe that the rules may not have been the best for the purpose of producing a "least cost" city form. The rules as they stand were conceived from the point of view of trying to replicate what the designers actually did. The point is that,
once having recognized that the rules did seem to express "least cost" or any other criterion in some fashion, the designer could then go on to design better rules for that purpose, test them, and observe their consequences.

**Structure**

The structure of the replication contains: acceptable characters, the variable and function names: industry, urbanization, nearest, adjacent; a list of postulates: the functions needed for the description and for the transformation rules; an axiom: the "initial state" of the environment; and a theorem to be proven: the "design state" of the designers.

In building the replication one could work forward to and backward from the design state, a procedure which would help to cut down the time needed to develop the rules for the replication. (2.13) Once he has set up the replication, the replicator's job is to find the rules of interpolation between the initial and final states. A designer, on the other hand, can be thought of as constantly inventing and re-inventing all the components of the structure just outlined, trying different components and studying the consequences of his choices. (2.14)

A system which would accommodate experiments in replication could also accommodate experiments in drawing implications from design assumptions. Chapter Two is an effort to determine what kinds of city design assumptions can
be made clear.
CIUDAD GUAYANA in 1961

LEGEND:

PRIMARY ATTRIBUTE ASSIGNMENTS — '1' = URB1961(20); '2' = IND1961(21)

'. ' = NON EMPTY LAND

REFERENCE ATTRIBUTE ASSIGNMENTS — '+ ' = RIVER(8); '-' = CHANNEL(12); '*' = CHANNEL & RIVER; ' ' = NO REF ATTS

Figure (2.01) Ciudad Guayana as it was in 1961 when the Venezuelan Development Corporation was formed. "urb1961" means "urbanization" in 1961; "ind1961" means "industry" in 1961.
AN ALTERNATIVE DESIGN FOR CIUDAD GUAYANA
BY THE CITY DESIGNERS IN THE DEVELOPMENT CORPORATION

LEGEND:

PRIMARY ATTRIBUTE ASSIGNMENTS — — '1' = UDESIGN(3); '2' = IDESIGN(2); '3' = CDESIGN(4)

'.' = NON EMPTY LAND

REFERENCE ATTRIBUTE ASSIGNMENTS — — '+' = RIVER(8); '-' = CHANNEL(12); '*' = CHANNEL & RIVER; '' = NO REF ATTS

Figure (2.02) An alternative design for Ciudad Guayana created by the city designers in the Development Corporation. "udesign" means their design for "urbanization", "idesign" for "industry" and "cdesign" for "center".
CHAPTER II: REPLICATION

PATTERN FOR CIUDAD GUAYANA GENERATED BY DECISION RULES

LEGEND:

PRIMARY ATTRIBUTE ASSIGNMENTS — '1' = URBANION(6); '2' = INDUSTRY(7); '3' = CENTER(5)

'B' = 1, 3

'.' = NON EMPTY LAND

REFERENCE ATTRIBUTE ASSIGNMENTS — '+' = RIVER(8); '-' = CHANNEL(12); '*+' = CHANNEL & RIVER; ' ' = NO REF ATTS

Figure (2.03) Pattern generated for Ciudad Guayana by the decision rules specified in this chapter.
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COMPARISON OF GENERATED PATTERN (URBANIZATION) WITH DESIGNER'S PATTERN (UDESIGN)

LEGEND:

PRIMARY ATTRIBUTE ASSIGNMENTS — - '1' = URBANION(6); '2' = UDESIGN(3)
'A' = 1, 2       '.' = NON EMPTY LAND

REFERENCE ATTRIBUTE ASSIGNMENTS — - '+' = RIVER(8); '-' = CHANNEL(12); '*' = CHANNEL & RIVER; ' ' = NO REF ATTS

Figure (2.04) Comparison of the pattern of urbanization generated by the decision rules ("urbanization") with the pattern of urbanization of the designers ("udesign").
CHAPTER II: REPLICATION

COMPARISON OF GENERATED PATTERN (INDUSTRY)
WITH DESIGNER'S PATTERN (IDESIGN)

LEGEND:

PRIMARY ATTRIBUTE ASSIGNMENTS — '1' = INDUSTRY(7); '2' = IDESIGN(2)
'A' = 1, 2  
'. ' = NON EMPTY LAND

REFERENCE ATTRIBUTE ASSIGNMENTS — '+ ' = RIVER(8); '- ' = CHANNEL(12); '* ' = CHANNEL & RIVER; ' ' = NO REF ATTS

Figure (2.05) Comparison of the pattern of industry generated by the decision rules ("industry") with the pattern of industry of the designers ("idesign")/
CHAPTER II: REPLICATION

COMPARISON OF GENERATED PATTERN (CENTER)
WITH DESIGNER'S PATTERN (CDESIGN)

LEGEND:

PRIMARY ATTRIBUTE ASSIGNMENTS — — '1' = CENTER(5); '2' = CDESIGN(4)
'A' = 1, 2 ' ' = NON EMPTY LAND

REFERENCE ATTRIBUTE ASSIGNMENTS — — '+' = RIVER(8); '-' = CHANNEL(12); '*' = CHANNEL & RIVER; ' ' = NO REF ATTS

Figure (2.06) Comparison of the pattern of center generated by the decision rules ("center") with the pattern of center of the designers ("cdesign").
CHAPTER II: REPLICATION

RULE FOR ASSIGNING URBANIZATION

RULE FOR ASSIGNING INDUSTRY

RULE FOR ASSIGNING CENTER

LEGEND: 1=slope0-5 2=slope6-15 3=unacceptable land 4=river 5=channel 6=industry 7=urbanization 8=center 9=center of gravity of 6,7,and8; a=at the location b=beside the location c=closest to (of 2 or more locations) d=assign; (1)=node number of the decision tree

Figure (2.07) Decision rules which generated Figure (2.03).
CHAPTER III
FUNCTIONAL ANALYSIS OF CITY DESIGN

A function is the specification of a rule which, when applied to values falling within its domain of definition, may be evaluated. Computers demand algorithms, realizations of functions which can be used to compute their values. If a function can be realized in the form of an algorithm, then it is programmable on some computer. (3.01) In order to consider how to assist designers with computers it is necessary to consider whether any of city design can be thought of in functional terms.

The replication of the last chapter was an algorithm but, it might be argued, that was an isolated case, not of any general application. This chapter is an effort to rebut that assessment by looking into some of what the designer does or might do and trying to extract the part which might be formalized. There are sections discussing functions of "Further Description", of "Transformation", and of "Testing". These three different kinds of functions have been arbitrarily constructed in order to explore the designers' ways of thinking, and to help reveal the sorts of capabilities needed for computer assistance.

At any instant in time during the process of design, the designer can be thought of as having data which describe the environment and rules of inference drawn from information
about environments and environment related matters. The rules, in combination with his data, permit him to further describe the environment, to transform the description, or to test the description against the achievement of some goal. The data which are "basic" to inferences are of two types: "primitive", or true by definition; and "derived", or true by our conventional notions or "laws" of logic, mathematics, space, and time. (3.02) For example, if "primitive" data were the locations of houses, then the total number of them, or the average distance between them would be "derived" data. Data resulting from the combination of of "basic" data and rules of inference are "inferred" data. The conclusion drawn from the primitive data given above that "the houses constituted a neighborhood" would be an "inferred" datum.

An inference can take many forms, but two of the most common are: the combination of a universal and an existential statement: "all drivers will be alerted to possible action by any sign more than one square foot in area within twenty feet of the road and which carries a message of danger"; "this sign satisfies the previously stated conditions"; therefore, this sign will alert drivers. The universal statement can also be phrased as a conditional statement, a variation of this first form. And the second is the functional form, \( t = f(x) \) where \( t \) is the value ("signs which alert drivers") obtained by evaluating the function \( f(x) \) where "\( f \)" is the rule expressed in the universal statement and "\( x \)" is the needed information
from the environment, the arguments of the function, (size of
the sign, distance from the road, and message content); and
"evaluating" means applying the rule to the arguments and
obtaining the value.

If the function is continuous there is a range of values
of the arguments which can be found to satisfy the function
within some standard, \( k \). (\( t + or - k = f(x) \)) In the previous
example both "size of the sign" and the "distance from the
road" were expressed as intervals of values rather than
discrete values, but the message content had to be the single
value, "danger". This function was continuous with respect to
two out of three of its arguments.

The discussion which follows is organized under the three
functional types identified above: functions of "further
description", "transformation of the description" and "testing
of the description". The examples are intended to illustrate
the functional types, not to serve as a comprehensive list of
what designers do.

I. FUNCTIONS OF FURTHER DESCRIPTION

Functions of further description consist of two major
types: "measurement functions" which result in "derived"
data; and "extension" functions which are defined to be those
which result in "inferred" data.

**Measurement**

Derived data are obtained from "measurement" functions
which receive as arguments the primitive data of the
CHAPTER III: FUNCTIONAL ANALYSIS

description and apply logical, mathematical and geometric manipulations to result in values in each of those realms. Many of the primitive data which the designer has are of the type "nominal". (3.03) They are a name attributed to a place which can be there or not there and can be a member of a category having the same or a similar name. Assuming that the categories of the description exist, the designer can ask "where is the transit stop in this area?", or "where are the transit stops?". He can ask where the "visually strategic points" are or where they coincide with transit stops. To make this last observation, he needs to look at each place where one category occurred and see whether the other occurred as well. If each occurrence of the category at a place is thought of as a member of a set by the same name, and the universe of discourse is all existing locations, then to see if two members share the same location is to logically intersect the two sets.

This same operation is accomplished almost literally when a designer overlays one map on another and makes a third map of the overlaps between the categories he is interested in at the moment. The new category may have empirical interpretations other than being the "coincidence of transit stops and visually strategic points", for example, those locations may be "ideal spots for public information centers". That shift of meaning connects the new category to another realm of thought. The functions which do that kind of
connecting involve a rule of inference and are dealt with in the next part of this chapter.

Observation regarding location can, in conventional practice, almost avoid the issue of precisely "where" things are. The reason, perhaps, is that because the map is both the medium of study and of communication to others; "location" never or seldom has to be described in any other medium. The answer to "where is it?" is "there, on the map, at that point." There are, of course, references to areas by ward, precinct, census tract, and urban renewal area, for examples, as well as by street, street corner, and address, and by "oak tree", "stone fence", "stream bed" or "abandoned logging road" to mention just a few fixed and not-so-fixed elements in the environment.

Location in relation to other locations rather than in relation to some larger geographic reference system, designers are quite explicit about. Distance away, nearest of several, number of occurrences per unit area; adjacency, connectedness, continuity; and direction, orientation, and relative position in three dimensions plus functions which can be written on them computing, for example, the rate of change of any of the elements per unit distance are some of the major kinds of locational manipulations which can be explicitly formulated.

The designer may have numbers and other names associated with his map description. The numbers may take ordinal or
cardinal values, each implying an allowable set of manipulations: for ordinal values, ranking, relations of magnitude; and for cardinal values, the arithmetic manipulations. He can ask, "are there more employees than residents in this neighborhood?" He can record the answer or not; this sort of question like those above derives more data from the description through manipulation but does not by itself add new empirical information; it does not "extend" the description.

Extension

The designer describes the environment in as many different ways as he has ways of looking at it. The description which informs him along the lines of his inquiry is design information because of its usefulness. When a new category of the description extends but does not change the existing data of the description then it is the result of what is called here a function of "extension".

A function of "extension" receives as arguments "basic" data of the description and information about some "system" related to the environment embodied in a rule of inference. It is characteristic of functions of "extension" that they can be empirically tested, at least in principle.

For example, a description of an environment might be "playgrounds easy to get to by children ages 6-9". The environment related system from which information would have to be drawn would be the behavior of children of those ages
with respect to moving about their local environment. The rule of inference would have to state the conditions under which a playground was easy to get to. Assume that one variable would suffice: distance of 0-500 feet from their residence. Then the measurement of the environment would be the distances between residences and playgrounds. The new category would be the name "playgrounds easy to get to by children ages 6-9" and would be given to those playgrounds which satisfied the condition, "within 500 feet of a residence of children ages 6-9". This new category of the description could be verified, possibly, by well designed interviews and observation procedures.

The discussion of functions of "extension" will be organized under several different ways the designer has of thinking about the environment: its relation to use; its development over time; its perception and form; and its ordering patterns.

Environmental Use. The designer may need to know about soil bearing capacities in an area. He may have access to the detailed data, he needs to connect them to something he wants to do before they become design information. Bearing capacities could, then, be related to what kinds of activities or construction might be placed on the land. Suppose that the bearing capacity were to be the sole determinant of the locations of tall buildings in some city. Suppose, furthermore, that the map of bearing capacities is highly
accurate as verified repeatedly by new measurements in the field. Use of locally available materials and labor prohibit other than conventional foundation types. Then a map showing bearing capacities above some amount would be a map of permissible tall building locations and a solution to the problem of where to put them.

If the map were also to be used for low buildings, and, assuming that the bearing capacity was still the critical design determinant (a doubtful assumption) then the designer would like another value of the variable, bearing capacity. The map dictated by the placement of soils having a bearing capacity at or above this new value would become a new category of the description which was isomorphic with the "allowable location of low buildings".

The designer might want to see what the implications were of assuming that he had a way of treating the soil or the foundations to permit tall buildings on soils presently having too low a bearing capacity. He could then see what pattern emerged for areas for tall buildings by mapping the areas with lower bearing capacities. There might be enough other reasons why one of the new maps was desirable to make it worth recommending that a breakthrough be sought which would permit the lower bearing capacity soils to be used.

In arriving at his recommendations the designer has connected two realms of thought: the environment and the human purpose of city building. He has isolated (by a process
not discussed) the single variable in the environment, "bearing capacity" and in city building, a rule of inference which has specified a range of values of bearing capacity which will accommodate specified values of buildings.

Soils bear a close relationship to other environmental characteristics like the climate in that they exhibit the effects of natural processes which are imperfectly known and, therefore, call for expert opinion. Although one can measure the effects of the local climate - its temperature, humidity, wind velocities and direction, one cannot always estimate with great accuracy what those same measurements will be under different circumstances. Nevertheless there are rules of thumb which help to fill out the descriptions of an area: tall buildings are likely to have high winds around their bases during the winter.

Other rules for the use of the natural environment can be found indicating the suitability of land for various activities, for the use of land in highway corridors, and for land development based on sewerage potential of the soil and other factors relating more directly to health. (3.04)

Another type of rule links human activity to enclosed space or vice versa. If a designer needed to find enclosed places for meetings of 400 to 1000 people, he might look for a drawing showing "meeting places" but, assuming that the drawing showed too few, he might have to look elsewhere. He could state (or look up) criteria for a space's
appropriateness to the task: clear spans of at least 40'; areas of not less than 3500 square feet; heights not less than 20 feet; means of egress to satisfy local codes; times at which those spaces would be free to compare with the times needed for the meetings in question; location in the city to be within some district; owner of the space to either the government or a cooperative private establishment; and many other factors. He would need to have such a space and use inventory of the environment and such a set of standards in order to be able to construct his new category. Many of these above mentioned data of the description are missing from descriptions normally available to city designers; they have to make the measurements themselves, or infer them from available descriptions. Once the designer has made a determination of where the meetings might go, he then might use the meeting places as data to further describe the environment in the category "where mass transit stops might go".

Other space-use or use-space standards have been developed for recreation facilities; employees per square foot, turnover of sales per square foot and many other measurements helpful in making an economic analysis of the environment; pupils per school by almost every school committee in the country; facilities use standards, and many others. (3.05)

Another type of explicit formulation of environmental
relationships, traffic and transportation models, links activities to other activities and environmental factors and is heavily dependent upon human trip behavior usually either expressed as an inverse ratio of distance raised to some power from home to work or fitted to an established mathematical curve to represent existing trip behavior. And still another type of relationship is based on adjacency or proximity of land uses or facilities and is based on the nuisance characteristics of each activity or facility. These standards are intended to insure human comfort and safety. The highway engineers have their standards for the design of highways which implicitly are based on human performance and comfort characteristics. And there have been efforts to explicitly formulate more complex mixes of different factors which might influence urban locational patterns. (3.06)

Development Over Time. Prediction is used in the sense of the designer's looking forward in time to see what would happen to the environment he is considering. The form of the prediction function is similar to for the "environmental use" functions: the latter, field testing is a way of seeing whether the new data are accurate; the predicted data, on the other hand, cannot be verified because they refer to future time. In both cases, the experts are generating new data by means of a body of generalizations which describe some system they know about.

The "system of environmental change" can be very complex.
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Taking one example: a developer's decision to build a commercial office building will be, very likely, a function of the price which he has to pay for the building site, the interest rates, the zoning regulations pertaining to the site, the market for office space, both type and amount, others' plans and schedule for building the same type of space, the city's and others' plans for other types of space and facilities in the area, and many other factors. His decision to request a zoning variance may depend upon whether he thinks he can make an economic "go" of it under the zoning considering the rents he will be able to charge plus other income producing potential of the building, and his development costs, and upon whether he anticipates a lot of resistance from people in the area or other groups and acceptance on the parts of the city council.

The designer, in order to represent the developer, might map factors like those mentioned above (the zoning, land prices, and so on) and then do a map showing where certain kinds of development would take place under those conditions. When he does that final map, the designer simulates the decision function of the developers.

Perception and Form. The designer records the qualities of the natural and man-made landscape. It is usually these qualities and the processes which are associated with changing these qualities with which the designer is most directly concerned. If the landscape were already described in terms of
its slope and direction of slope in great detail then three dimensional natural forms might be computed by means of rules for finding them. The categories "ridge", "military crest", "isolated hill", and even "hill" persist because they are, in most landscapes, identifiable. There are other landscapes where those categories are not as readily perceived as concave shapes such as "saddles", "valleys", "passes", and "bowls". The designer's knowledge of and sensitivity to the visual qualities of the land and to how people perceive the land would guide him most appropriate set of categories of "description". The rules used to obtain the categories, however, might well be sufficiently difficult to externalize that the designer would be forced to make the judgments himself in the field rather than inferring them from such data as slope and direction of slope.

In the object world the nature of the vocabulary of forms permits an overlaying of forms and building of form upon form. The environmental medium both verbal and non-verbal permits other kinds of overlapping and it allows similar messages to be conveyed when the perceiver is in a variety of different positions and sequences; it permits economical phrasing and a distinctive grammar where, for example, the subject can be an object, and the predicate words. (3.07)

The components of experience which function as sign, object or symbol may be the same, functioning first as one and then as the other, action and conception fused together into
the experience "that makes human life an adventure in understanding". (3.08)

The data of the environment which contribute to the communication of meaning are difficult to specify, and are probably highly variable with respect to the sensitivity to form and knowledge of the connotations on the part of the perceiver. In most aspects of the perception and form of the environment, it is necessary to rely on the designer for both the data of the description and the manipulations.

Nevertheless, there may be a limited role in the design process which could be played by making functions of "perception and form" explicit. One might try to substitute a rule of inference for the behavior of the subject which would produce the same response.

For example, if a designer wanted to know which aspects of one of the major streets in his "corridor" zone which were generally perceived as the most "dominant forms" he might identify the following data from the environment needed to compute his new category: singularity of form in the local context, clarity of outline against the background, proximity to observer and size of building, presence of signs, surface and texture of the building; number of people driving, and walking to whom exposed, duration of exposure and the centrality to their view; and viewer type, perhaps only three groups: newcomers, local employees and shoppers, and passers by. (3.09) Once having classified the environment in those
categories, the designer would have to complement the existing description where necessary with field observation by trained designers and, where possible, computing some categories from other data: clarity of outline, for example, might be measured by projecting lines from street level at the edges of the forms to determine if they then intersected with other forms. He then could evaluate which forms would be dominant for the three groups identified. And he could try, through interviewing samples of the different groups, to verify his hypothesis of their response. A seemingly personal and "esthetic" kind of judgment can, at least in part, be made explicit.

Order

"Functions of order" differ from "functions of extension" in that the importance of the function to the designer is the organizational scheme which it provides for the data rather than the specific data which are part of the scheme. An example which may help to clarify this idea follows: designers sometimes arrange elements of the environment in linear patterns, densely clustered along the line with density falling off away from the line and with smaller lines extending out normal to the major line with higher densities following the lines out. This particular pattern can be expressed as a function. Its arguments are any data of the description which come even close to suggesting that they might fall into such a pattern. Its value is the
specification of data not present in the existing description, data required to fill in the gaps of the specified pattern. (3.10)

"Functions of order" have a powerful heuristic role in design: they provide places to put things. In the linear form example just cited the designer introduced a rule which when applied to the existing environment left open questions as to what would fill it in at the empty points and what the empirical correlates would be of its various parts.

For example, urban designers often organize the environment in a strongly geometric pattern, a grid perhaps: the intersections are sometimes called "centers", the connecting links and left over areas, "roads" and "neighborhoods", and each member of the centers, roads, and neighborhoods is arranged in a hierarchy corresponding to some "level" of importance, movement, or activity. (3.11) Often, in addition, the grid itself is assumed to be a strong and rectilinear structural "framework" for the growth of the city which is supposed to afford flexibility of growth over time. Admittedly somewhat out of date, these "megaforms" are helpful in illustrating a good many of the designer's conventions. (3.12)

Other organizing schemes for the man made environment beside the grid and the linear form with arms extending out are the radial, circumferential, star, galaxy, and network; and, analogies with trees, with organisms and with
rivers. (3.13) Some elements which bespeak their formal origins have become permanent parts of the conventional vocabulary of city form: green belts, radials, circumferentials, and satellite centers.

The designer, as he works with these "functions of order" may tug and pull against them resisting the full extent of the regularity they force on him by making ad hoc adjustments to them, some explicable in terms of some local building to be saved, or some particularly important natural feature which may cause a bend or even a break in the pattern, some in terms of the designer's wish simply to introduce variety into the pattern, and others inexplicable either to the analyst or to the designer. (3.14)

Some "functions of order" instead of being based on geometric patterns in plan view, may be based on patterns of events in which the visual form and the communicated meaning of each event and their order and timing of occurrence (as perceived) play a major role in determining the strength of each event and the success of the pattern as a whole. The empirical correlates of the elements of these patterns may be the doorways, paving, signs, and lights of the designer of the public or popular world. (3.15)

Other "functions of order" include "seriation" within a single class: for example, three sub-categories of centers: small, medium and large, each with its own composition of activities and "role" in the city. Dichotomization is the
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Division into two often opposed classes, and is often accompanied by the establishment of a scale of values between the opposites: for example, five gradations between "community" and "privacy", each associated with some data of the description as well as with some social role which it is expected to play for some group. (3.16) "Morpho-logical" organization, the cross classification of classes, serves to draw the designer's attention to the intersections of each of the classes in the table and to afford the possibility either of assigning that new class to some existing part of the environment or to create a new datum. Like the other "functions of order", morpho-logical organization creates gaps to be filled and regularities to be challenged. And diagrams exhibiting connection and clustering, bubble diagrams, are often used as ways of studying essential relationships in the design which are then distorted to fit the existing environment, or, perhaps, to fit some other "functions of order" more strongly geometric in its specification. (3.17)

II. FUNCTIONS OF TRANSFORMATION

The designer engages in descriptions of hypothetical possibilities which he looks at and examines along with the description of the existing environment to study out the possibilities for change and the ways of satisfying the many purposes of his design. He may investigate many such hypotheses. A design alternative is a set of changes to the existing description of the environment in which the changes
are mutually consistent. A design alternative differs from the isolated hypotheses tried out by the designers in that it can be analysed as an entire and new description of the environment. Moreover, it presumably achieves some entire set of purposes which has been formulated to solve some design problem.

The city designer most often works on an environment in which he can exercise only partial control over the course of events. The world gets designed and built even if he does not intervene. He can often intervene by altering the preconditions upon which the environment related "systems" he has envisioned operate; or by altering the rules which describe how the system he envisions operates.

A function of "transformation" receives as arguments, the "primitive" data of the environmental description and functions of "further description". When evaluated, it yields a changed description. It does so by altering either the "primitive" data or the rules of inference in the "functions of extension".

**Transforming the Data.** The designer can imagine himself as looking at a world which is best described by envisioning "systems of environmental change".

For example, the designer might change the "environment" within which a developer acts in such a way as to change what he does and where he does it but not to change the criteria by which he evaluates the choices open to him.
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The designer is intervening to alter some of the environmental conditions upon which the system in question operates. He assumes that he can control these conditions, specifies the changes, simulates the action of the systems on the changed environment and then might check to see if the environment so obtained is satisfactory.

A variation on this theme would be if the designer chose to influence the environment related constraints on the agent of environmental change. At the local level, changes to the zoning ordinances to encourage industrial development through increasing the areas available for such use or to exclude lower income people by increasing the lot size, as misguided as these actions may be they have, in combination with other activities, such as active promotion of industry or discriminatory behavior on the part of real estate agents, achieved their stated purposes.

Changing the developer's actions by changing the environment within which he acts is transforming the basic data of the function of "development over time". The designer could also alter the basic data of other types of "functions of extension": "functions of environmental use" and "functions of perception and form". Illustrating the latter type: in the example cited above the designer may have been guided to his interest in "form dominance" by wishing to direct the attention of as much of the population as possible to certain kinds of facilities on the premise that "form dominance" would
increase awareness and use of those facilities. He could, with his rule of how people perceived the environment, try to rearrange the environment to achieve his goal.

**Transforming the Rules of Inference.** A second mode the designer can operate in is to change the rule of inference instead of the basic data of the functions. In the previous example, the designer could have chosen to change the characteristics of the "system" he was representing by the rules of perception. He might have trained people to observe better and, hence, changed their perceptions of the environment. Inasmuch as the perceived "form dominance" is part of the description of the environment, the designer would have transformed the description.

A second example of this mode of work might be the design of a new type of developer which would respond to the needs of low income residents without a very high financial incentive. For example, settlement houses have gotten into housing development, an existing institution with motives which seem well suited to the purpose but which previously did not engage in that sort of activity. Cooperatives have been set up composed of the affected individuals, a new institution on an existing model, for the same reasons. In these cases, the designer tries to bring together a group whose motivations are in line with the designer's convictions about how things ought to be done. Once again, as in the case of the private developer, the new group may be described as acting freely.
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within some opportunity area (3.18), an area which may be bounded by such considerations as the locations of roads and utilities existing patterns of land ownership, and existing legislation pertaining to the environment. These considerations are particularly important for the city designer, for after he has imagined some new agent of environmental change, he will probably want to see how it might change the environment or, perhaps, revert to the first mode of operating in order to change the conditions within which the new system acts, and, after that, see how the changed environment affect the quality of life in a variety of different ways.

Thirdly, the designer could establish a set of environmental development rules based on a body of expert wisdom about a geographic region, wisdom which pertains to safety, health, comfort, and other dimensions of human experience as well as technological, economic, and political feasibility of environmental change. An example of the latter would be the soils engineer's recommendation about where to build tall buildings. This set of development rules, if associated with institutions which could enforce them, would constitute the invention of a new environment related "system", one which would provide new constraints on what the other agents of environmental change actually did.

III. FUNCTIONS OF TESTING

During the design process the designer is constantly
testing his ideas, either implicitly or explicitly, against many criteria. The "testing" which is referred to here is neither the comprehensive evaluation of a single design alternative nor the comparative evaluation of many alternatives. These activities pose special conceptual and procedural problems many of which are dealt with elsewhere. (3.19) "Testing", as used here, refers to what the designer is doing as he is working toward a design alternative.

A "testing" functions receives three kinds of arguments: data of the environmental description; data obtained from other sources; and a standard of comparison. The function compares the data of the description with the data from other sources and, if they match within the standard, the value of the "test" is "true", or "passed". To change the value of the "testing" function the designer can transform the data of the description; he can change the data obtained from other sources; or he can change the standard of comparison, that is, he can relax the "fit" between the two types of data. (3.20)

"Testing" functions in city design can be of two basic types: internal consistency and external consistency. Internal consistency refers to the consistency of the environmental description: either among data of the environment (e.g. that there were no more than one hundred acres of house lots in one hundred acres of land) or between data of the description and rules of inference representing
environment related "systems", (e.g. that the shadows were drawn in the proper position considering the longitude and latitude of the environment and the time of day and year being represented). External consistency refers to the consistency between the data of the description and the specification of purpose, (e.g. that the noise index at this place is within an acceptable range for these people engaged in recreational activities).

Highway noise and people's tolerance of noise will be used as an example. The measurements of the environment are of the values of a noise index in the environment being considered. The noise index was in turn obtained from a function of "description" which received three kinds of arguments from the environment: highway position, use of the highway, and vehicle type; and from the environment related system of acoustics: coefficients which could convert the environmental measurements into a noise index. The "testing" function then compares the measured noise index with a "desired value" of the noise index, a value obtained from a source which expresses some group's tolerance of noise when engaged in some activity. If the measured noise index in the environment matches the "desired value" within the standard then the test is passed. The "desired value" could as well refer to the designer's preferred level or the average of many groups. The values and standards for comparison can be stated in other ways. And the "desired value" may change with
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exposure to the new environment, for example, people may be able to stand more (or less) noise after they have lived there a while. This consideration could be built into the above example, or embodied in another example which might demonstrate the long term adaptation effects. (3.21)

The "functions" of city design as spelled out here are of three types: "functions of further description" which derive or infer new data of the description; "functions of transformation" which alter the data of the description directly, or indirectly by altering the rules of inference; and "functions of testing" which compare the data of the description with data obtained from other sources.
CHAPTER IV
THE DISCOURSE LANGUAGE

The language of DISCOURSE will be presented in three sections: the first dealing with LOCATIONS and ATTRIBUTES, the basic features of the language; the second, with the elaboration of the data structure to include numerical values; and the third a short description of the components of the DISCOURSE system.

The structure of DISCOURSE has been made as simple and transparent as possible in order that the designer have a clear understanding of what he is manipulating and changing and in order that he be able to depict the world as he chooses. The operations have been developed to be close to what the designer does in any event, though he may not always realize it, and are intended to be so basic as to avoid commitment of the designer to an uncomfortable or unwanted way of working.

The basic features of the language allow it to accommodate the types of functions developed in the previous chapter: functions of the derivation and inference of new data, the transformation of the data, and the comparison of the data with values obtained from other sources which may represent standards or norms.

As a designer works he creates new ways of working, of analysing, and of generating environmental forms. The
techniques he uses toward the finish of a design exercise may be entirely different than those he used at the beginning. No programmer can anticipate all the requests a designer will want to make. The language, therefore, has additional features which permit the designer to construct his own special requests, allowing him to build and to modify his own techniques of design as well as his design proposals as he works. The designer must, therefore, do some "programming" in order to make his special requests. DISCOURSE eases his programming job by taking care of much of the bookkeeping for him. But he still must program. There appears to be an unresolvable dilemma: that the designer, in order to make requests which respond better to his needs, will demand more features of the language and, as a consequence, he will have to become proficient in an increasingly complex language. Ease of use and subtlety of expression may be opposed. This issue is taken up in Chapter VI, on future development.

1. BASIC STRUCTURE OF THE LANGUAGE

Places (or LOCATIONS) and ATTRIBUTES are the basic features of the data structure of DISCOURSE. Some of the limitations of the system which have resulted from this kind of structure will be explored later in this chapter, but principally in Chapter VI.

LOCATIONS usually mean a position in some geographic space which can be distinguished from all other positions in that space. The space is two dimensional; two coordinates
are necessary to describe any LOCATION uniquely. It should be noted that the computer ultimately reduces any N dimensional space to a single dimensional array. One cannot deduce from the two coordinate addressing of the LOCATIONS in DISCOURSE that three or n dimensional space is inconsistent with the data structure; rather it is inconsistent with its particular implementation at the moment.

A pair of coordinates can be thought of as the name for a LOCATION list; the members of the LOCATION list contain information about what is at that particular LOCATION. Coordinates refer to an area rather than a single point; the LOCATION may be the size of a city block or, as in the example in Chapter II, a square mile. The presence or absence of an ATTRIBUTE at a LOCATION gives no clue as to its placement within that LOCATION. Thus the "resolving power" of the designer's lense is limited in major part by the size of each LOCATION he uses. Other ways of increasing the detail of the description will be discussed below.

**ATTRIBUTES**

An ATTRIBUTE is descriptive of LOCATIONS. In DISCOURSE an ATTRIBUTE is the name of a list of LOCATIONS which share it. Examples of ATTRIBUTE names are "water", "tidal flats" and "middle income residents". An ATTRIBUTE which exists at a LOCATION is called an "ATTXLOC". Most maps can be thought of as a display of ATTXLOCS.

The data structure of DISCOURSE I is a particularly
eloquent representation of the logical structure of ATTRIBUTES and LOCATIONS, figure (4.01). Two "dictionaries" were created: one for LOCATIONS in which the name for each LOCATION consisted of its two coordinates; and the other for ATTRIBUTES.

Organization of data by lists means that the physical organization of the data inside the computer is divorced from the logical organization of the data. One logical record (the geographic location of industry, for example) is located in computer storage by storage allocation features which are part of the computer language in which DISCOURSE I was programmed. (4.01) In order to find that record again, it is pointed at by the previous member of the same list and it, in turn, points to the next member of the list. The values of the pointers are determined once the storage location has been determined.

With list organization the lists can be lengthened or shortened having had to predict only the total amount of working space required for all lists plus expansion instead of having had to reserve a specific place in computer storage for the expansion area of any particular list. For problems in which the data are seldom changed or come in predictably sized packages, this feature is meaningless. But in problems of design where the designer is adding, subtracting, and changing his data constantly, it is significant. But list organization has disadvantages as well. The pointers which permit random organization in computer storage take up space themselves;
time is required for moving around through storage which is in excess of that required for searching sequentially organized records; and because each list is continuous it is expensive to cut it, leaving part in the computer's core and part in some other memory device if it has to be constantly used as part of the search procedure, for it would have to be read in and out of the computer's core. This consideration becomes crucial for problems in which such search in the categories of the description is commonplace and for problems in which the data are likely to be extensive. Both are true of city design.

The list organization of computer storage must be contrasted with an organization in which the logical records are placed physically in sequence, like a phone book. One common attribute of the records is selected by which to key them in sequence; in the case of the phone book, it is the name. If one were to look for a particular phone number or address it would be difficult. If one record is to be lengthened either all subsequent or all previous records must be moved to leave space.

These are limitations to sequential organization when the problems to be dealt with involve records of changing lengths as well as continuous modification of the records. But sequentially organized records can be stored redundantly, that is, one could make three phone books: one alphabetically by name; a second ordered by telephone number; and a third by
street address. Redundant storage affords many of the same advantages of record access as multiple list structures. The overhead which one has to pay for the operation of either the list or sequential organization will depend upon many factors among which are the size of the core-resident memory of the computer plus the amount of the data that the programmers must deal with, and the features of the particular hard- and software being used. The transparency of logical structure of the pure list organization utilized in the first version of DISCOURSE gave way to a structure which took advantage of both list and array features of the computer. (4.02)

In the first version of DISCOURSE the LOCATION and ATTRIBUTE names were associated with three types of lists: "initial", "permanent extension" and "temporary extension". The paradigm of behavior on the part of the designer this earlier arrangement of lists suggested was roughly as follows: a designer makes an "initial" description of the environment, indicating where things are; during the course of his work he looks around at where things are, and where they are in combination, creating categories of the description which are of "temporary" use to him; and, finally, he makes a "permanent" change of the description either by adding (or deleting) a category of the description to (or from) some LOCATIONS or by creating a new category and adding it to some LOCATION. The designer persists in this way, repeatedly looking around and then changing things until he reaches the
end of his working session. At that point he stores what he has done. At the next working sessions he again starts with an initial description, but, this time, it can be either the "initial" or the terminal description of the previous (or any other) working session.

In the latest version of DISCOURSE there is only one type of list but the designer can create his own variety through the ways in which he names and manipulates them.

Questions like "where are the places with a good view, good drainage, fine trees, not too steep, ..." can be answered by logical operations on ATTRIBUTES and LOCATIONS. A new category of the description is a new ATTRIBUTE list; a design change is an alteration of the ATTRIBUTES of LOCATIONS.

In DISCOURSE two ATTRIBUTE lists exist which are useful to the designer in various ways: "universe" and "null". Universe is an ATTRIBUTE which exists at every LOCATION and null exists at no LOCATIONS. Universe is essential in such operations as finding all LOCATIONS except those which have water. (Eg. "dryland *** universe .and..not. water") Null is less obviously useful for keeping a category of the description which at that moment does not exist at any LOCATIONS. (Eg. "new population *** null") The logical operators of DISCOURSE are illustrated in figures (4.02) to (4.10).
Figure 4.01 Data structure of DISCOURSE I
LEGEND:

PRIMARY ATTRIBUTE ASSIGNMENTS - - 'a' = A(2); 'b' = B(3)
't' = a, b
'.' = NON EMPTY LAND (contains ATTRIBUTES other than "a" or "b")

Figure (4.02) Positions of ATTRIBUTES "a" and "b", the basic data
Figure (4.03) "a", "b" and "universe"
In figures (4.03) to (4.10) the desired results are always in capital letters.
intersection = a .and. b
map* (a b intersection) 1-7 1-9

1 2 3 4 5 6 7 8 9
1 1 1 1 1 1 1 1 1
2 a a a b b b 2
3 a a T T b b b 3
4 a a T T b b b 4
5 a a a b b b 5
6 6 6 6 6 6 6 6 6
7 7 7 7 7 7 7 7 7
1 2 3 4 5 6 7 8 9

LEGEND:
PRIMARY ATTRIBUTE ASSIGNMENTS -- 'a' = A(2); 'b' = B(3); '0' = INTERSECT(4)
'T' = a, b, 0
'.' = NON EMPTY LAND

Figure (4.04) Logical #intersection
aandnotb ** a .and..not. b
map* (a b aandnotb) 1-7 1-9

1 2 3 4 5 6 7 8 9
1 . . . . . . . . . 1
2 . A A A . b b b . 2
3 . A A t t b b b . 3
4 . A A t t b b b . 4
5 . A A A . b b b . 5
6 . . . . . . . . . . . 6
7 . . . . . . . . . . 7
1 2 3 4 5 6 7 8 9

LEGEND:
PRIMARY ATTRIBUTE ASSIGNMENTS - - 'a' = A(2); 'b' = B(3); '0' = AANDNOTB(7)
't' = a, b
'A' = a, 0
'.i' = NON EMPTY LAND

Figure (4.05) "a" and not "b"
eitheror *** a .or. b
map* (a b eitheror) 1-7 1-9

1 2 3 4 5 6 7 8 9
1  
2  A A A  B B B  2
3  A A T T B B B  3
4  A A T T B B B  4
5  A A A  B B B  5
6  
7  
1 2 3 4 5 6 7 8 9

LEGEND:

PRIMARY ATTRIBUTE ASSIGNMENTS -- 'a' = A(2); 'b' = B(3); '0' = EITHEROR(8)

'A' = a, 0
'B' = b, 0
'T' = a, b, 0
'.' = NON EMPTY LAND

Figure (4.06) Either "a" or "b" or both
ornot *** a .or..not. b
map* (a b ornnot) 1-7 1-9

1 2 3 4 5 6 7 8 9
1 0 0 0 0 0 0 0 0 0 1
2 0 A A A 0 b b b b 0 2
3 0 A A T T b b b b 0 3
4 0 A A T T b b b b 0 4
5 0 A A A 0 b b b b 0 5
6 0 0 0 0 0 0 0 0 0 6
7 0 0 0 0 0 0 0 0 0 7
1 2 3 4 5 6 7 8 9

LEGEND:

PRIMARY ATTRIBUTE ASSIGNMENTS - - 'a' = A(2); 'b' = B(3); '0' = ORNOT(9)
'A' = a, 0
'T' = a, b, 0
'.' = NON EMPTY LAND

Figure (4.07) "a" plus all the LOCATIONS which do not contain "b"
exclusive or **= a \cdot eor \cdot b
map* (a b exclusive or) 1-7 1-9

1 2 3 4 5 6 7 8 9
1 . . . . . . . . . 1
2 \ A \ A \ A \ B \ B \ . \ 2
3 \ A \ A \ t \ t \ B \ B \ B \ . \ 3
4 \ A \ A \ t \ t \ B \ B \ B \ . \ 4
5 \ A \ A \ A \ . \ B \ B \ B \ . \ 5
6 . . . . . . . . . . 6
7 . . . . . . . . . . 7

LEGEND:

PRIMARY ATTRIBUTE ASSIGNMENTS \_-- \ 'a' = A(2); \ 'b' = B(3); \ '0' = EXCLUSOR(10)

't' = a, b
'A' = a, 0
'B' = b, 0
'.' = NON EMPTY LAND

Figure (4.08) either "a" or "b" but not both: logical "exclusive or"
eornot *== a.eor..not. b
map* (a b eornot) 1-7 1-9

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1 2 3 4 5 6 7 8 9

LEGEND:

PRIMARY ATTRIBUTE ASSIGNMENTS — 'a' = A(2); 'b' = B(3); '0' = EORN(11)

'1' = a, b, 0
'.1' = NON EMPTY LAND

Figure (4.09) Not either "a" or "b", the negative of Figure (4.08)
int *** commerce .and. highpoint
map* (commerce highpoint int) 1-7 1-9

1 2 3 4 5 6 7 8 9

1 T . . . . . . . . . . 1
2 . . . . . . . . . . . 2
3 . . . . . . . . . . . 3
4 . . T . . . . . . . . 4
5 . . . . . . . . . . . 5
6 . . . . . a a a . . . 6
7 . . . . . T a a . . . 7

1 2 3 4 5 6 7 8 9

LEGEND:
PRIMARY ATTRIBUTE ASSIGNMENTS - - 'a' = COMMERCE(12); 'b' = HIGHPONT(=3); '0' = INT(14)
'T' = a, b, 0
'.' = NON EMPTY LAND

Figure (4.10) Logical "intersection" used to find out where both "commerce " and "highpoint" share the same LOCATIONS
In the logical operations described above, the computer had to look down the ATTRIBUTE lists member by member in order to determine, for example, whether or not some other ATTRIBUTE was present at any of the LOCATIONS on the list. This looking down a list member by member is called "looping". The looping operation may be easier to remember if it is realized that each ATTRIBUTE list can also be thought of as a ring in which the last member points back to the first.

A second kind of looping for geometrical functions was required because each LOCATION is represented in DISCOURSE as two numbers: its coordinates. Additional features of the language were necessary to permit the designer to manipulate them (and to manipulate numerical data which will be discussed below). Both arithmetic and relational features were required.

The arithmetic operators are:

"+" = plus
"-" = minus
"*" = times
"/" = divided by
".power." = raised to the power

The relational operators are:

".grt." = greater than
".geq." = greater than or equal to
".leq." = less than or equal to
".les." = less than
".eql." = equal to
".neq." = not equal to

Additional objects of the description were required as well:
temporary variables which would store a number in order to keep track of the results of numerical computation. The rules specifying the precise use of these features are included in the "Notation" and "Reference" manuals. (4.03) The features are illustrated in the several examples in this chapter and in Chapter V.

Three examples of geometric functions which are frequently used are "block" which creates a rectangular block of a specified size around some LOCATION; "circle" which creates a circle of specified dimension; and "nearest" which finds the nearest member of some ATTRIBUTE list to some LOCATION. These three have been included as basic requests in DISCOURSE. These and others which a particular designer may want but which are probably not of general use can still be written in DISCOURSE.

To illustrate the features of the system pertaining to LOCATIONS and ATTRIBUTES a simple data file will be made. Commands in DISCOURSE will appear on the left margin, single spaced except where clarity demands an extra space and separated from the preceding and following text by an extra space. Commands given by the designer are in lower case type; the computer responds in upper case.

Step 1. The designer selects the size of the map and LOCATION and, therefore, the size of the grid. The "setup" command establishes the grid with rows numbered 1 to 8 and columns numbered 1 to 11, space for 32 ATTRIBUTES and 32
CHAPTER IV: LANGUAGE

temporary variables.

comment step 1.

setup 1 8 11 32 32

Step 2. He decides upon the initial set of categories of his description.

comment step 2.

land *** null
water *** null
lowres *** null
midres *** null
tidal *** null
highpoint *** null

Step 3. The ATTRIBUTE lists can be expanded or contracted by saying:

put lowres 6,7
delete lowres 6,7

in order to put or delete "lowres" on all the high points:

put lowres for each loc on highpoint
delete lowres for each loc on highpoint

and, finally, to add or subtract "lowres" from a block of LOCATIONS, one gives the following commands in which the corners of the block are identified:
put lowres(6,7)...lowres(7,9)
delete lowres(6,7)...lowres(7,9)

The following commands pertain to the data file which is being built:

comment step 3. Locating the ATTRIBUTES comment or describing the LOCATIONS.

put land(1,1)...land(4,5) land(1,6)...land(1,7) '
land(1,8)...land(5,11) land(5,1)...land(8,1)
put water for each loc on universe .and..not. land
put lowres(1,1)...lowres(2,3) lowres(2,3)...lowres(3,4)
put midres(2,8)...midres(3,8) midres(2,9)...midres(5,11)
put tidal(2,2)...tidal(4,5)
delete tidal(2,2)
put highpoint 1,6 4,8 5,11 6,1

comment to store this file for future use:
store mapp p

Step 4. He may wish to display the data in order to check them for errors and in order to begin to look around. Display in DISCOURSE is of two major types at present: map display and tabular display. The command "show" yields values in tabular form; "map" makes a map-like table.

comment step 4

show lowres
LOWRES(1,1)
LOWRES(1,2)
LOWRES(1,3)
LOWRES(2,1)
LOWRES(2,2)
LOWRES(2,3)
LOWRES(2,4)
Step 5. He could "fill" the land where the low income residents lived:

comment step 5 altering the data
put land for each loc on tidal .and. lowres
delete tidal for each loc on tidal .and. lowres

Step 6. He might decide to assemble a zone for new development subject to the following criteria: that it be adjacent to existing residential development; that it not be
on water, not on a high point, and not on tidal flats; and that the LOCATION on that list closest to a highpoint be assigned to low income residents.

The sequence of requests might look as follows:

1. "tlist1 *** lowres .or. midres"
   This creates a new ATTRIBUTE which includes all the LOCATIONS on "lowres" or "midres".

2. "ex beside (tlist1)"
   This creates a new ATTRIBUTE named "beside" which includes all the LOCATIONS which are beside "tlist1", but not on "tlist1".

3. "tlist2 *** beside .andn. water .andn. not. highpoint .andn. tidal"
   This creates a new ATTRIBUTE in which the LOCATIONS of "beside" which also contain "water", "highpoint" or "tidal" have been eliminated.

4. "ex dnearest (highpoint tlist2)"
   This finds the LOCATION on "tlist2" which is closest to any LOCATION on "highpoint", puts its row coordinate in "qi", its column coordinate in "qj", and its distance from the closest highpoint in "q".

5. "put lowres qi,qj"
   This puts "lowres" in that LOCATION found by "dnearest".

6. "show loc qi,qj"
   This simply displays to the designer the contents of the LOCATION which has been changed.
CHAPTER IV: LANGUAGE

If the designer wanted to repeat that series of requests he could make them a Request COMbination file (RCOM file) and call it by a name. Additionally, he might want to leave the choice open when he called that RCOM file of what type of residence he would assign. Therefore, he might rewrite it substituting "argl" for "lowres" in line 5 above which would then read "put argl qi,qj". The first named argument in the RCOM call would be substituted for "argl" when the file was executed. The execution of the RCOM file follows:

comment step 6
oldzone *== lowres .or. midres

rd newzone p(lowres)
LOWRES HAS BEEN ASSIGNED TO LOCATION 1,7
AND IS 500 FEET AWAY FROM THE NEAREST HIGHPOINT
rd newzone p(lowres)
LOWRES HAS BEEN ASSIGNED TO LOCATION 1,5
AND IS 500 FEET AWAY FROM THE NEAREST HIGHPOINT
rd newzone p(lowres)
LOWRES HAS BEEN ASSIGNED TO LOCATION 1,8
AND IS 1000 FEET AWAY FROM THE NEAREST HIGHPOINT
rd newzone p(lowres)
LOWRES HAS BEEN ASSIGNED TO LOCATION 1,4
AND IS 1000 FEET AWAY FROM THE NEAREST HIGHPOINT
rd newzone p(lowres)
LOWRES HAS BEEN ASSIGNED TO LOCATION 3,1
AND IS 1500 FEET AWAY FROM THE NEAREST HIGHPOINT
rd newzone p(lowres)
LOWRES HAS BEEN ASSIGNED TO LOCATION 4,1
AND IS 1000 FEET AWAY FROM THE NEAREST HIGHPOINT
rd newzone p(midres)
MIDRES HAS BEEN ASSIGNED TO LOCATION 5,1
AND IS 500 FEET AWAY FROM THE NEAREST HIGHPOINT
rd newzone p(midres)
MIDRES HAS BEEN ASSIGNED TO LOCATION 1,9
AND IS 1500 FEET AWAY FROM THE NEAREST HIGHPOINT
rd newzone p(midres)
MIDRES HAS BEEN ASSIGNED TO LOCATION 1,10
AND IS 1802 FEET AWAY FROM THE NEAREST HIGHPOINT
comment the results of the RCOM file
comment can then be mapped:

newzone *** lowres .or. midres .and..not. oldzone
mapset standard (6;+) red
map* (newzone oldzone;highpoint land) 1-8 1-11

LEGEND:
PRIMARY ATTRIBUTE ASSIGNMENTS -- '1' = NEWZONE(16); '2' = OLDZONE(12)
'.' = NON EMPTY LAND

REFERENCE ATTRIBUTE ASSIGNMENTS -- ' + ' = HIGHPONT(10); '-' = LAND(5); '+ ' = LAND & HIGHPONT; ' ' = NO REF ATTS

comment the RCOM file, "newzone p", which generated
comment the new pattern follows:

printf newzone p

TLIST1 *** LOWRES . OR. MIDRES
EX BESIDE (TLIST1)
TLIST2 *** BESIDE . AND.. NOT. WATER . AND.. NOT. HIGH'
POINT. AND.. NOT. TIDAL
EX DNEAREST (HIGHPONT TLIST2)
PUT ARG1 QI, QJ
EXPAND +$2ARG1 HAS BEEN ASSIGNED TO LOCATION $3QI,$3QJ/+ EXPAND + AND IS $1Q FEET AWAY FROM THE NEAREST HIGHPONT/+ READ_CONSOLE
comment newzone p requires three other small files
comment which are geometric "Functions of Measurement".
comment (see Chapter III)
comment lbeside p results in an ATTRIBUTE list which
comment is beside the named ATTRIBUTE list but not on it.
comment lnearest p find the nearest member of the
comment second named list to any member of the
comment first named list.
comment and lnearest p is called by
comment dnearest p in the course of its work, finding the
comment closest member of the list named to the
comment LOCATION specified.

printf lbeside p

BEGIN_MACRO BESIDE
BESIDE *** NULL
FOR I= EACH LOC ON ARG1 BLOCK 1. BESIDE(I)
BESIDE *** BESIDE .AND..NOT. ARG1
END_MACRO
RETURN

printf lnearest p

BEGIN_MACRO DNEAREST
Q = 999999.
THROUGH LABEL FOR I=, J= EACH LOC ON ARG1
EX NEAREST (I J ARG2)
IF Q .LES. MINDIST GOTO LABEL
Q = MINDIST
QI = BESTI
QJ = BESTJ
LABEL$ CONTINUE
END_MACRO
RETURN

printf lnearest p

BEGIN_MACRO NEAREST
MINDIST = 999999.
THROUGH NE2 FOR II=, JJ= EACH LOC ON ARG3
SUM1 = ARG1 - II .POWER. 2.
DIST = ARG2 - JJ .POWER. 2. + SUM1 .POWER. 0.5
IF DIST .GRT. MINDIST GOTO NE2
MINDIST = DIST
BESTI = II
BESTJ = JJ
NE2$ CONTINUE
MINDIST = MINDIST * GRIDSIZE
Through the introduction of the loop (the "for" and "through" statements), the branch ("goto" statement), and the conditional (the "if" statement) plus the capacity to name a series of requests and call them with that name (to make RCOM files), most of the sorts of manipulations which the designer can make on his description are possible in DISCOURSE.

II. CHARACTERISTICS OF ATTRIBUTES
CHARVARS AND CHARCONS

An ATTRIBUTE can have two kinds of characteristics: a CHARVAR is a CHARACTERISTIC of an ATTRIBUTE whose value may vary at different LOCATIONS; and a CHARCON is a CHARACTERISTIC whose value remains CONSTANT regardless of LOCATION. For example, if the ATTRIBUTE "lowres" (low income residents) had a CHARVAR "number" and a CHARCON "income", its CHARVAR "number" would have values which could vary with different LOCATIONS; its CHARCON "income" would have the same value everywhere. The CHARCON names and values permit calculations of total income or income per person in locations where more than one income level is found. If a designer were doing a land use survey he could assign the ATTRIBUTES "residence", "industry", "commerce", and "open space" to that LOCATION (or some finer breakdown). Probably he would be well
advised to make a small grid size. The smaller grid size would permit mapping of the uses in distinct areas or at least with as many of the LOCATIONS as possible in distinct categories. Of course, if he were involved in a regional transportation study and all he needed to know at the time was the number of origins and destinations by type and quantity and time of day in that LOCATION, then the grid size of 500 feet square might be satisfactory.

The ATTRIBUTE "residence" could have as CHARVARS the numbers of residents broken down by age and sex and as a CHARCON the average income per family. A school could have the number of students, teachers, administrators and staff; industry and commerce could be elaborated in similar ways.

In DISCOURSE, the new ATTRIBUTE plus CHARVARS and CHARCONS would be defined:

"define residence with 3 charvars: men women children 
and with 1 charcon: averageincome = 9000"

and it would be placed in LOCATION i,j:

"put residence i,j(22. 30. 32.)"

indicating that there were 22 men, 30 women, and 32 children. Note that the average income per family refers to all LOCATIONS where the ATTRIBUTE residence occurs. If it had been desired to state the average income for this LOCATION alone then "residence" would have to have had "income" as a CHARVAR rather than a CHARCON. The two statements would have been:
"define residence with 4 charvars: men women children ' averageincome"

"put residence i,j(22. 30. 32. 9000.)"

Another kind of legend might be an inventory of types of spaces and of human activity where the two categories were kept separate as much as possible. For example, the designer might like to record the number of loft spaces of more than some area, and the average areas of those recorded. His purpose might be to find under-used spaces for public events of a certain size. He might also like to know the time tables of use of the spaces. (Whereas he might have gotten much of the data for the previous legend from census and other surveys already completed, he might well have had to collect most of the data for this legend by his own field surveys.)

One way of recording this information would be:

"define loftspace with 4 charvars: number averagesize ' use6to8 use8to10* and with 1 charcon: minsize = 5000."

In "number" would go the number of loftspaces which were greater than or equal to 5000 square feet; in "averagesize" would go their average size for this LOCATION; in "use6to8" and "use8to10" would go the number of those spaces in use from 6 to 8 and from 8 to 10 PM respectively.

If the designer could describe other types of spaces in similar ways, and he could describe people engaged in different activities, he could build up a picture of the environment as space and activity. For example:
"define people with 4 charvars: working residing 'shopping playing"

In this case, however, there would be no way of knowing in which type of space they were working. Instead, the designer could make a finer breakdown of types of people:

"define workingpeople with 2 charvars: inloftspace insmallspace"

Similarly there would be no way to know what kind of space industrial establishments were in unless there were a further specification under that category:

"define industry with 2 charvars: inloftspace 'insmallspace"

Nor would there be any way to know whether the working people were working at industry or retail, for example, unless there were the further specification:

"define industry with 4 charvars: inloftspace 'insmallspace workingloft workingsmall"

With categories of the description of the environment referring to classes of individuals rather than to individuals enrichment of the description can be done by elaborating the description of each category, even to the point (and well beyond the point) of redundancy as has been done above. (Enrichment of the description is further discussed in Chapter VI.)

To illustrate the display features of the language pertaining particularly to data which include CHARVARS and
CHAPTER IV: LANGUAGE

CHARCONS, the data file used in the Section 1. of the chapter has been elaborated and will be shown in various ways in figures (4.11) to (4.21). Figures (4.11) to (4.15) can be read as part of the text.
comment step 1: finding out what is in the data file.

1 list attributes

ATTR 0 -- NULL
ATTR 1 -- UNIVERSE
ATTR 2 -- ROW
ATTR 3 -- HIGRISE
ATTR 4 -- DETACHED
ATTR 5 -- LAND
ATTR 6 -- WATER
ATTR 7 -- LOWRES
ATTR 8 -- MIDRES
ATTR 9 -- TIDAL
ATTR 10 -- HIGHPONT
ATTR 11 -- RENTS

1 list row

CHARVAR 1 OF ROW IS CALLED RENT
CHARVAR 2 OF ROW IS CALLED UNITSOCC
CHARVAR 3 OF ROW IS CALLED UNITSVAC
CHARVAR 4 OF ROW IS CALLED DUSPACE
CHARCON 1 OF ROW IS CALLED COST

1 list land

LAND HAS NO CHARVARS
LAND HAS NO CHARCONS

1 list lowres

CHARVAR 1 OF LOWRES IS CALLED NUMBER
CHARCON 1 OF LOWRES IS CALLED INCOME

1 list tidal

CHARVAR 1 OF TIDAL IS CALLED AREA
TIDAL HAS NO CHARCONS

1 list highpoint

CHARVAR 1 OF HIGHPONT IS CALLED HEIGHT
HIGHPONT HAS NO CHARCONS

1 list rents

CHARVAR 1 OF RENTS IS CALLED AVERAGE
CHARVAR 2 OF RENTS IS CALLED TOTALD
CHARVAR 3 OF RENTS IS CALLED TOTALP
RENTS HAS NO CHARCONS
list temporary variables

GRIDSIZE = 500.
I = 0.
T = 9.
S = 975.
Q = 1.
R = 11.
N = 1.
P = 8.

comment step 2: continuing the search, now using
comment "Functions of Measurement"
show count lowres

LOWRES EXISTS AT 9 LOCATIONS

comment this also could have been written as a loop:
for i = each loc on lowres t#z = z + 1.
show z
Z = 9.
show total lowres(number)
TOTAL OF LOWRES(NUMBER) = 975.

comment similarly the last command could have been:
for i = each loc on lowres y = y + lowres(number i)
show y
Y = 975.
show total lowres(number) with tidal
TOTAL OF LOWRES(NUMBER) = 175.

comment this totals up the number of "lowres" living in
comment locations where there is also "tidal", and
comment would have needed:
tlist * =* lowres .and. tidal
for i= each loc on tlist u = u + lowres(number i)
show u
U = 175.

Figure (4.12)
show lowres

LOWRES(1,1)
LOWRES(1,2)
LOWRES(1,3)
LOWRES(2,1)
LOWRES(2,2)
LOWRES(2,3)
LOWRES(2,4)
LOWRES(3,3)
LOWRES(3,4)

show lowres with tidal

LOWRES(3,3)
LOWRES(3,4)

show row with lowres .or. midres

ROW(1,1)
ROW(1,3)
ROW(2,2)
ROW(2,4)
ROW(3,3)
ROW(3,4)
ROW(3,9)
ROW(3,10)
ROW(3,11)

comment this shows all the locations which contain row comment houses and either "lowres" or "midres".

show row(rent)

ROW(RENT 1,1) = 100.
ROW(RENT 1,3) = 100.
ROW(RENT 2,2) = 90.
ROW(RENT 2,4) = 120.
ROW(RENT 3,3) = 100.
ROW(RENT 3,4) = 90.
ROW(RENT 3,9) = 250.
ROW(RENT 3,10) = 250.
ROW(RENT 3,11) = 300.

show row(rent 1,1)

ROW(RENT 1,1) = 100.

Figure (4.13)
show highpoint(height)

HIGHPONT(HEIGHT 1,6) = 30.
HIGHPONT(HEIGHT 4,8) = 55.
HIGHPONT(HEIGHT 5,11) = 65.
HIGHPONT(HEIGHT 6,1) = 25.

show loc 1,1

LOCATION 1,1 CONTAINS
ATTR 1 -- UNIVERSE
ATTR 2 -- ROW
ATTR 3 -- HIGHRISE
ATTR 5 -- LAND
ATTR 7 -- LOWRES
ATTR 11 -- RENTS

show gridsize

GRIDSIZE = 500.

comment any DISCOURSE element can be renamed.

rename lowres lowincome
list attributes

ATTR 0 -- NULL
ATTR 1 -- UNIVERSE
ATTR 2 -- ROW
ATTR 3 -- HIGHRISE
ATTR 4 -- DETACHED
ATTR 5 -- LAND
ATTR 6 -- WATER
ATTR 7 -- LOWINCME
ATTR 8 -- MIDRES
ATTR 9 -- TIDAL
ATTR 10 -- HIGHPONT
ATTR 11 -- RENTS
ATTR 12 -- TLIST

rename lowincome lowres
delete tlist

Figure (4.14)
comment step 3: generating new values, a "Functions of Further Description"

rd rents p

AVERAGE RENT, TOTAL RENT, AND NUMBER OF DWELLING UNITS PAYING RENT HAVE BEEN COMPUTED. THEY ARE ADDRESSED: RENTS(AVERAGE), RENTS(TOTALD), AND RENTS(TOTALP).

ALL NON-MACRO LABELS REMOVED

printf rents p

SUBSTITUTION ON
THROUGH R3 FOR I = EACH LOC ON RENTS
FOR Z = 1. STEP 1. UNTIL 3. RENTS(Z I) = 0.
R3$ CONTINUE
THROUGH R2 FOR QQ = 2. STEP 1. UNTIL 4.
THROUGH R1 FOR I = EACH LOC ON QQ
RENTS(TOTALD I) = QQ(RENT I) * QQ(UNITSOCC I)
RENTS(TOTALP I) = QQ(UNITSOCC I)
R1$ CONTINUE
R2$ CONTINUE
THROUGH R4 FOR I = EACH LOC ON RENTS
RENTS(AVERAGE I) = RENTS(TOTALD I)/RENTS(TOTALP I)
R4$ CONTINUE
EXPAND +AVERAGE RENT, TOTAL RENT, AND NUMBER OF DWELLING/
EXPAND +UNITS PAYING RENT HAVE BEEN COMPUTED'/
EXPAND +THEY ARE ADDRESSED: $RENTS*($RENTS(AVERAGE)*),/
EXPAND +$RENTS*($RENTS(TOTALD)*), /
EXPAND +AND $RENTS*($RENTS(TOTALP)*)' . ///
SUBSTITUTION OFF
READ_CONSOLE

R; T=0.04/0.87 23.32.55

Figure (4.15)
comment step 4: display

rd tabmap2 p(rents average rents totalp)

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</tbody>
</table>

RENTS(AVERAGE) AND RENTS(TOTALP)
HAVE BEEN GIVEN A VALUE WHERE THEY EXIST
"B" INDICATES THAT THEY DO NOT EXIST AT THAT LOCATION

ALL NON-MACRO LABELS REMOVED

comment The top values in each LOCATION are the average rent paid in that LOCATION; the bottom values are the numbers of swelling units in each which pay rent.

Figure (4.16)
comment the designer-written RCOM file which
comment created the display
printf tabmap2 p

SET_CARRIAGE_WIDTH 120
TABSET 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100 105 110 115 120
THROUGH P1 FOR J= Q STEP 1. UNTIL R
EXPAND +.$3J+
P1$ CONTINUE
EXPAND +///<+
THROUGH P2 FOR I = N STEP 1. UNTIL P
EXPAND +$3I+
THROUGH P3 FOR J= Q STEP 1. UNTIL R
IF ARG1(ARG2 I,J) GOTO P5
EXPAND +.B+
GOTO P3
P5$ CONTINUE
EXPAND +.$3ARG1(ARG2 I,J)+
P3$ CONTINUE
EXPAND +.$3I/+ 
THROUGH P6 FOR J= Q STEP 1. UNTIL R
IF ARG3(ARG4 I,J) GOTO P7
EXPAND +.B+
GOTO P6
P7$ CONTINUE
EXPAND +.$3ARG3(ARG4 I,J)+
P6$ CONTINUE
EXPAND +///<+
P2$ CONTINUE
THROUGH P4 FOR J= Q STEP 1. UNTIL R
EXPAND +.$3J+
P4$ CONTINUE
EXPAND +/$2ARG1*($2ARG1(ARG2))* AND $2ARG3*($2ARG3(ARG4))*/+ 
EXPAND +HAVE BEEN GIVEN A VALUE WHERE THEY EXIST/+ 
EXPAND +"B" INDICATES THAT THEY DO NOT EXIST AT THAT LOCATION/+ 
RETURN

R; T=0.05/0.47 00.59.43

Figure (4.17)
comment step 5: showing the LOCATIONS of row housing with respect to low and middle income residents. The "mapset" command allows the designer to pick his own character set for the map if he chooses.

mapset standard (1;a) red (6;+) red
map* (row lowres midres; highpoint land) 1-8 1-11

<table>
<thead>
<tr>
<th>1 2 3 4 5 6 7 8 9 0 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 -A-2-A-.-.+.-.-.-.-.-. 1</td>
</tr>
<tr>
<td>2 -2-A-2-A-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.- 2</td>
</tr>
<tr>
<td>4 -.-.-.-.+.3-3-3 4</td>
</tr>
<tr>
<td>5 -.-.-.-.-.3-3+3 5</td>
</tr>
</tbody>
</table>
| 6 +.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-. Figure (4.18)
comment alternatively one could differentiate between the comment combination of "lowres" and "row" and of "midres" comment and "row".

mapset standard (1 2;a) red only (1 3;b) red only (6;+) red map* (row lowres midres; highpoint land) 1-8 1-11

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1 2 3 4 5 6 7 8 9 0 1

LEGEND:

PRIMARY ATTRIBUTE ASSIGNMENTS - - '1' = ROW(2); '2' = LOWRES(7); '3' = MIDRES(8)

'A' = 1, 2
'B' = 1, 3
'. ' = NON EMPTY LAND

REFERENCE ATTRIBUTE ASSIGNMENTS - - '+' = HIGHPONT(10); '-' = LAND(5); '+' = LAND & HIGHPONT; ' ' = NO REF ATTS

Figure (4.19)
2, 4(50.) 3, 3(75.) 3, 4(100.)
DEFINE MIDRES 1:  NUMBER* 1:  INCOME = 9000.
PUT MIDRES 2, 8(30.) 2, 9(40.) 2, 10(50.) 2, 11(30.) 3, 8(25.) 3, 9(40.) 3, 
10(50.) 3, 11(30.) 4, 9(30.) 4, 10(40.) 4, 11(30.) 5, 9(25.) 5, 10(40.) 5, 11 
(40.)
DEFINE TIDAL 1:  AREA*
PUT TIDAL 2, 5(1.2) 3, 2(2.5) 3, 3(1.2) 3, 4(1.2) 3, 5(2.5) 4, 2(5.8) 4, 3(' 
5.8) 4, 4(3.) 4, 5(2.5)
DEFINE HIGHPONT 1:  HEIGHT*
PUT HIGHPONT 1, 6(30.) 4, 8(55.) 5, 11(65.) 6, 1(25.)
DEFINE RENTS 3:  AVERAGE TOTALD TOTALP*
PUT RENTS 1, 1(80. 6400. 80.) 1, 2(80. 16000. 200.) 1, 3(85. 2550. 30.) 2 '
1(80. 8000. 100.) 2, 2(90. 1800. 20.) 2, 3(140. 1400. 10.) 2, 4(120. '
4800. 40.) 2, 8(200. 6000. 30.) 2, 9(200. 8000. 40.) 2, 10(210. 10500. '
50.) 2, 11(210. 6300. 30.) 3, 3(85. 2125. 25.) 3, 4(85. 5100. 60.) 3, 8(' 
200. 5000. 25.) 3, 9(175. 1750. 10.) 3, 10(150. 2250. 15.) 3, 11(150. '
1500. 10.) 4, 9(190. 5700. 30.) 4, 10(180. 7200. 40.) 4, 11(190. 5700. '
30.) 5, 9(280. 7000. 25.) 5, 10(310. 12400. 40.) 5, 11(250. 10000. 40.)
GRIDSIZE = 500.
I = 0.
Z = 4.
QQ = 5.
Q = 1.
R = 11.
N = 1.
P = 8.
READ_CONSOLE
EOF:

Figure (4.21)
III. SYSTEM COMPONENTS

The components of the DISCOURSE system are the designer's console at which he issues his requests and receives most of his output; core, the central processing unit of the computer, which is the active part of the computer's memory where the computation takes place and where the main program of DISCOURSE resides; and "disk files" which contain the rest of the DISCOURSE system and the designer's data files and special RCOM files.

The path followed during a typical request is initiated at the console, interpreted by the main program which then branches to the appropriate pre-compiled subprogram which is read into core from the disk if it is not already in core, also reading in the appropriate parts of the data if they are not in there already, executes the requests and either returns the reply to the designer at his console, prints it on a line printer in the computation center if the designer does not want to wait for what he has requested to be typed by the console, or writes the reply on a disk file.

The examples in the previous two sections of this chapter were all generated from within DISCOURSE, but some of them involved work in another program called EDIT (4.04) which is utilized to create and to modify disk files. To be as comfortable as presently possible in working with DISCOURSE, the designer must be fluent in both DISCOURSE and EDIT.
CHAPTER IV: LANGUAGE

DISCOURSE permits the making of a special type of RCOM file called a MACRO without having to leave DISCOURSE and enter EDIT. MACROS have been useful for short series of requests which the user has wanted to repeat quite often during the course of this work, but DISCOURSE does not have features which permit editing MACROS once created; instead, the old ones which are not wanted can be erased and new ones created in their places.

The files used in connection with the examples in this chapter were all written in EDIT, tried out in DISCOURSE which returned an error message if it found something it could not interpret, edited in EDIT, tried again in DISCOURSE, and so on until the RCOM file worked. Communication between DISCOURSE and EDIT is easy: one need only "store" what he has been working on in DISCOURSE, enter EDIT, create the needed file, return to DISCOURSE recall the "stored" data and resume work, able to utilize his newly created RCOM file. The communication will become even easier because soon the user will be able to call EDIT from within DISCOURSE.

When a designer commences to work on a design exercise he has to spend a great deal of time entering the data which he does have about the environment into a data file. Although this file is easily modified, there is, nevertheless, apt to be more work in the early than in later stages associated with the building of the data file. It should be emphasized, however, that one of the major virtues of DISCOURSE is that
new data can be easily added and then stored for later use. The data file which is stored on the disk is, like other
designer constructed files, only a series of requests which
could be made from the console. Thus, there is no distinction
in the system between the initial data and new data. The
designer can, of course, make that distinction if he chooses.
It might seem reasonable to a given designer that the likelihood of people using recreational facilities at a place in an urban area would vary with the distance of those facilities from places of employment. The designer might then begin to look more closely at where the recreational facilities and the places of employment were, perhaps adding recreational facilities at different locations and making some guesses about how the use pattern would be affected.

This experiment is an effort to extend the designer's ability to consider this one aspect of his design problem. In order to set up the experiment, the designer left himself the opportunity to explore the consequences of differing assumptions about how people use environments.

I. DESCRIPTION OF THE EXPERIMENT

In the highly simplified world of this experiment, the designer has described only: places of recreation; places where managerial, clerical, and bluecollar employees work; and the numbers of employees in each category at each place. He has included a little extra information, namely, the average income and educational level achieved by the three categories of employees. He has described the piece of the urban area he is working on as a collection of 400 blocks, 200 feet square.
Files. A "file," or "RCOM file," is either a description of the data or a designer-written supplement to the basic language of DISCOURSE, adapting DISCOURSE to the special needs of the experiment. (5.01) All the files needed for the experiment are included later in this chapter as part of the text and are explained where they appear. The file in which the designer has recorded the initial state of the environment is entitled RECREAT P.

The designer has expressed his assumptions about how people will use the environment in a general way but left himself the opportunity to change certain aspects: namely what proportion of people employed at one location will use recreational facilities within what distance. The RCOM file, a file in which the basic DISCOURSE Requests are COMbined, which actually makes the computation is entitled RECUSE P. In the terminology of Chapter III, RECUSE P is a "Function of Further Description," and, specifically, a "Function of Extension" because it generates new data by means of existing data plus a rule of inference about how people use the environment.

The designer wants to be able to get at the information he has generated with RECUSE P: to find out where people are using the recreational facilities, PWHERE P; where those using some recreational facility come from, RWHERE P; and to map the locations which are used by more than some number which the designer will decide at the time, MAP P. Again, according
to Chapter III, these are "Functions of Measurement" in that they do not add new data, but simply represent the data which are there, or derive data by the rules of arithmetic, logic, or geometry.

It should be noted that as the designer works, he may wish to generate and interrogate data in many ways besides those easily handled by the basic requests in DISCOURSE or by the files he has already written. He will, therefore, be engaged in intermittent "programming."

II. USES OF THE EXPERIMENT

The most obvious use to be made of this experiment is to try new locations for recreational facilities and to observe how they are used by whom and from where. Note that RECUSE P simulates how the environment will be used, given information about the environment, the data in RECREAT P, and the procedure, or rule of inference, in RECUSE P. (5.02)

Given some disposition of the employment and recreation, the designer can establish new values for the parameters which are directly accessible to him in the file RECUSE P. These parameters are: the type of the employees whose use of environment he wishes to simulate; the distances he thinks they will walk to recreational facilities; and the proportion of employees at some workplace which will use the recreational facilities at those distances.

There are several reasons why he might do this. First, he might neither be sure how far people would go to use
CHAPTER V: SIMULATION

recreational facilities given some transportation mode, like walking, nor know what proportion of those employed would go at all. If he could state extreme but reasonable limits, he could then see the range of consequences in terms of recreational use of his assumptions. He might, for example, vary the distances from one to several blocks and the proportion of users from 0.5 percent to 50 percent. Second, he might try to establish reasonable assumptions for different groups and then see where they might be using the same recreational facilities. Third, he might want to assume a new mode of transportation in order to extend the distance which people would go and then observe the differences in the patterns of use.

If he found that the range in the intensity and pattern of use due to variations of the parameters was sufficient to imply radically different programs for the location of recreational facilities, the designer might want to initiate a field survey or a literature search in order to generate new information which might help to reduce the uncertainty about the parameter values. He might, of course, discover that making his best assumptions about how people use the environment and his best guesses about the capacities of recreational facilities, better data about how people use environments would make no difference in the recreation development program. The second consequence of working through a problem in this way should be that the designer
becomes more aware of the environmental elements which are critical to his description and the relationships which he believes to exist among them.

The uses which the designer would make of this experiment might reflect the range of his ideas about where recreation might be placed, how people use the environment, and what transportation facilities were imaginable. He might change the experiment in response to its not being interesting to him; in response to his own growing understanding of the problem and changing perceptions of what was important to observe; or in response to new information becoming available about how people use the environment or about new modes of transportation.

He might develop new ways of interrogating the data, for example, to compute the available purchasing power of recreation users at any recreation location as a function of their annual income; or to compute average distance traveled by recreation users. If he could assign a cost to some new transportation system as well as to new recreation locations, he could compare alternative proposals, one of which depended heavily upon making better use of existing parks and the other of which did not change the modes of travel or distance traveled by people, but provided more recreation areas.

The designer could, after experimenting for some time, change his data, or his procedure for generating new data, RECUSE P. He might decide that he needed to discriminate
among more types of environmental users or introduce times of day of use; or he might decide that the procedure embodied in RECUSE P which selected the nearest recreation location was not spreading people out enough to approximate reality so that he could get a sense of where people would meet. He might, therefore, rewrite it to distribute people to all recreation locations which fell within some radius from their places of work.

III. THE EXPERIMENT

The experiment on the following pages is preceded by a cursory look at the data file, RECREAT P, listing some of its contents and mapping "office," "industry," and "recreation." The experiment itself commences with "design2 p" on the second following page. Explanatory comments are embedded within it.
recreat p is a data file containing information about places of employment and recreation. One can find out about it by reading "irecreat p" which is included later in this section of the comment chapter.

List attributes

- ATTR 0 -- NULL
- ATTR 1 -- UNIVERSE
- ATTR 2 -- MANAGEAL
- ATTR 3 -- CLERICAL
- ATTR 4 -- BLUECOAR
- ATTR 5 -- INDUSTRY
- ATTR 6 -- OFFICE
- ATTR 7 -- RECREAON
- ATTR 8 -- TLIST
- ATTR 9 -- TLIST1
- ATTR 10 -- TLIST2
- ATTR 11 -- ALLWORK
- ATTR 12 -- ALLREC
- ATTR 13 -- SUBREC
- ATTR 14 -- SUBWORK

List recreation

- CHARVAR 1 OF RECREAON IS CALLED CLERICAL
- CHARVAR 2 OF RECREAON IS CALLED MANAGEAL
- CHARVAR 3 OF RECREAON IS CALLED BLUCOLAR

Recreaon has no charcons.

List managerial

- CHARVAR 1 OF MANAGEAL IS CALLED NUMBER
- CHARVAR 2 OF MANAGEAL IS CALLED RECLOCI
- CHARVAR 3 OF MANAGEAL IS CALLED RECLOCJ
- CHARVAR 4 OF MANAGEAL IS CALLED RECNUMB
- CHARCON 1 OF MANAGEAL IS CALLED EDUCATION
- CHARCON 2 OF MANAGEAL IS CALLED INCOME

List office

- CHARVAR 1 OF OFFICE IS CALLED EMPLOYEES

Office has no charcons.
map (office industry; recreation) 1-20 1-20

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 0 |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 0 |

LEGEND:

PRIMARY ATTRIBUTE ASSIGNMENTS - - '1' = OFFICE(6); '2' = INDUSTRY(5)

'.' = NON EMPTY LAND

REFERENCE ATTRIBUTE ASSIGNMENTS - - '+' = RECREATION(7); ' ' = NO REF ATTS

comment each grid location
comment is 200 feet square:
show gridsize
GRIDSIZE = 200.
design2 p

IF DESIGN SYSTEM CRASHES GIVE THE DEBUG COMMAND:
   DUMP NAME 12000 3D000

R 0.03/0.03
rd recreat p
R 0.69/0.72
rd execrecr p
comment this file has a few convenience commands for this
comment particular experiment.
printf execrecr p

READY OFF
MESSAGE OFF
SET_CARRIAGE_WIDTH 62
RD_LNEAREST P
RETURN

rd recuse p(managerial 300. 600. 0.3 0.1)
USE OF RECREATIONAL FACILITIES BY MANAGEAL EMPLOYEES HAS BEEN
COMPUTED
rd pwhere p(managerial)
   NUMBER OF MANAGEAL   RECREATIONAL
   EMPLOYEES USING   FACILITIES AT
comment the distances of 300 feet and 600 feet were too short
rd recuse p(managerial 500. 1000. 0.2 0.1)
USE OF RECREATIONAL FACILITIES BY MANAGEAL EMPLOYEES HAS BEEN
COMPUTED
rd pwhere p(managerial)
   NUMBER OF MANAGEAL   RECREATIONAL
   EMPLOYEES USING   FACILITIES AT
   30.00          3,11
   20.00          3,13
   80.00         17,12
   40.00         17,19
   20.00         17,20
   10.00         18,12
   10.00         19,12
   10.00         20,12

rd rwhere p(managerial 17 12)
MANAGEAL EMPLOYEES FROM THE FOLLOWING LOCATIONS
USE THE RECREATION AT LOCATION 17,12
FROM 13,9          40.00
FROM 14,8          10.00
FROM 15,8          10.00
FROM 16,8          10.00
FROM 17,8          10.00
TOTAL AT 17,12      80.00
USE OF RECREATIONAL FACILITIES BY CLERICAL EMPLOYEES HAS BEEN COMPUTED.

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<tr>
<td>5040.00</td>
<td>17,12</td>
</tr>
<tr>
<td>680.00</td>
<td>17,19</td>
</tr>
<tr>
<td>480.00</td>
<td>17,20</td>
</tr>
<tr>
<td>160.00</td>
<td>18,12</td>
</tr>
<tr>
<td>160.00</td>
<td>19,12</td>
</tr>
<tr>
<td>160.00</td>
<td>20,12</td>
</tr>
</tbody>
</table>

CLERICAL EMPLOYEES FROM THE FOLLOWING LOCATIONS USE THE RECREATION AT LOCATION 17,12.

| FROM 11,8                          | 160.00                      |
| FROM 11,9                          | 680.00                      |
| FROM 12,7                          | 680.00                      |
| FROM 12,8                          | 680.00                      |
| FROM 12,9                          | 680.00                      |
| FROM 13,7                          | 680.00                      |
| FROM 13,8                          | 160.00                      |
| FROM 13,9                          | 680.00                      |
| FROM 14,8                          | 160.00                      |
| FROM 15,8                          | 160.00                      |
| FROM 16,8                          | 160.00                      |
| FROM 17,8                          | 160.00                      |
| TOTAL AT 17,12                     | 5040.00                     |

CLERICAL EMPLOYEES FROM THE FOLLOWING LOCATIONS USE THE RECREATION AT LOCATION 17,19.

| FROM 12,19                          | 680.00                      |
| TOTAL AT 17,19                      | 680.00                      |
comment map p maps the most used locations.
rd imap p

THIS FILE MAPS THE SUBSET OF ALL RECREATION LOCATIONS IN WHICH MORE THAN "ARG1" EMPLOYEES USE THE RECREATIONAL FACILITIES. IT MAPS THE LOCATIONS OF EMPLOYMENT WHERE THE USER CAME FROM. AND IT REFERENCES THESE AGAINST ALL EMPLOYMENT AND RECREATION PLACES. IT IS CALLED BY SAYING "MAP P (ARG1)" WHERE ARG1 IS A CONSTANT.
rd map p(150.)

LEGEND:
PRIMARY ATTRIBUTE ASSIGNMENTS - - '1' = SUBREC(13); '2' = SUB WORK(14)
'. ' = NON EMPTY LAND
REFERENCE ATTRIBUTE ASSIGNMENTS - - '+' = ALLREC(12); '-' = ALLWORK(11); '*' = ALLWORK & ALLREC; ' ' = NO REF ATTS
CHAPTER V: SIMULATION

IV. FILES FOR THE EXPERIMENT

All of the files necessary to do the experiment are included in the remainder of this chapter. All files in which each line is preceded by the word SAY simply print the rest of the line for the designer when he calls that file. In RECFILES P the designer is keeping track of what files he does have. The other files follow in the order in which they are listed in RECFILES P.

RECFILES P

SAY THERE ARE THE FOLLOWING FILES:
SAY RECREAT P, RECUSE P, NEAREST P, PWHERE P,
SAY RWHERE P, AND MAP P.
SAY THE DESIGNER CAN GET INFORMATION ABOUT EACH
SAY BY CALLING ANY OF THEM WITH THE PREFIX "I",
SAY EG. "RD IRECREAT P".
READ_CONSOLE

IRECREAT P

SAY THIS FILE CONTAINS THE INITIAL DATA DESCRIBING THE
SAY ENVIRONMENT. THERE ARE SIX DIFFERENT "ATTRIBUTES",
SAY MANAGERIAL, CLERICAL AND BLUECOLLAR (WHICH IDENTIFY TYPES
SAY OF EMPLOYEES); INDUSTRY, OFFICE AND RECREATION (WHICH
SAY IDENTIFY TYPES OF ACTIVITIES). EACH TYPE OF EMPLOYEE
SAY HAS ASSOCIATED THE NUMBER AT ANY LOCATION, THE ROW AND
SAY COLUMN NUMBERS OF THE RECREATION LOCATION
SAY THEY USE AND THE NUMBER USING THE RECREATION THERE, THEIR
SAY AVERAGE YEARS OF EDUCATION AND AVERAGE INCOME.
SAY OFFICE AND INDUSTRY HAVE THE NUMBER OF EMPLOYEES IN ALL
SAY CATEGORIES; AND RECREATION HAS THE NUMBER
SAY OF EMPLOYEES IN EACH CATEGORY. "PUT CLERICAL 5,6(400.
SAY 0. 0. 0.)" MEANS PUT 400. CLERICAL EMPLOYEES AT ROW
SAY 5 COLUMN 7 AND SET THE VALUES OF THE 2ND, 3RD AND 4TH
SAY VARIABLES (THE ROW AND COLUMN NUMBERS OF THE LOCATION
SAY OF RECREATION AND THE NUMBER USING IT) TO 0. INITIALLY.
SAY THE COMMAND "SETUP 1 20 1 20 40 40 0"
SAY ESTABLISHES A GRID OF LOCATIONS 20 BY 20 NUMBERED 1 TO 20
SAY IN EACH DIRECTION. ALSO IT CREATES SPACE FOR 40 "ATTRI
SAY BUTES", 40 TEMPORARY VARIABLES AND 0 ALPHANUMERIC VARIABLES.
SAY THIS FILE ALSO DEFINES THE "GRIDSIZE" OF THE BLOCKS (OR
SAY INDIVIDUAL LOCATIONS) AS 200 FEET SQUARE.
CHAPTER V: SIMULATION

READ_CONSOLE

RECREAT P

SETUP 1 20 1 20 40 40 0
DEFINE MANAGEAL 4: NUMBER RELOCJ RELOCJ RECNUMB* 2: EDUCATON = 14.
  INCOME = 15000.
  PUT MANAGEAL 5,7(100. 0. 0. 0.) 6,4(100. 0. 0. 0.) 5,8(100. 0. 0. 0.) 6,7(100. 0. 0. 0.)
  7,1(100. 0. 0. 0.) 7,2(100. 0. 0. 0.) 7,3(100. 0. 0. 0.) 7,14(100. 0. 0. 0.)
  7,15(100. 0. 0. 0.) 11,7(400. 0. 0. 0.) 11,8(400. 0. 0. 0.)
  11,20(100. 0. 0. 0.) 12,8(400. 0. 0. 0.) 12,19(400. 0. 0. 0.) 12,20(100. 0. 0. 0.)
  13,7(400. 0. 0. 0.) 13,8(100. 0. 0. 0.) 13,9(400. 0. 0. 0.) 13,20(100. 0. 0. 0.)
  14,8(100. 0. 0. 0.) 15,8(100. 0. 0. 0.) 16,8(100. 0. 0. 0.) 17,8(100. 0. 0. 0.)
  18,8(100. 0. 0. 0.) 19,8(100. 0. 0. 0.) 20,8(100. 0. 0. 0.)
DEFINE CLERICAL 4: NUMBER RELOCJ RELOCJ RECNUMB* 2: EDUCATON = 11.
  INCOME = 6000.
  PUT CLERICAL 5,7(1000. 0. 0. 0.) 6,4(400. 0. 0. 0.) 5,8(400. 0. 0. 0.) 6,7(400. 0. 0. 0.)
  7,1(400. 0. 0. 0.) 7,2(400. 0. 0. 0.) 7,3(400. 0. 0. 0.) 7,14(400. 0. 0. 0.)
  7,15(800. 0. 0. 0.) 11,7(3400. 0. 0. 0.) 11,8(3400. 0. 0. 0.) 11,9(3400. 0. 0. 0.)
  12,7(3400. 0. 0. 0.) 12,8(3400. 0. 0. 0.) 12,9(3400. 0. 0. 0.) 12,19(3400. 0. 0. 0.)
  13,19(3400. 0. 0. 0.) 13,7(3400. 0. 0. 0.) 13,9(3400. 0. 0. 0.) 13,20(800. 0. 0. 0.)
  14,8(800. 0. 0. 0.) 15,8(800. 0. 0. 0.) 16,8(800. 0. 0. 0.) 17,8(800. 0. 0. 0.)
  18,8(800. 0. 0. 0.) 19,8(800. 0. 0. 0.) 20,8(800. 0. 0. 0.)
DEFINE BLUECOAR 4: NUMBER RELOCJ RELOCJ RECNUMB* 2: EDUCATON = 8.
  INCOME = 8000.
  PUT BLUECOAR 5,7(1000. 0. 0. 0.) 6,4(1000. 0. 0. 0.) 5,8(1000. 0. 0. 0.) 6,7(1000. 0. 0. 0.)
  7,1(1000. 0. 0. 0.) 7,2(1000. 0. 0. 0.) 7,3(1000. 0. 0. 0.) 7,14(50. 0. 0. 0.)
  7,15(50. 0. 0. 0.) 11,7(200. 0. 0. 0.) 11,8(50. 0. 0. 0.) 11,9(200. 0. 0. 0.)
  12,7(200. 0. 0. 0.) 12,19(200. 0. 0. 0.) 12,20(50. 0. 0. 0.) 13,7(200. 0. 0. 0.)
  13,19(50. 0. 0. 0.) 13,8(50. 0. 0. 0.) 13,9(200. 0. 0. 0.) 14,8(50. 0. 0. 0.)
  15,8(50. 0. 0. 0.) 16,8(50. 0. 0. 0.) 17,8(50. 0. 0. 0.) 18,8(50. 0. 0. 0.)
  19,8(50. 0. 0. 0.) 20,8(50. 0. 0. 0.)
CHAPTER V: SIMULATION

0. 0.)
DEFINE INDUSTRY 1: EMPLOYES*
PUT INDUSTRY 5,7(1500.) 5,8(1500.) 6,4(1500.) 6,5(1500.)
6,6(1500.) 6,7(1500.) 7,1(1500.) 7,2(1500.) 7,3(1500.)
DEFINE OFFICE 1: EMPLOYES*
PUT OFFICE 7,14(950.) 7,15(950.) 11,7(4000.) 11,8(950.)
11,9(4000.) 11,20(950.) 12,7(4000.) 12,8(4000.) 12,9(4000.)
12,19(4000.) 12,20(950.) 13,7(4000.) 13,8(950.) 13,9(4000.) 13,20(950.)
14,8(950.) 15,8(950.) 16,8(950.) 17,8(950.) 18,8(950.) 19,8(950.)
20,8(950.)
DEFINE RECREATION 3: CLERICAL MANGERAL BLUCOLAR*
PUT RECREATION 2,12(0. 0. 0.) 3,11(0. 0. 0.) 3,12(0. 0. 0.)
3,13(0. 0. 0.) 17,12(0. 0. 0.) 17,13(0. 0. 0.) 17,14(0. 0. 0.)
17,15(0. 0. 0.) 17,16(0. 0. 0.) 17,17(0. 0. 0.) 17,18(0. 0. 0.)
0. 0.) 17,19(0. 0. 0.) 17,20(0. 0.) 18,12(0. 0. 0.) 19,12(0. 0. 0.)
20,12(0. 0. 0.)
GRIDSIZE = 200.
RD LNEAREST P
READ_CONSOLE

RECUSE P

SAY THIS FILE COMPUTES HOW MANY PEOPLE WILL USE RECREATION
SAY AS A FUNCTION OF DISTANCE FROM PLACE OF EMPLOYMENT.
SAY IT IS CALLED BY SAYING "RD RCUSE P (ARG1 ARG2
SAY ARG3 ARG4 ARG5)" WHERE ARG1 IS THE TYPE OF PEOPLE
SAY EMPLOYED, EG. "CLERICAL", ARG2 AND ARG3 ARE
SAY TWO DISTANCES AWAY FROM PLACES OF EMPLOYMENT,
SAY AND ARG4 AND ARG5 ARE THE PERCENTAGES OF EMPLOYEES (OF
SAY TYPE ARG1) WHO WOULD USE THE RECREATION IF IT
SAY FELL IN THE ZONES DELIMITED BY ARG2 AND ARG3.
SAY EG. "RD RCUSE P (CLERICAL 400. 1000. 0.3 0.1)"
SAY WOULD MEAN THAT IF THE RECREATION
SAY WAS 500 FEET AWAY 10 PERCENT OF THE
SAY CLERICAL EMPLOYEES AT THAT LOCATION WOULD USE IT,
SAY OR IF THE RECREATION WAS 300 FEET AWAY 30 PERCENT
SAY WOULD USE IT.
READ_CONSOLE

RECUSE P

TLIST **= NULL
FOR I=, J= EACH LOC ON RECREATION ' 
RECREATION(ARG1 I,J) = 0.
Z = ARG3/GRIDSIZE
THROUGH RE1 FOR I=, J= EACH LOC ON ARG1
BLOCK Z TLIST(I,J) *
TLIST **= TLIST .AND. RECREATION
EX NEAREST (I J TLIST)
IF MINDIST .GRT. ARG3 GOTO RE1
IF MINDIST .GRT. ARG2 GOTO RE4
PCT = ARG4 * ARG1(NUMBER I,J)
GOTO RE5
RE4$ PCT = ARG5 * ARG1(NUMBER I,J)
RE5$ ARG1(RECNUMB I,J) = PCT
RECREATION(ARG1 BESTI,BESTJ) = RECREATION(ARG1 ' 
BESTI,BESTJ) + PCT
ARG1(RECLCI I,J) = BESTI
ARG1(RELCOC J I,J) = BESTJ
RE1$ CONTINUE
EXPAND +USE OF RECREATIONAL FACILITIES BY $2ARG1 EMPLOYEES+
EXPAND + HAS BEEN COMPUTED/+ READ_CONSOLE

INEAREST P

SAY THIS FILE IS CALLED BY "RECUSE P" TO COMPUTE
SAY THE NEAREST LOCATION WHICH CONTAINS ATTRIBUTE "ARG3"
SAY TO THE LOCATION IN QUESTION, "ARG1 ARG2" WHERE "ARG1"
SAY IS THE ROW NUMBER AND "ARG2" IS THE
SAY COLUMN. THIS FILE CAN ALSO BE USED BY THE DESIGNER IN ORDER,
SAY FOR EXAMPLE, TO DETERMINE THE NEAREST "INDUSTRY"
SAY TO SOME LOCATION, EG. 12,18, CONTAINING "OFFICE".
SAY THAT COMMAND WOULD BE "EX NEAREST (12 18 INDUSTRY)".
SAY THIS FILE GENERATES VALUES FOR THREE VARIABLES:
SAY MINDIST, BESTI, AND BESTJ WHICH ARE, RESPECTIVELY,
SAY THE DISTANCE AWAY OF THE NEAREST MEMBER OF ARG3, AND
SAY THE I AND J COORDINATES OF THAT MEMBER.
READ_CONSOLE

NEAREST P

BEGIN_MACRO NEAREST
MINDIST = 999999.
THROUGH NE2 FOR II=, JJ= EACH LOC ON ARG3
SUM1 = ARG1 - II .POWER. 2.
DIST = ARG2 - JJ .POWER. 2. + SUM1 .POWER. 0.5
IF DIST .GRT. MINDIST GOTO NE2
MINDIST = DIST
BESTI = II
BESTJ = JJ
NE2$ CONTINUE
MINDIST = MINDIST * GRIDSIZE
RETURN
END_MACRO
READ_CONSOLE
CHAPTER V: SIMULATION

1PWHERE P

SAY THIS FILE IS USED WITH THE DATAFILE "RECREAT P"
SAY AND AFTER CALLING "RECUSE P". IT COMPUTES
SAY HOW MANY ARG1 EMPLOYEES ARE USING THE
SAY RECREATIONAL FACILITIES AND AT WHICH LOCATIONS.
SAY ARG1 IS THE TYPE OF PEOPLE EMPLOYED, EG. "MANAGERIAL".
SAY IT IS CALLED BY SAYING "RD PWHERE P ARG1".
READ_CONSOLE

PWHERE P

TABSET 10 40
EXPAND +.NUMBER OF $2ARG1.RECREATIONAL/+ EXPAND +.EMPLOYEES USING.FACILITIES AT/+ THROUGH PW1 FOR I=, J= EACH LOC ON RECREATION IF RECREATION (ARG1 I,J) .EQL. 0. GOTO PW1 EXPAND +.$1RECREATION(ARG1 I,J).$31,$3J/+ PW1$ CONTINUE
READ_CONSOLE

1RWHERE P

SAY THIS FILE IS USED WITH THE DATAFILE "RECREAT P", SAY AND AFTER CALLING "RECUSE P".
SAY IT COMPUTES HOW MANY "ARG1" ARE USING RECREATION SAY AT "ARG2, ARG3" WHERE "ARG1" IS THE TYPE OF PEOPLE SAY EMPLOYED, EG. "CLERICAL", AND "ARG2" AND "ARG3" ARE SAY THE COORDINATES OF THE LOCATION OF THE RECREATION.
SAY IT IS CALLED BY SAYING "RD RWHERE P (ARG1 ARG2 ARG3)".
READ_CONSOLE

RWHERE P

TABSET 30
Q = 0.
EXPAND +$2ARG1 ** EMPLOYEES FROM THE FOLLOWING LOCATIONS/+ EXPAND +USE THE RECREATION AT LOCATION $3ARG2,$3ARG3/+ THROUGH WH1 FOR I=, J= EACH LOC ON ARG1 IF ARG1(RECLOC1 I,J) .EQL. ARG2 IF ARG1(RECLOCJ I,J) .EQL. ARG3 ' GOTO WH2 GOTO WH1 WH2$ CONTINUE Q = Q + ARG1(RECNUMB I,J) EXPAND +FROM $31*,$3J.$1ARG1(RECNUMB I,J)/+ WH1$ CONTINUE EXPAND +TOTAL AT $3ARG2,$3ARG3.$1Q/+ READ_CONSOLE
IMAP P

SAY THIS FILE MAPS THE SUBSET OF ALL RECREATION LOCATIONS SAY IN WHICH MORE THAN "ARG1" EMPLOYEES USE THE RECREATIONAL SAY FACILITIES. IT MAPS THE LOCATIONS OF EMPLOYMENT WHERE SAY THE USER CAME FROM, AND IT REFERENCES THESE AGAINST ALL SAY EMPLOYMENT AND RECREATION PLACES. IT IS CALLED BY SAY SAYING "MAP P (ARG1)" WHERE ARG1 IS A CONSTANT.

READ_CONSOLE

MAP P

SUBSTITUTION ON
TLIST1 *** NULL
TLIST2 *** NULL
THROUGH MA1 FOR I=, J= EACH LOC ON RECREATION
SUM = 0.
FOR Q = 1. STEP 1. UNTIL 3. SUM = SUM + RECREATION(Q I,J)
IF SUM .GRT. ARG1 PUT TLIST1 I,J
MA1$ CONTINUE
THROUGH MA2 FOR R=2. STEP 1. UNTIL 4.
THROUGH MA3 FOR I=, J= EACH LOC ON R
F = R(RECLOC1 I,J)
G = R(RECLOCJ I,J)
IF R(RECNUMB I,J) .GRT. 0. IF TLIST1(F,G) PUT TLIST2 I,J
MA3$ CONTINUE
MA2$ CONTINUE
ALLWORK *** OFFICE .OR. INDUSTRY
ALLREC *** RECREATION
SUBREC *** TLIST1
SUBWORK *** TLIST2
MAP (SUBREC SUBWORK; ALLREC ALLWORK) 1-20 1-20
READ_CONSOLE
CHAPTER VI
FUTURE DEVELOPMENT OF DISCOURSE

As it stands right now, DISCOURSE offers the user a data structure which can be easily interpreted as a geographic grid of LOCATIONS with properties (or ATTRIBUTES) attached to the LOCATIONS and numbers attached to the ATTRIBUTES, (for example, 400 residents at location i,j).

An ATTRIBUTE, ("residents" in this example), is the name of a list of LOCATIONS which are described by it. ATTRIBUTES can have numerical or nominal values associated with them of two types: those which vary with different LOCATIONS and those which remain constant regardless of LOCATION. The system also accommodates temporary variables which can have numeric and alphanumeric values. All elements have both names and values.

There are three dictionaries: LOCATIONS, ATTRIBUTES and temporary variables. Any datum in the system can and must be accessed through these dictionaries by means of the name of the element in which the datum resides.

Reflecting the designer's need to add new data and modify the existing data, DISCOURSE has a full range of commands for this purpose, and for storing the different "states" of the data at any time. Reflecting his need to manipulate data ad hoc and to manipulate according to rules all of the elements of the description, DISCOURSE contains logical, relational,
and arithmetic operators as well as a full range of control statements including branching, conditional and iteration (looping) statements. The last mentioned are of two types reflecting the list and array structures: one which looks successively at each member of ATTRIBUTE lists and the other which increments the values of a variable and which can be used to examine specific parts of an array.

In addition to its "show" and "map" requests which produce tabular and map-like displays for the designer, DISCOURSE features a flexible output facility called "EXPAND" which resembles a combination of FORTRAN's "WRITE" and "FORMAT" statements. The EXPAND statement permits the designer to specify the way he wants information displayed. (see figure (4.16), page 103) EXPAND, also, is the first step in the direction of putting information contained in DISCOURSE in such a form that it can be used as input by other systems.

And, finally, reflecting the designer's need to create a language for himself simpler than the basic requests of DISCOURSE, but exactly as he, the designer, chooses it to be, DISCOURSE contains facilities for writing subroutines (RCOM files) using the basic requests of the language.

In the first version of DISCOURSE, for example, the command "center" executed a particular algorithm, implemented in a language invisible to the user, which found the "center of gravity" of a geographically distributed set of elements. In DISCOURSE II it is possible to write and name one's own
"center" algorithm. It can then be used as part of the language, like the writing of subroutine subprograms in FORTRAN. A similar increase in the richness of facilities available to the system user has occurred in the other aspects of the system, including more and more of the features of a general purpose computer language. This line of development has increased the possible richness of usage; it has been required because the users have consistently demanded that more features be accessible to their use. But, despite this increase of complexity, the language remains possible to use for some purposes without having to "program" in the language.

The language of DISCOURSE has changed from being somewhat specific to its initial uses to being much more general but still allowing the individual user to develop his own specific style. Any language forces the user into a way of using it which may not be best for what he is doing; a richer language may be difficult to use, but in it the user may achieve subtlety of expression; an awkward language may prevent self expression altogether.

Much of the time using DISCOURSE is spent building RCOM files, that is, building a higher level language which is more specific to the design problem than the basic requests and which is more specific to what the designer wants to do at the moment. The dilemma posed by the apparent conflict between two of the goals for the development of the language - richness of the language permitting subtle expression and simplicity of
the language permitting ease of usage - may be resolved in the future through the development of problem oriented features for the system; and by developing prototypes of the use of the system.

1. PROBLEM ORIENTED FEATURES

Problem oriented features are ready made techniques or functions which the designer can use in connection with his work, techniques requiring a minimum of alteration to suit his particular needs. Although the experience of usage of the system to-date is limited (6.01) there seem to be RCOM files built by several users which are sufficiently similar that they or elements of them could have been provided in the basic language. The result would have been increased ease of use without loss of subtlety of expression. The problem oriented features will range from those which have a clear reference to particular types of problems to those which do not.

Examples of one end of the range might be a "land use intensity ratio" function or a "density of persons residing per square foot of residential construction." Although many of these are easy to write in the language as it is, their presence ready made in the list of features available to the user would help him to begin to use the system, might be useful to him during the course of his designing, and would serve as models for his own making of techniques better suited to his own needs. Examples at the other end of the range are: a function which computes the equivalence of two lists of
LOCATIONS which share common ATTRIBUTES, weighting functions, an average distance function, and many others which, although they can be written in the language, the writing of them does not yield any fruits of insight to the designer with respect to his design problem. On the other hand, the "compactness" of a pattern or the "mix" of two activities might well be implemented in a variety of different ways, and would stand for many different designer-defined functions. The tactics for developing "problem oriented features" will be:

**Design Problems**: looking at the specific kinds of considerations which come up in connection with design problems, for example, the kinds of accounting procedures associated with design for very dense urban areas: floor area ratios, parking ratios and so on.

**Design Functions**: looking at the functions used over and over again by designers in connection with their using the system. As can be seen in the examples in Chapters IV and V, the geometric requests have had to be written by the designers. Many of these, like "average distance," or "nearest of several" could be written in generalized form which would have served in every situation. Some implemented already in DISCOURSE as RCOM files should probably be included as basic commands in the language; others of less general applicability will probably be left in the DISCOURSE language with instructions for use.

**Data Structure**: looking at the data structure as it
presently stands and determining whether there are more types of manipulations which could easily be written on it. Reviewing the data structure briefly, it features: a two dimensional array (the GRID) which can have members (ATTXLOCS) of lists (ATTRIBUTES) associated with LOCATIONS in the GRID; the ATTRIBUTES and the ATTXLOCS can have values associated (CHARCONS and CHARVARS) which can as well be treated like vectors; and temporary variables. Each of these features can be examined to see if it can be manipulated, if it can be compared with other features easily and if the results can be made available for immediate or later use. Examples are the comparison of lists, rank ordering of lists according to values contained in CHARVARS, comparison of vectors and list to array comparisons. Many other examples can be created from different combinations of these features. Each example would then be looked at for possible empirical interpretations and for its usefulness to the designer.

Techniques to Borrow: looking at techniques which have been useful in other fields and surveying the kinds of design problems to which the techniques may be applied. Obvious candidates are mathematical optimization techniques, and matrix construction and manipulation. Some of these latter techniques exist already in CHOICE (6.02), a system to help the designer in the evaluation of several design alternatives. Many of the techniques may require data structures and manipulations facilities other than those which exist at
present in DISCOURSE. The issue of whether new facilities should be built into DISCOURSE or the data from DISCOURSE taken out, processed in some other system and returned is one which will have to be resolved on an individual basis and will depend on factors pertaining to the particular implementation of the computer system such as programming time and free storage available in the central processing unit for other programs.

**Interface:** finding ways to interface with data from other sources, for example, the census or from various kinds of surveys: characterizing each of the sources identified, in terms of its data and how they are at least conventionally used; and developing techniques, programs and, where needed, utilizing other computer hardware which will help to ease the burden of entering large quantities of data into the system. Small quantities of data are easy to get into the system: witness the several examples in Chapters IV and V.

II. USE PROTOTYPES

The second type of difficulty inhibiting the use of the system to-date has stemmed neither from its design nor its implementation but from a lack of well explained examples of its use, examples which strongly suggest whole classes of uses. Such "use prototypes" should help the designer both to think about his design problem and to implement in DISCOURSE the parts he thinks about. These "use prototypes" will probably result from two approaches: from the use of DISCOURSE
by city designers in the field working in agencies and for private firms; and from continuing efforts to analyse the process of design.

The functional analysis of city design in Chapter III is intended to be a first step toward building a library of use prototypes. The library will probably contain some prototypes which are close to the functional types of "description," "transformation" and "testing"; and others which describe patterns of work by the designer during the course of design. Subcategories within each type will probably be developed from different empirical applications. Many of the first type have been used for illustrations in Chapter III. What remains is to implement them on the system, improving them and adding to them where necessary. Some of the second type should be developed in the context of a design project and will probably result in a range of techniques used to address a particular problem which was being faced at the time; and others of the second type should be developed in the context of trying to explore some specific idea like "adaptability" (6.03)

III. GRAPHICS AND MODES OF REPRESENTATION

The most needed improvement in the system is a richer variety of displays and for displays which can be easily changed by means of a graphic input device. At the present time the designer has to carry the latest changes to the description in his head, update a map independent of the system, or wait from time to time for the console to type out
CHAPTER VI: DEVELOPMENT

the latest map. With the recently purchased ARDS (6.04) display cathode ray tubes it will be possible to create a continuous display of selected ATTRIBUTES of the description. This feature should help to portray "growth" and "change" of the environment over time, activity patterns as well as sequences through the environment, achieving some of the effects of true "dynamic" display (6.05).

Additional features which are readily programmed on the ARDS and which represent a major improvement over present input and output are: first, the "pointing" feature which will permit the designer to direct his interrogation of the display and to introduce data manually. He can point at, for example, LOCATIONS, areas, ATTRIBUTES, and names listed along side the map display which may refer to any element or to specified functions; second, the maps may be shifted in scale, for example, to enlarge the grid so that numerical data can readily be displayed; third, outline and tone maps can be made available as well as the present map of symbols. These and related features are either under development at present or will be in the very near future. A second kind of display which will be developed when the hardware has been identified is hard copy display from a printer, plotter and or by photography so that the designer can have a permanent record of his work.

Other features which may help through their availability in the system to stimulate the development of graphics are:
CHAPTER VI: DEVELOPMENT

the various symmetrical transformations: mirror, inversion, rotation, translation, change of scale and the combinations and permutations of those with respect to two and three dimensional forms in two dimensional projection; and plan to section to perspective viewing along with a symbolic language which will make evident to the designer that he is looking at the same form in the different views.

Not so clear, however, is the development of support for the less easily described activities of the designer. Some of the time spent designing is spent working with pencil on paper making sketches, the majority of which are in plan view, but some of which may be in section or perspective, and others of which may diagram relations which have little or no direct spatial analogue.

A sketch consists of elements, sometimes finely graded one into the other, but a group of elements the members of which can generally be distinguished one from the other. The elements are positioned in two dimensions or in three, as in a rough model. And, with the introduction of a range of variation in the same type of element, often done through variations in the intensity of color, tone, or strength of line, a still further richness of the representation can be achieved.

**Metric and Non-metric Representations**

These elements are represented in a spatial framework which, in the case of city designers, is usually metric or
non-metric. Each of these types of spaces has its own set of rules. In metric space, distance is interpreted as the linear (straight line) distance between points as measured by some ruler; when non-metric space is represented by a graph distance is measured by the number of nodes away one node is from the other. In metric space, if the unit of distance refers to a unit of distance on the land, the representation can be mapped point for point onto the land.

If the representation is in a particular kind of metric space, for example euclidean space, then all the axioms of euclidean geometry become applicable. (6.06) If the representation is in non-metric space as represented by a graph, then all of the axioms of graph theory become applicable.

An organization chart is usually better in non-metric space than metric space, though the latter would be possible. Even so, some positional importance is usually ascribed to the chart making it a mixture of the two types of representations: top is up organizationally; sideways is indifferent to rank in the organization, though often those in the center of the chart at the same level are more important because it is often easier to draw the boxes with more connections to them in the center.

In the metric representation, the possibilities for fit of the spaces represented into a three dimensional building form is more evident; in the non-metric representation, the
centrality of some officer in an organization's decision making may be more evident than in metric space, particularly if the network of communication is very rich.

If the designer assigns a meaning in some realm of thought to the elements and to the relations of some mode of representation then conclusions he may draw from valid inferences in the representation are true for the realm he has been referring to. For example, if he assigns positions in an organization to the nodes of a graph and the possibility of sending a message to the links, then for the president to receive a message from the treasurer, it must first pass through the vice president; but the president can send a message directly to the treasurer. The further interpretation of the diagram can be made that the president has more "power" and the vice president more information if the appropriate assumptions about the directional component of the arrow have been made.

Likewise in a metric representation aspects of reality may be associated with the rules which govern the representation: for example, greater proximity may be associated with greater likelihood of communication between two groups in the population.

Distortion of Metric Representation

Change in the function mapping the metric representation to a geographic region will result when distance in the metric representation refers to time or, perhaps, time and a mode of
CHAPTER VI: DEVELOPMENT

transportation rather than to geographic distance alone. A designer might like to know who was within five minutes walking distance of a certain group; and who was within five minutes driving distance of the same group. He might then wish to represent in metric space the proximities so derived. The resulting map would look very different from the map of distance alone. Although the representation would be metric, geography would be distorted. Distortion of geography may be very informative to the designer in that it might reveal relationships which were not previously obvious.

Mixed Representations

Graphs can be used to represent road networks and, for some purposes, in that application, need to have a geographic reference. The designer needs to be able to associate names and values with each of the elements of the network: its nodes, its links, and its faces; and he needs to be able to move along links toward nodes, find his way through the network by the shortest or the longest path. He also will want to see what is on or adjacent to any of its elements. The last requirement probably means that the network will have to be overlayed onto the geographic grid. The first requirements imply a data structure somewhat different from that employed so far in DISCOURSE II. If a data structure were added to handle networks easily than it might also be used for graphical analysis. If networks are used for graphical analysis it is important to have flexibility in
 CHAPTER VI: DEVELOPMENT

attaching meanings to the elements, for a network can represent a communications system, a diagram of power relations, a family structure, or a logical proposition. Each interpretation should be possible to make explicitly in the system just as it is now possible to make such explicit interpretations of the data in DISCOURSE.

Three general principles for the development any mode of representation seem to emerge from the experience of building DISCOURSE: first, that a full range of manipulations is needed which is proper to that mode.

With respect to a grid of LOCATIONS, the major categories of manipulations seem to be: existence at, proximity, adjacency, and orientation functions. With respect to a network: existence at, direction, connection, and proximity functions and all other manipulations based on matrices.

(6.07)

The second principle is in three parts: first, that each distinguishable element of the mode selected have the possibility of being named, and having values associated with that name which are specific at the named elements, and having values which are true of all similarly named elements (analogous to the ATTRIBUTE, CHARVAR, and CHARCON respectively); second, that all names and values be manipulable: ie., that the parallel set of operators (logical, relational, and arithmetic) which exist now in DISCOURSE be usable in the new mode; and third, that each
element should be individually named such that its name calls forth all the information associated with that particular element (analogous to the LOCATION and its name, its coordinates).

A third principle, even more tentatively advanced, is that translation and communication between modes should be made possible and that the rules for such translation and, possibly, communication, be accessible to the user. "Communication," here, means laying one representation onto another such that the information contained in one can be obtained from the other. For example, if a network is overlaid onto a geographic grid, then the LOCATIONS on that grid across which one of the links passes will be associated to that link such that when the link is queried for what falls "along" it, the information stored at those geographic LOCATIONS will be available. And, by "translation" is meant the possibility of passing from, for example, a network representation to a matrix representation of the same material.

IV. DESCRIPTION OF THE ENVIRONMENT

The present system seems to require constant reference to LOCATIONS by their two coordinates, and the use of LOCATIONS as the objects of the description to which qualities or properties are attributed. The first characteristic may inhibit the use of the because of its lack of fit with designers' traditional modes of working; and the second may
CHAPTER VI: DEVELOPMENT

inhibit subtlety of description.

When a designer speaks of "places" he is usually speaking of ATTRIBUTE and LOCATION combinations, not the LOCATIONS alone. For example one speaks of Harvard Square, or Mt. Auburn Street but not of the latitude and longitude which would be necessary if one were to pinpoint the place in a geographic sense. Harvard Square is the label for a geographic region. Its limits or its center, whichever is used as the symbol of the whole, may be defined more by the activities and the people present than by the geography. The designer seldom if ever has to use a coordinate scheme. He can usually describe a place from points of common knowledge using measures of proximity, or he can "show" somebody a map which enables the other person to understand "where" it is. Some coordinate system is necessary if geographic functions are to be completely described. However, this statement does not imply that the coordinate scheme need be prominent in the language which the designer uses.

Ways of making the coordinate system less prominent include developing graphic input procedures to eliminate much of the burden of typing data in according to coordinates, and developing new techniques for describing the environment which rely less on coordinates, but instead rely upon the names of places. To illustrate this possibility see the example in figures (6.01) and (6.02).

Required is a special category of ATTRIBUTES which can be
thought of as objects of the description, so that when the designer asks "where are specialty shops?" the answers are "Harvard Square" and "Mt. Auburn Street," not "location 3,4 4,5." Other operations need to be thought through in the same way and can probably also be simulated on the present system.

It is probably not only LOCATIONS to which designers give name and sense. The transparency of the DISCOURSE data structure clouds somewhat when one has to ascribe facilities and activities to LOCATIONS as ATTRIBUTES of those LOCATIONS. It should be possible to more richly describe a physical world to which we then ascribe meaning. In DISCOURSE a building type is an ATTRIBUTE of a LOCATION; the activity in that building must also be an ATTRIBUTE of the LOCATION. Instead it should be an ATTRIBUTE of the building. There should be other objects of the description which have the same status in the language as the present LOCATIONS.

One possible solution is to create new objects of the description capable of having ATTRIBUTES assigned, like ACTIVITIES and FACILITIES; the existence of an ATTRIBUTE at these objects might be ATTXACT and ATTXFAC, corresponding to the existing ATTXLOCS. And these would have to be ways of associating LOCATIONS ACTIVITIES and FACILITIES in relation to how the designer wanted the environment described. A way of thinking about this possibility is to use some of LOCATIONS for purposes which are non geographic and not consistent with the rest of the representation which would be geographic, for
Again, to illustrate the idea but not to prove its worth, the activity unit, a family named "Smith," might be equivalent to a LOCATION called "i,j." "Middle income residents," or "father" might be two of the ATTRIBUTES of "Smith." "Father" could have several CHARVARS: "age," "income," and "work location," all specific to that particular family. The "Smith" family's place of residence, and the use of recreational facilities and shopping habits of each of its members could be specified and manipulated.

Summary of Future Development Plans

The test of the DISCOURSE language is its capacity to accommodate what the city designer does. The data structure and manipulations of DISCOURSE - its basic features - have been developed to the point where they can accommodate many aspects of the city designers' work, but there may be many more, some of which may not be accommodated in the language as it stands. The discovery of these can be greatly hastened by having the system used by many designers in addition to those who have been most involved in its development to-date. Improvements of the present system are needed, therefore, to increase its ease of usage. These improvements include adding a wide variety of displays, adding functions which can be written on the DISCOURSE data structure which increase its convenience of usage, and developing clear instructions for and examples of the use of the system.

There are, however, two major difficulties of the language which are presently evident and which challenge its basic features: it is hard to accommodate the designer's activity of "sketching;" and it is hard to describe "objects," "facilities," or "activities" as distinguished from "LOCATIONS." These difficulties may be resolved by introducing new modes of representation and new objects of the description. Such changes may point toward the next stage of development of DISCOURSE.
IF DESIGN SYSTEM CRASHES GIVE THE DEBUG COMMAND:
    DUMP NAME 12000 3D000

R 0.03/0.03
comment That loaded the DISCOURSE system into core.
R 0.01/0.04
ready off
comment That turned off the time message.
rd attsdata p
comment That read in the data file.
lst attributes

ATTR 0 -- NULL
ATTR 1 -- UNIVERSE
ATTR 2 -- HARVSQ
ATTR 3 -- MTAUBURN
ATTR 4 -- A
ATTR 5 -- B
ATTR 6 -- MASSAVE
ATTR 7 -- C
ATTR 8 -- D
ATTR 9 -- E
ATTR 10 -- F
ATTR 11 -- FAKENAME
ATTR 12 -- SPESHOPS
ATTR 13 -- BRICKFES

comment ATTRIBUTES 2-10 are place names.
rd ltryatts p
comment That read in the "macro"; now it's ready to use.
ex whereare (speshops)
SPESHOPS EXIST AT HARVSQ
    MTAUBURN
ex whereare (brickfactories)
BRICKFES DO NOT EXIST AT THE NAMED PLACES
foodstores ** harvsq .or. mtauburn .or. massave
ex whereare (foodstores)
FOODSTES EXIST AT HARVSQ
    MTAUBURN
    MASSAVE

Figure (6.01) PLACES IDENTIFIED BY NAMES NOT COORDINATES
printf Itryatts p

COMMENT THE REASON THIS WAS SET UP AS A "MACRO"
COMMENT WAS SO THAT IT COULD BE CALLED WITH A SINGLE NAME
COMMENT AND SO THAT IT COULD BE CALLED FROM OTHER RCOM FILES.
BEGIN_MACRO WHEREARE
COMMENT THIS SETS TABS TO POSITION THE PRINTED OUTPUT.
TABSET 20
COMMENT THIS ALLOWS ME TO SUBSTITUTE ATTRIBUTE NUMBERS
COMMENT FOR THEIR NAMES.
SUBSTITUTION ON
COMMENT Q HELPS ME TO KNOW WHERE I'VE BEEN IN THE PROGRAM.
Q = 0.
COMMENT THIS GOES THROUGH THE ATTRIBUTES WHICH ARE PLACE NAMES.
THROUGH WH1 FOR I = 2. STEP 1. UNTIL 10.
COMMENT THIS INTERSECTS "ARG1", THE ATTRIBUTE I AM ASKING ABOUT
COMMENT WITH EACH OF THE PLACE NAMES.
TLIST *** ARG1 .AND. 1
COMMENT IF THE INTERSECTION DOES NOT EXIST THEN IT BRANCHES.
IF TLIST .EQL. 0. GOTO WH1
COMMENT IF "ARG1" HAS BEEN FOUND TO EXIST AT SOME PLACE THEN
COMMENT THE PROGRAM SKIPS THE NEXT THREE LINES.
IF Q .EQL. 1. GOTO WH2
COMMENT THIS IS THE FIRST TYPED LINE IF "ARG1" IS ANY PLACE.
EXPAND +$2ARG1 EXIST AT $2FAKENAME(1)+
Q = 1.
GOTO WH1
WH2$ CONTINUE
EXPAND +***$2FAKENAME(1)/+
WH1$ CONTINUE
COMMENT IF THE PROGRAM HAS GONE THROUGH ALL THE PLACE NAMES
COMMENT AND "ARG1" DOES EXIST AT ANY OF THEM THE PROGRAM SKIPS
COMMENT THE FOLLOWING LINE.
IF Q .EQL. 1. GOTO WH3
EXPAND +$2ARG1 DO NOT EXIST AT THE NAMED PLACES/+ 
WH3$ SUBSTITUTION OFF
RETURN
END_MACRO
READ_CONSOLE

R; T=0.06/0.84 13.34.27
APPENDIX

DOCUMENTATION OF AN EXPERIMENT IN THE REPlication OF A DESIGN

This Appendix contains some of the evidence of the work on the replication of the design for Ciudad Guayana. The "First" pattern which is referred to in the illustrations is the pattern exhibited in Chapter II. The "Second" pattern was generated later with a single change in the data: the channel was moved from location 4,12 to location 4,11. The reason for the change was that if the channel were in 4,12, then 5,13 was "beside" it according to the decision rules whereas in fact location 5,13 is not near the channel.

This adjacency was unintended by the author and it was, therefore, changed in order to improve the "accuracy" of the data. The change, given the same assignment orderings and decision rules, was enormous. Urbanization in the "Second" pattern stayed almost entirely on the eastern side of the river, much more like Ciudad Guayana 1969 (p 152) than the design. In the "First" pattern, "industry" had been assigned first to 5,13. If the single change in the data caused the difference in the generated pattern, (further examination may reveal other reasons) then it shows the importance of initial judgments of the designers in describing the environments they will design.

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Ciudad Guayana Data File 183-184
LEGEND:

PRIMARY ATTRIBUTE ASSIGNMENTS — — '1' = URB1961(20); '2' = IND1961(21)

'.' = NON EMPTY LAND

REFERENCE ATTRIBUTE ASSIGNMENTS — — '*' = RIVER(8); '-' = CHANNEL(12); '*' = CHANNEL & RIVER; ' ' = NO REF ATTS

CIUDAD GUAYANA -- 1961
SHOWING URBANIZATION AND INDUSTRY
LEGEND:

PRIMARY ATTRIBUTE ASSIGNMENTS — '1' = URB1969(13); '2' = IND1969(14)
'. ' = NON EMPTY LAND

REFERENCE ATTRIBUTE ASSIGNMENTS — '+' = RIVER(8); '-' = CHANNEL(12); '* ' = CHANNEL & RIVER; ' ' = NO REF ATTS

CIUDAD GUAYANA -- 1969
SHOWING URBANIZATION AND INDUSTRY
APPENDIX

LEGEND:

PRIMARY ATTRIBUTE ASSIGNMENTS - - '1' = UDESIGN(3); '2' = IDESIGN(2); '3' = CDESIGN(4)

'.' = NON EMPTY LAND

REFERENCE ATTRIBUTE ASSIGNMENTS - - '+' = RIVER(8); '-' = CHANNEL(12); '*' = CHANNEL & RIVER; ' ' = NO REF ATTS

DESIGN FOR CIUDAD GUAYANA
BY THE DESIGNERS OF THE DEVELOPMENT CORPORATION
SHOWING URBANIZATION, INDUSTRY AND CENTER
design2 p

IF DESIGN SYSTEM CRASHES GIVE THE DEBUG DUMP NAME 12000 3D000

R 0.02/0.02
rd dataguay p
R 0.78/0.80
rd macsguay p
rd assignu p
"URBANIZATION" HAS BEEN PLACED AT 3,17
DECISION PATH WAS U1 U2 U3 U4 U6

d@rd assignu p
"URBANIZATION" HAS BEEN PLACED AT 8,11
DECISION PATH WAS U1 U2 U3 U4 U7

assignu p
ERROR 1001
rd assignu p
"URBANIZATION" HAS BEEN PLACED AT 9,12
DECISION PATH WAS U1 U2 U3 U4 U6

rd assigni p
"INDUSTRY" HAS BEEN PLACED AT 5,13
DECISION PATH WAS 11 12 13 16 110

rd assign i p
"INDUSTRY" HAS BEEN PLACED AT 9,4
DECISION PATH WAS 11 12 13 16 110

rd assigni p
"INDUSTRY" HAS BEEN PLACED AT 8,5
DECISION PATH WAS 11 12 13 16 110

rd assignc p
"CENTER" HAS BEEN PLACED AT 8,11
DECISION PATH WAS C1 C2 C6 C7

rd assignu p
"URBANIZATION" HAS BEEN PLACED AT 7,9
DECISION PATH WAS U1 U2 U3 U4 U7

rd assignu p
"URBANIZATION" HAS BEEN PLACED AT 8,9
DECISION PATH WAS U1 U2 U3 U4 U7

rd assignu p
"URBANIZATION" HAS BEEN PLACED AT 9,9
DECISION PATH WAS U1 U2 U3 U4 U7

rd assigni p
"INDUSTRY" HAS BEEN PLACED AT 7,6
DECISION PATH WAS 11 12 13 16 110
"INDUSTRY" HAS BEEN PLACED AT 7,7
DECISION PATH WAS 11 12 13 16 110

"INDUSTRY" HAS BEEN PLACED AT 6,7
DECISION PATH WAS 11 12 13 16 110

"URBANIZATION" HAS BEEN PLACED AT 7,8
DECISION PATH WAS U1 U2 U3 U4 U7

"URBANIZATION" HAS BEEN PLACED AT 8,8
DECISION PATH WAS U1 U2 U3 U4 U7

"URBANIZATION" HAS BEEN PLACED AT 9,8
DECISION PATH WAS U1 U2 U3 U4 U7

"INDUSTRY" HAS BEEN PLACED AT 10,2
DECISION PATH WAS 11 12 13 16 110

"INDUSTRY" HAS BEEN PLACED AT 11,2
DECISION PATH WAS 11 12 13 16 110

"INDUSTRY" HAS BEEN PLACED AT 11,1
DECISION PATH WAS 11 12 13 16 110

"CENTER" HAS BEEN PLACED AT 9,12
DECISION PATH WAS C1 C2 C3 C5 C7

"URBANIZATION" HAS BEEN PLACED AT 8,7
DECISION PATH WAS U1 U2 U3 U4 U7

"URBANIZATION" HAS BEEN PLACED AT 9,7
DECISION PATH WAS U1 U2 U3 U4 U7

"URBANIZATION" HAS BEEN PLACED AT 10,8
DECISION PATH WAS U1 U2 U3 U4 U7

"INDUSTRY" HAS BEEN PLACED AT 4,15
DECISION PATH WAS 11 12 13 16 111
"INDUSTRY" HAS BEEN PLACED AT 2,17
DECISION PATH WAS 11 12 13 16 111

"INDUSTRY" HAS BEEN PLACED AT 2,13
DECISION PATH WAS 11 12 13 16 110

"URBANIZATION" HAS BEEN PLACED AT 11,7
DECISION PATH WAS U1 U2 U3 U4 U6

"URBANIZATION" HAS BEEN PLACED AT 12,6
DECISION PATH WAS U1 U2 U3 U4 U6

"URBANIZATION" HAS BEEN PLACED AT 10,7
DECISION PATH WAS U1 U2 U3 U4 U7

"INDUSTRY" HAS BEEN PLACED AT 10,5
DECISION PATH WAS 11 12 14 17 112

"INDUSTRY" HAS BEEN PLACED AT 10,6
DECISION PATH WAS 11 12 14 17 112

"INDUSTRY" HAS BEEN PLACED AT 11,6
DECISION PATH WAS 11 12 14 17 112

"CENTER" HAS BEEN PLACED AT 7,9
DECISION PATH WAS C1 C2 C6 C7

"URBANIZATION" HAS BEEN PLACED AT 11,5
DECISION PATH WAS U1 U2 U3 U4 U7

"URBANIZATION" HAS BEEN PLACED AT 12,5
DECISION PATH WAS U1 U2 U3 U4 U7

"URBANIZATION" HAS BEEN PLACED AT 12,4
DECISION PATH WAS U1 U2 U3 U4 U7

"INDUSTRY" HAS BEEN PLACED AT 12,3
DECISION PATH WAS 11 12 14 17 112

"INDUSTRY" HAS BEEN PLACED AT 13,4
DECISION PATH WAS 11 12 14 17 112
"INDUSTRY" HAS BEEN PLACED AT 13,5
DECISION PATH WAS 11 12 14 17 112

"URBANIZATION" HAS BEEN PLACED AT 13,3
DECISION PATH WAS U1 U2 U3 U4 U7

"URBANIZATION" HAS BEEN PLACED AT 12,2
DECISION PATH WAS U1 U2 U3 U4 U7

"URBANIZATION" HAS BEEN PLACED AT 14,4
DECISION PATH WAS U1 U2 U3 U4 U7

"INDUSTRY" HAS BEEN PLACED AT 14,5
DECISION PATH WAS 11 12 14 17 112

"INDUSTRY" HAS BEEN PLACED AT 13,2
DECISION PATH WAS 11 12 14 17 112

"INDUSTRY" HAS BEEN PLACED AT 14,3
DECISION PATH WAS 11 12 14 17 112

"CENTER" HAS BEEN PLACED AT 8,8
DECISION PATH WAS C1 C2 C3 C5 C7

"URBANIZATION" HAS BEEN PLACED AT 15,4
DECISION PATH WAS U1 U2 U3 U4 U7

"URBANIZATION" HAS BEEN PLACED AT 12,1
DECISION PATH WAS U1 U2 U3 U4 U7

"URBANIZATION" HAS BEEN PLACED AT 14,2
DECISION PATH WAS U1 U2 U3 U4 U7

"INDUSTRY" HAS BEEN PLACED AT 15,3
DECISION PATH WAS 11 12 14 17 112

"INDUSTRY" HAS BEEN PLACED AT 13,1
DECISION PATH WAS 11 12 14 17 112

"INDUSTRY" HAS BEEN PLACED AT 14,1
DECISION PATH WAS 11 12 14 17 112

store d2guay p
list center

CHARVAR 1 OF CENTER IS CALLED ORDER
CHARCON 1 OF CENTER IS CALLED C1
CHARCON 2 OF CENTER IS CALLED C2
CHARCON 3 OF CENTER IS CALLED C3
CHARCON 4 OF CENTER IS CALLED C4
CHARCON 5 OF CENTER IS CALLED C5
CHARCON 6 OF CENTER IS CALLED C6
CHARCON 7 OF CENTER IS CALLED C7
CHARCON 8 OF CENTER IS CALLED C8
CHARCON 9 OF CENTER IS CALLED C9
CHARCON 10 OF CENTER IS CALLED C10
CHARCON 11 OF CENTER IS CALLED C11
CHARCON 12 OF CENTER IS CALLED C12347
CHARCON 13 OF CENTER IS CALLED C12357
CHARCON 14 OF CENTER IS CALLED C1267
CHARCON 15 OF CENTER IS CALLED C17

for i = 12. 1. 15. show center(i)

CENTER(C12347) = 0.
CENTER(C12357) = 2.
CENTER(C1267) = 2.
CENTER(C17) = 0.
@for i=17. step 1. until 22. show urbanization(i)
URBANION(U12346) = 4.
URBANION(U12347) = 20.
URBANION(U12358) = 0.
URBANION(U123359) = 0.
URBANION(U1210) = 0.
URBANION(U110) = 0.

for i=23. step 1. until 30. show industry(i)
INDUSTRY(112358) = 0.
INDUSTRY(112359) = 0.
INDUSTRY(1123610) = 10.
INDUSTRY(1123611) = 2.
INDUSTRY(1124712) = 12.
INDUSTRY(1124713) = 0.
INDUSTRY(112414) = 0.
INDUSTRY(1114) = 0.
LEGEND:

PRIMARY ATTRIBUTE ASSIGNMENTS -- '1' = URBANIZATION(6); '2' = INDUSTRY(7); '3' = CENTER(5)

'B' = 1, 3
'. ' = NON EMPTY LAND

REFERENCE ATTRIBUTE ASSIGNMENTS -- '+' = RIVER(8); '-' = CHANNEL(12); '*' = CHANNEL & RIVER; ' ' = NO REF ATTS

FIRST PATTERN FOR CIUDAD GUAYANA
GENERATED BY DECISION RULES
SHOWING URBANIZATION, INDUSTRY AND CENTER
LEGEND:

PRIMARY ATTRIBUTE ASSIGNMENTS -- '1' = URBANION(6); '2' = UDESIGN(3)

'A' = 1, 2

'.' = NON EMPTY LAND

REFERENCE ATTRIBUTE ASSIGNMENTS -- '+' = RIVER(8); '-' = CHANNEL(12); '*' = CHANNEL & RIVER; '' = NO REF ATTS

COMPARISON OF FIRST URBANIZATION PATTERN GENERATED BY DECISION RULES (URBANION) WITH URBANIZATION PATTERN GENERATED BY DESIGNERS (UDESIGN)
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URBANION(ORDER), UDESIGN(ORDERLO), AND UDESIGN(ORDERHI) HAVE BEEN GIVEN A VALUE WHERE THEY EXIST.
"B" INDICATES THAT THEY DO NOT EXIST AT THAT LOCATION.
TOP NUMBER IN EACH LOCATION IS THE ORDER ASSIGNED
BY THE DECISION RULE.
MIDDLE AND BOTTOM NUMBERS INDICATE THE DESIGNERS' ACCEPTABLE RANGE OF ASSIGNMENT ORDER.

COMPARISON OF FIRST URBANIZATION PATTERN
GENERATED BY DECISION RULES
WITH URBANIZATION PATTERN
GENERATED BY DESIGNERS
ROW 1, COL 11 TO ROW 10, COL 18
LEGEND:

PRIMARY ATTRIBUTE ASSIGNMENTS - - '1' = INDUSTRY(7); '2' = IDESIGN(2)

'A' = 1, 2      '.' = NON EMPTY LAND

REFERENCE ATTRIBUTE ASSIGNMENTS - - '+' = RIVER(8); '-' = CHANNEL(12); '*' = CHANNEL & RIVER; ' ' = NO REF ATTS

COMPARISON OF FIRST INDUSTRY PATTERN
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GENERATED BY DESIGNERS (IDesign)
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COMPARISON OF FIRST INDUSTRY PATTERN
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INDUSTRY(ORDER), IDESIGN(ORDERLO), AND IDESIGN(ORDERHI) HAVE BEEN GIVEN A VALUE WHERE THEY EXIST. "B" INDICATES THAT THEY DO NOT EXIST AT THAT LOCATION. TOP NUMBER IN EACH LOCATION IS THE ORDER ASSIGNED BY THE DECISION RULE. MIDDLE AND BOTTOM NUMBERS INDICATE THE DESIGNERS' ACCEPTABLE RANGE OF ASSIGNMENT ORDER.

COMPARISON OF FIRST INDUSTRY PATTERN GENERATED BY DECISION RULES WITH INDUSTRY PATTERN GENERATED BY DESIGNERS
ROW 1, COL 11 TO ROW 10, COL 18
LEGEND:

PRIMARY ATTRIBUTE ASSIGNMENTS - - '1' = CENTER(5); '2' = CDESIGN(4)
'A' = 1, 2
'. ' = NON EMPTY LAND

REFERENCE ATTRIBUTE ASSIGNMENTS - - '+' = RIVER(8); '-' = CHANNEL(12); '*' = CHANNEL & RIVER; ' ' = NO REF ATTS

COMPARISON OF FIRST CENTER PATTERN
GENERATED BY DECISION RULES (CENTER)
WITH CENTER PATTERN
GENERATED BY DESIGNERS (CDESIGN)
design2 p

IF DESIGN SYSTEM CRASHES GIVE THE DEBUG COMMAND:
DUMP NAME 12000 3D000

R 0.02/0.02
rd dataguay p
R 0.78/0.80
rd execguay p
printf execguay p

SET_CARRIAGE_WIDTH 60
READY OFF
MESSAGE OFF
RD LBESIDE P
RD LGRAVITY P
RETURN

comment execguay p sets the carriage width to 60 characters,
comment turns the ready message off, turns other messages
comment off, and reads in two files which are needed in the
comment Guayana assignment rules.
rd assignu p
"URBANIZATION" HAS BEEN PLACED AT 3,17
DECISION PATH WAS U1 U2 U3 U4 U6

comment this last command assigned urbanization to the land
comment according to the decision rules developed in
comment Chapter II.
comment to complete the algorithm of Chapter II it is
comment necessary to go through the whole series of
comment assignments: 3u, 3i, 1c, 3u and 3i - 4 times.
rd assignu p
"URBANIZATION" HAS BEEN PLACED AT 8,11
DECISION PATH WAS U1 U2 U3 U4 U7

rd assignu p
"URBANIZATION" HAS BEEN PLACED AT 9,12
DECISION PATH WAS U1 U2 U3 U4 U6

rd assigni p
"INDUSTRY" HAS BEEN PLACED AT 9,4
DECISION PATH WAS 11 12 13 16 110

rd assigni p
"INDUSTRY" HAS BEEN PLACED AT 8,5
DECISION PATH WAS 11 12 13 16 110

rd assigni p
"INDUSTRY" HAS BEEN PLACED AT 7,6
DECISION PATH WAS 11 12 13 16 110
rd assignc p
"CENTER" HAS BEEN PLACED AT 7,9
DECISION PATH WAS C1 C2 C6

rd assignu p
"URBANIZATION" HAS BEEN PLACED AT 4,17
DECISION PATH WAS U1 U2 U3 U4 U7

rd assignu p
"URBANIZATION" HAS BEEN PLACED AT 5,16
DECISION PATH WAS U1 U2 U3 U4 U7

rd assignu p
"URBANIZATION" HAS BEEN PLACED AT 6,17
DECISION PATH WAS U1 U2 U3 U4 U7

rd assigni p
"INDUSTRY" HAS BEEN PLACED AT 6,7
DECISION PATH WAS 11 12 13 16 110

rd assigni p
"INDUSTRY" HAS BEEN PLACED AT 7,7
DECISION PATH WAS 11 12 13 16 110

rd assigni p
"INDUSTRY" HAS BEEN PLACED AT 10,2
DECISION PATH WAS 11 12 13 16 110

comment now starts the second time through the series.

rd assignu p
"URBANIZATION" HAS BEEN PLACED AT 7,17
DECISION PATH WAS U1 U2 U3 U4 U7

rd assignu p
"URBANIZATION" HAS BEEN PLACED AT 8,17
DECISION PATH WAS U1 U2 U3 U4 U7

rd assignu p
"URBANIZATION" HAS BEEN PLACED AT 5,17
DECISION PATH WAS U1 U2 U3 U4 U7

rd assigni p
"INDUSTRY" HAS BEEN PLACED AT 11,2
DECISION PATH WAS 11 12 13 16 110

rd assigni p
"INDUSTRY" HAS BEEN PLACED AT 11,1
DECISION PATH WAS 11 12 13 16 110
"INDUSTRY" HAS BEEN PLACED AT 4,15
DECISION PATH WAS 11 12 13 16 111

"CENTER" HAS BEEN PLACED AT 8,9
DECISION PATH WAS C1 C2 C3 C5

"URBANIZATION" HAS BEEN PLACED AT 9,17
DECISION PATH WAS U1 U2 U3 U4 U7

"URBANIZATION" HAS BEEN PLACED AT 10,16
DECISION PATH WAS U1 U2 U3 U4 U7

"URBANIZATION" HAS BEEN PLACED AT 10,17
DECISION PATH WAS U1 U2 U3 U4 U7

"INDUSTRY" HAS BEEN PLACED AT 2,17
DECISION PATH WAS 11 12 13 16 111

"INDUSTRY" HAS BEEN PLACED AT 2,18
DECISION PATH WAS 11 12 13 16 110

"INDUSTRY" HAS BEEN PLACED AT 7,8
DECISION PATH WAS 11 12 14 17 112

"URBANIZATION" HAS BEEN PLACED AT 7,18
DECISION PATH WAS U1 U2 U3 U4 U7

"URBANIZATION" HAS BEEN PLACED AT 6,18
DECISION PATH WAS U1 U2 U3 U4 U7

"URBANIZATION" HAS BEEN PLACED AT 8,18
DECISION PATH WAS U1 U2 U3 U4 U7

"INDUSTRY" HAS BEEN PLACED AT 8,8
DECISION PATH WAS 11 12 14 17 112
"INDUSTRY" HAS BEEN PLACED AT 9,9
DECISION PATH WAS 11 12 14 17 112

"INDUSTRY" HAS BEEN PLACED AT 9,8
DECISION PATH WAS 11 12 14 17 112

"CENTER" HAS BEEN PLACED AT 9,9
DECISION PATH WAS C1 C2 C3 C5

"URBANIZATION" HAS BEEN PLACED AT 5,18
DECISION PATH WAS U1 U2 U3 U4 U7

"URBANIZATION" HAS BEEN PLACED AT 9,18
DECISION PATH WAS U1 U2 U3 U4 U7

"URBANIZATION" HAS BEEN PLACED AT 10,18
DECISION PATH WAS U1 U2 U3 U4 U7

"INDUSTRY" HAS BEEN PLACED AT 10,8
DECISION PATH WAS 11 12 14 17 112

"INDUSTRY" HAS BEEN PLACED AT 8,7
DECISION PATH WAS 11 12 14 17 112

"INDUSTRY" HAS BEEN PLACED AT 9,7
DECISION PATH WAS 11 12 14 17 112

"URBANIZATION" HAS BEEN PLACED AT 5,13
DECISION PATH WAS U1 U2 U3 U5 U8

"URBANIZATION" HAS BEEN PLACED AT 6,14
DECISION PATH WAS U1 U2 U3 U5 U8

"URBANIZATION" HAS BEEN PLACED AT 9,11
DECISION PATH WAS U1 U2 U3 U5 U8
"INDUSTRY" HAS BEEN PLACED AT 10,7
DECISION PATH WAS 11 12 14 17 112

"INDUSTRY" HAS BEEN PLACED AT 11,7
DECISION PATH WAS 11 12 14 17 112

"INDUSTRY" HAS BEEN PLACED AT 10,6
DECISION PATH WAS 11 12 14 17 112

"CENTER" HAS BEEN PLACED AT 7,8
DECISION PATH WAS C1 C2 C3 C5

"URBANIZATION" HAS BEEN PLACED AT 6,9
DECISION PATH WAS U1 U2 U3 U5 U8

"URBANIZATION" HAS BEEN PLACED AT 10,11
DECISION PATH WAS U1 U2 U3 U5 U8

"URBANIZATION" HAS BEEN PLACED AT 6,8
DECISION PATH WAS U1 U2 U3 U5 U8

"INDUSTRY" HAS BEEN PLACED AT 11,6
DECISION PATH WAS 11 12 14 17 112

"INDUSTRY" HAS BEEN PLACED AT 10,5
DECISION PATH WAS 11 12 14 17 112

"INDUSTRY" HAS BEEN PLACED AT 12,6
DECISION PATH WAS 11 12 14 17 112

comment that completes the series.

store d4guay p
comment to exhibit some of the bookkeeping, and to find
comment out where to look for the information which has
comment been kept, "list" and "show" commands follow.
list center

CHARVAR 1 OF CENTER IS CALLED ORDER
CHARCON 1 OF CENTER IS CALLED C1
CHARCON 2 OF CENTER IS CALLED C2
CHARCON 3 OF CENTER IS CALLED C3
CHARCON 4 OF CENTER IS CALLED C4
CHARCON 5 OF CENTER IS CALLED C5
CHARCON 6 OF CENTER IS CALLED C6
CHARCON 7 OF CENTER IS CALLED C7
CHARCON 8 OF CENTER IS CALLED D8
CHARCON 9 OF CENTER IS CALLED D9
CHARCON 10 OF CENTER IS CALLED D10
CHARCON 11 OF CENTER IS CALLED D11
CHARCON 12 OF CENTER IS CALLED C1234
CHARCON 13 OF CENTER IS CALLED C1235
CHARCON 14 OF CENTER IS CALLED C126
CHARCON 15 OF CENTER IS CALLED C17

for i = 12. step 1. until 15. show center(i)

CENTER(C1234) = 0.
CENTER(C1235) = 3.
CENTER(C126) = 1.
CENTER(C17) = 0.

for i = 23. step 1. until 30. show industry(i)
INDUSTRY(I12358) = 0.
INDUSTRY(I12359) = 0.
INDUSTRY(I123610) = 9.
INDUSTRY(I123611) = 2.
INDUSTRY(I124712) = 13.
INDUSTRY(I124713) = 0.
INDUSTRY(I12414) = 0.
INDUSTRY(I1114) = 0.

for i = 17. step 1. until 22. show urbanization (i)
URBANON(U12346) = 2.
URBANON(U12347) = 16.
URBANON(U12358) = 6.
URBANON(U12359) = 0.
URBANON(U1210) = 0.
URBANON(U110) = 0.
LEGEND:

PRIMARY ATTRIBUTE ASSIGNMENTS — '1' = URBANION(6); '2' = INDUSTRY(7); '3' = CENTER(5)
'C' = 2, 3   '. ' = NON EMPTY LAND

REFERENCE ATTRIBUTE ASSIGNMENTS — '+' = RIVER(8); '-' = CHANNEL(12); '*' = CHANNEL & RIVER; ' ' = NO REF ATTS

SECOND PATTERN FOR CIUDAD GUAYANA
GENERATED BY DECISION RULES
SHOWING URBANIZATION, INDUSTRY AND CENTER
LEGEND:

PRIMARY ATTRIBUTE ASSIGNMENTS -- '1' = URBANION(6); '2' = UDESIGN(3)
'A' = 1, 2       '.' = NON EMPTY LAND

REFERENCE ATTRIBUTE ASSIGNMENTS -- '+1' = RIVER(8); '-' = CHANNEL(12); '*1' = CHANNEL & RIVER; '1' = NO REF ATTS

COMPARISON OF SECOND URBANIZATION PATTERN
GENERATED BY DECISION RULES (URBANIZATION)
WITH URBANIZATION PATTERN
GENERATED BY DESIGNERS (UDESIGN)
LEGEND:

PRIMARY ATTRIBUTE ASSIGNMENTS -- '1' = INDUSTRY(7); '2' = IDESIGN(2)
'A' = 1, 2  '.' = NON EMPTY LAND

REFERENCE ATTRIBUTE ASSIGNMENTS -- '+' = RIVER(3); '-' = CHANNEL(12); '*' = CHANNEL & RIVER; '' = NO REF ATTS

COMPARISON OF SECOND INDUSTRY PATTERN
GENERATED BY DECISION RULES (INDUSTRY)
WITH INDUSTRY PATTERN
GENERATED BY DESIGNERS (IDESIGN)
LEGEND:

PRIMARY ATTRIBUTE ASSIGNMENTS -- '1' = CENTER(5); '2' = CDESIGN(4)

'A' = 1, 2       '..' = NON EMPTY LAND

REFERENCE ATTRIBUTE ASSIGNMENTS -- '+' = RIVER(8); '-' = CHANNEL(12); '*' = CHANNEL & RIVER; ' ' = NO REF ATTS

COMPARISON OF SECOND CENTER PATTERN
GENERATED BY DECISION RULES (CENTER)
WITH CENTER PATTERN
GENERATED BY DESIGNERS (ICENTER)
APPENDIX

DECISION RULE FOR URBANIZATION

SUBSTITUTION ON
FOR I = 1, STEP 1, UNTIL 10. URBANIZATION(I) = 0.
COMMENT THIS SETS THE CHARCONS WHICH KEEP TRACK OF
COMMENT THE DECISION PATH TO 0. INITIALLY
TLIST0 *=* CENTER .OR. URBANIZATION .OR. INDUSTRY
EX GRAVITY (TLIST0 X Y)
COMMENT LOC X,Y IS THE CENTER OF GRAVITY OF ALL ACTIVITIES
URBANIZATION(U1) = 1.
COMMENT URBANIZATION(U1) IS ONE OF THE CHARCONS KEEPING
COMMENT TRACK OF THE DECISION PATH
TLIST1 *=* SLOPE05 .OR. SLOPE615 .ANDN. TLIST0
COMMENT TLIST1 IS THE DEVELOPMENT ZONE FOR URBANIZATION
COMMENT FORMED AT THE FIRST NODE ON THE DECISION TREE
COMMENT DECISION TREE
IF TLIST1 .EQL. 0. GOTO UR3
COMMENT IF IT DOESN'T EXIST THEN THE PROGRAM BRANCHES TO UR3$
EX BESIDE (URBANIZATION)
COMMENT THIS PRODUCES A LIST NAMED "BESIDE" WHICH CONTAINS
COMMENT ALL THE LOCATIONS NEXT TO "URBANIZATION"
TLIST2 *=* TLIST1 .AND. BESIDE
URBANIZATION(U2) = 1.
IF TLIST2 .EQL. 0. GOTO UR3
TLIST1 *=* TLIST2
TLIST2 *=* TLIST1 .AND. SLOPE05
URBANIZATION(U3) = 1.
IF TLIST2 .EQL. 0. GOTO UR3
EX BESIDE(RIVER)
TLIST1 *=* TLIST2
TLIST2 *=* TLIST1 .AND. BESIDE
URBANIZATION(U4) = 1.
URBANIZATION(U7) = 1.
IF TLIST2 .EQL. 0. GOTO UR3
URBANIZATION(U7) = 0.
URBANIZATION(U6) = 1.
TLIST1 *=* TLIST2
GOTO UR8
UR8$ CONTINUE
EX BESIDE(RIVER)
TLIST2 *=* TLIST1 .AND. BESIDE
URBANIZATION(U5) = 1.
URBANIZATION(U9) = 1.
IF TLIST2 .EQL. 0. GOTO UR3
URBANIZATION(U9) = 0.
TLIST1 *=* TLIST2
URBANIZATION(U8) = 1.
UR8$ CONTINUE
APPENDIX

NEAREST TLIST1 X,Y BESTI, BESTJ MINDIST
PUT URBANIZATION BESTI, BESTJ
EXPAND +**"URBANIZATION" HAS BEEN PLACED AT $3BESTI,$3BESTJ/+ ORDERU = ORDERU + 1.
URBANIZATION(ORDER BESTI,BESTJ) = ORDERU
UR12$ CONTINUE
EXPAND +DECISION PATH WAS U1 +
T = 1.
THROUGH UR10 FOR I=2. STEP 1. UNTIL 10.
IF URBANIZATION(I) .EQL. 0. GOTO UR10
EXPAND + U$31 +
IF I .GEQ. 10. A = 100.
IF I .LES. 10. A = 10.
T = T*10. + 1
UR10$ CONTINUE
EXPAND +//+
THROUGH UR11 FOR I=11. STEP 1. UNTIL 17.
J = I + 6.
IF T-URBANIZATION(I) .EQL. 0. URBANIZATION(J) = URBANIZATION(J) + 1.
UR11$ SUBSTITUTION OFF
READ_CONSOLE
UR3$ URBANIZATION(U10) = 1.
EXPAND +NO LAND SUITABLE FOR "URBANIZATION" +
EXPAND +WAS FOUND/+ GOTO UR12

DECISION RULE FOR URBANIZATION
DECISION RULE FOR INDUSTRY

SUBSTITUTION ON
FOR I = 1. STEP 1. UNTIL 14. INDUSTRY(1)=0.
TLIST0***CENTER.OR.INDUSTRY.OR.URBANIZATION EX GRAVITY (TLIST0 X Y)
INDUSTRY(1)=1.
TLIST1***SLOPE05 .OR. SLOPE615 .ANDN. TLIST0
IF TLIST1 .EQL. 0. GOTO IQ3
EX BESIDE (CHANNEL)
TLIST2 **= TLIST1 .AND. BESIDE
INDUSTRY(2)=1.
IF TLIST2 .EQL. 0. GOTO IQ4
TLIST1 **= TLIST2
TLIST2 **= TLIST1 .AND. SLOPE05
INDUSTRY(3) = 1.
IF TLIST2 .EQL. 0. GOTO IQ6
EX BESIDE (INDUSTRY)
TLIST1 ** = TLIST2
TLIST2 ** = TLIST1 .AND. BESIDE
INDUSTRY(5) = 1.
INDUSTRY(9) = 1.
IF TLIST2 .EQL. 0. GOTO IQ8
INDUSTRY(9) = 0.
TLIST1*** TLIST2
INDUSTRY(8) = 1.
GOTO IQ8
IQ6$ INDUSTRY(6) = 1.
EX BESIDE (INDUSTRY)
TLIST2*** TLIST1 .AND. BESIDE
INDUSTRY(11) = 1.
IF TLIST2 .EQL. 0. GOTO IQ8
INDUSTRY(11) = 0.
TLIST1** = TLIST2
INDUSTRY(10) = 1.
GOTO IQ8
IQ4$ INDUSTRY(4) = 1.
EX BESIDE (INDUSTRY)
TLIST2** = TLIST1 .AND. BESIDE
IF TLIST2 .EQL. 0. GOTO IQ3
TLIST1** = TLIST2
TLIST2** = TLIST1 .AND. SLOPE05
INDUSTRY(7) = 1.
INDUSTRY(13) = 1.
IF TLIST2 .EQL. 0. GOTO IQ8
INDUSTRY(13) = 0.
INDUSTRY(12) = 1.
TLIST1** = TLIST2
IQ8$ CONTINUE
NEAREST TLIST1 TO X,Y BESTI,BESTJ MINDIST
PUT INDUSTRY BESTI, BESTJ
EXPAND +**"INDUSTRY" HAS BEEN PLACED AT $#BESTI,$#BESTJ/+ 
ORDERI = ORDERI + 1. 
INDUSTRY(OORDER BESTI,BESTJ) = ORDERI
IQ12$ CONTINUE
EXPAND +DECISION PATH WAS 11 + 
T=1. 
THROUGH IQ10 FOR I=2. 1. 14. 
IF INDUSTRY(I) .EQL. 0. GOTO IQ10
EXPAND + I$31 + 
IF I .GEQ. 10. A = 100. 
IF I.LES. 10. A = 10. 
T = T*A + 1 
IQ10$ CONTINUE
EXPAND +//+ 
THROUGH IQ11 FOR I=15. 1. 22. 
J = I + 8. 
IF T- INDUSTRY(I) .EQL. 0. INDUSTRY(J) = INDUSTRY(J) + 1. 
IQ11$ SUBSTITUTION OFF 
READ_CONSOLE
IQ3$ INDUSTRY(14)=1. 
EXPAND +NO LAND SUITABLE FOR "INDUSTRY" + 
EXPAND +WAS FOUND/+ 
GOTO IQ12

DECISION RULE FOR INDUSTRY
SUBSTITUTION ON
FOR I = 1. STEP 1. UNTIL 7. CENTER(I) = 0.
TLIST0 *** CENTER .OR. URBANIZATION .OR. INDUSTRY
EX GRAVITY (TLIST0 X Y)
TLIST1 *** SLOPE05 .AND..NOT. UNACCEPTABLE .AND..NOT. ' RIVER .AND..NOT. CENTER
CENTER(C1) = 1.
IF TLIST1 .EQL. 0. GOTO CE3
EX BESIDE (CENTER)
TLIST2 *** TLIST1 .AND. BESIDE
CENTER(C2) = 1.
IF TLIST2 .EQL. 0. GOTO CE7
EX BESIDE (URBANIZATION)
TLIST1 *** TLIST2
TLIST2 *** TLIST1 .AND. BESIDE
CENTER(C3) = 1.
IF TLIST2 .EQL. 0. GOTO CE6
TLIST1 *** TLIST2
CENTER(C4) = 1.
CE7$ CENTER(C6) = 1.
GOTO CE4
CE6$ CENTER(C5) = 1.
CE4$ CONTINUE
NEAREST TLIST1 X,Y BESTI,BESTJ MINDIST
PUT CENTER BESTI, BESTJ
EXPAND ***"CENTER" HAS BEEN PLACED AT $3BESTI,$3BESTJ/+ ORDERC = ORDERC + 1.
CENTER(ORDER BESTI, BESTJ) = ORDERC
EXPAND +DECISION PATH WAS C1 + T=1.
THROUGH CE5 FOR I=2. STEP 1. UNTIL 6.
IF CENTER(I) .EQL. 0. GOTO CE5
EXPAND + C$31 + T=T*10. + 1
CE5$ CONTINUE
EXPAND +/+ THRU CE8 FOR I=8. STEP 1. UNTIL 11.
J = I + 4.
IF T- CENTER(1) .EQL. 0. CENTER(J) = CENTER(J) + 1.
CE8$ SUBSTITUTION OFF
READ_CONSOLE
CE3$ CONTINUE
EXPAND + NO LAND SUITABLE FOR "CENTER" WAS FOUND/+ EXPAND + DECISION PATH WAS C1 C7/+ CENTER(C17) = CENTER(C17) + 1.
SUBSTITUTION OFF
READ_CONSOLE

DECISION RULE FOR CENTER
CIUDAD GUAYANA DATA

SETUP 1 15 1 18 60 60
DEFINE IDESIGN WITH 2 CHARVARS: ORDERLO ORDERHI*
DEFINE UDESIGN WITH 2 CHARVARS: ORDERLO ORDERHI*
DEFINE CDESIGN WITH 2 CHARVARS: ORDERLO ORDERHI*
PUT IDESIGN 2,17(2. 7.) 4,13(1. 1.) 5,11(1. 1.)
5,16(2. 7.) 5,17(2. 7.) 6,7(8. 14.) 6,8(15. 25.) 6,9(8. 14.)
7,6(8. 14.) 7,7(15. 25.) 8,5(8. 14.) 8,6(15. 25.) 8,7(2. 7.)
9,3(1. 1.) 9,4(8. 14.) 9,6(2. 7.) 9,7(15. 25.) 10,2(15. 25.)
10,3(1. 1.) 10,4(1. 1.) 10,5(2. 7.) 10,6(15. 25.)
11,2(15. 25.) 11,3(8. 14.) 11,4(8. 14.) 11,5(15. 25.)
12,1(15. 25.) 12,2(15. 25.) 12,3(15. 25.) 12,4(15. 25.)
PUT UDESIGN 3,15(1. 1.) 3,16(1. 1.) 3,17(6. 11.)
4,14(1. 1.) 4,15(2. 5.) 4,16(2. 5.)
5,13(12. 14.) 5,14(1. 1.) 5,15(6. 11.)
6,10(1. 1.) 6,14(6. 11.) 7,3(15. 25.) 7,9(12. 14.)
7,11(1. 1.) 7,12(1. 1.) 8,8(15. 25.) 8,9(12. 14.) 8,15(1. 1.)
9,11(2. 5.) 9,12(2. 5.) 10,7(15. 25.) 10,8(6. 11.)
10,9(6. 11.) 10,11(5. 10) 11,6(15. 25.) 11,7(15. 25.)
11,8(15. 25.) 11,10(15. 25.) 11,11(15. 25.)
12,5(15. 25.) 12,6(15. 25.) 12,7(15. 25.)
PUT CDESIGN 8,11(2. 2.) 8,10(4. 4.)
7,8(5. 5.) 7,9(3. 3.)
DEFINE CENTER WITH 1 CHARVAR: ORDER * AND WITH 15'
CHARCONS: C1 = 0. C2 = 0. C3=0. C4=0. C5=0. C6=0. C7=0.
C1234=0. C1235 = 0. C126=0. C17=0.
DEFINE URBANIZATION WITH 1 CHARVAR:ORDER * AND
WITH 22 CHARCONS: U1=0. U2=0. U3=0. U4=0. U5=0. U6=0.
U7=0. U8=0. U9=0. U10=0. U11=12346. U12=12347.
U12346=0. U12347=0. U12358=0. U12359=0. U1210=0.
U110=0.
DEFINE INDUSTRY WITH 1 CHARVAR: ORDER * AND WITH
30 CHARCONS: I1=0. I2=0. I3=0. I4=0. I5=0. I6=0. I7=0. I8=0.
I9=0. I10=0. I11=0. I12=0. I13=0. I14=0.
D20=124713. D21=12414. D22=114. I12358=0. I12359=0.
I123610=0. I123611=0. I124712=0. I124713=0.
I12414=0. I114=0.
RIVER *** NULL
SLOPE05 *** NULL
SLOPE15 *** NULL
UNACCEPTABLE *** NULL
CHANNEL *** NULL
ORDERC = 1.
ORDERU=1.
ORDERI=1.
APPENDIX

PUT INDUSTRY 4,13 5,11 9,3 10,5 10,4
PUT URBANIZATION 3,15 3,16 4,14 5,14 6,10 7,11 7,12 8,15
PUT RIVER 1,17 2,15 2,16 2,14 3,12 3,13 3,14 4,10 4,11 4,12 ' 5,12 6,4 6,5 6,6 6,12 6,13 7,4 7,14 7,15 8,2 8,3 3,4 8,13 ' 8,14 9,1 9,2 9,13 9,14 10,1 10,12 10,13 11,12 12,8 12,9 ' 12,10 12,11 13,7 13,8 13,9 14,7 15,7 5,6 5,7 5,8 5,9 5,10
PUT SLOPE 0 3,17 4,14 4,17 5,16 5,17 5,18 6,17 6,18 7,8 7,9 ' 7,17 7,18 8,7 8,8 8,9 8,11 8,17 8,18 9,7 9,8 9,9 9,12 9,17 ' 9,18 10,3 10,5 10,6 10,7 10,8 10,16 10,17 10,18 ' 11,5 11,6 11,7 12,1 12,2 12,3 12,4 12,5 12,6 13,1 13,2 13,3 ' 13,4 13,5 14,1 14,2 14,3 14,4 14,5 15,1 15,2 15,3 15,4
PUT SLOPE 615 2,17 2,18 3,16 3,18 4,15 4,16 4,18 5,11 5,13 5,14 ' 5,15 6,7 6,8 6,9 6,10 6,14 6,15 7,6 7,7 7,11 7,12 8,2 8,6' 8,15 8,16 9,3 9,4 9,6 9,11 9,15 9,16 10,2 10,4 10,9 10,11 ' 11,1 11,2 11,3 11,4 11,8 11,10 11,11 12,7 13,6 14,6 15,5 15,6
PUT UNACCEPTABLE 1,18 4,13 6,1 6,16 7,5 7,10 7,13 7,16 ' 8,10 8,12 9,5 9,10 10,10 10,14 10,15 11,9 11,13 12,12 13,10
PUT CHANNEL 1,17 2,15 2,16 3,13 3,14 4,11 6,4 6,6 6,5 7,4 8,2 ' 8,3 8,4 9,1 9,2 10,1 5,6
GRIDSIZE = 1.
N = 1.
P = 15.
Q = 1.
R = 18.
BESTI = 0.
BESTJ = 0.
MINDIST = 0.
A = 0.
READ_CONSOLE

DATA FILE FOR CIUDAD GUAYANA, 1961
INCLUDING THE DESIGNERS' DESIGN
BIOGRAPHICAL NOTE

William Lyman Porter was born in Poughkeepsie, N.Y. on February 19, 1934. Prior to entering the doctoral program he attended Yale University where he majored in Architecture. He received a B.A. degree in 1955 and a B. Arch. in 1957.

In 1958 he was drafted into the U.S. Army where he served as a draftsman-designer. Upon his release from active duty he was commissioned 2nd Lieutenant in the U.S. Army reserve. He was honorably discharged in 1964.

From 1960 to 1962 he worked for Louis I. Kahn, Architect in Philadelphia. It was there that his interest in the analysis of design and of the creative process was nurtured. He became registered to practice architecture in Pennsylvania in 1961.

From 1962 to 1964 he worked as an urban designer on the fast-growing industrial city of Ciudad Guayana in the southeastern part of Venezuela.

In 1964 he entered the doctoral program in M.I.T.'s Department of City and Regional Planning. He received a Mellon Fellowship from M.I.T. in 1964 and a Stouffer Fellowship from the Joint Center for Urban Studies of Harvard and M.I.T. in 1966.

He has been an Instructor in Civic Design at the University of Pennsylvania in 1961, and in City Planning at M.I.T. in 1966. He is presently Assistant Professor of Urban Design in the Departments of Architecture and Urban Studies and Planning.


Mr. Porter is a member of the American Institute of Architects, and the Boston Society of Architects. He is married and has three children.
CHAPTER I: FOOTNOTES

(1.01) The team which has developed DISCOURSE has included: Katherine J. Lloyd and Wren McMains as overall systems programmers; Corrie Menger, Stanley Hoderowski, and Chris Reedy programming various aspects of the system; Michael O'Hare, David Sandahl as users of the system contributing to its development by placing specific demands upon it; and Aaron Fleisher for overall direction and coordination.

The project has enjoyed the support of IBM, The Urban Systems Laboratory and the Department of Urban Studies and Planning.

(1.02) "It is a profoundly erroneous truism, repeated by all copy-books and by eminent people when they are making speeches, that we should cultivate the habit of thinking of what we are doing. The precise opposite is the case. Civilization advances by extending the number of important operations which we can perform without thinking about them. Operations of thought are like cavalry charges in a battle—they are strictly limited in number, they require fresh horses, and must only be made at decisive moments."


(1.03) There is a wide range in the literature of what is meant by "city, "civic" or "urban" design and "physical" city planning. Locating the point of view represented here in that range is not crucial for the development of the DISCOURSE language. The discussion of city design is intended to help the reader to imagine some of the implied or understated examples throughout the rest of the thesis.


(1.05) Ibid., p. 142.


(1.07) A great deal has been created at the time of problem formulation or recognition. A restricted number of variables has been identified, major points of conflict noted, and a hint of the nature of the solution because of the kinds of conflict to which the designer's attention has been drawn. See also Mackworth in his discussion of "problem finding" versus "problem solving." He regards the former as the activity demanding much greater originality.

(1.08) Let me stress here and elsewhere that the aspects of the design process which I have addressed are those concerned with the designer's communication with himself and his thinking through of the design issues independently during the time he is generating design ideas; not all the activities of the designer during that process.

(1.09) Lynch speaks of several of these in his "Quality in City Design," op. cit., pp. 141-152.

(1.10) Although the sequence of technical studies associated with the physical planning and design of cities may be continuous, that is, goals constantly being formulated and revised, new information gathering activities being initiated and so forth, with respect to any particular design product there will probably have been the kinds of changes over the duration of generating it which are spoken of in the text.


(1.11) This is probably especially true for problems which are complex and ill-defined. For surveys of such sequences of activities see for example:


And for suggested strategies to improve problem solving see:


(1.12) A fascinating discussion of the designer, the design and the representation of the design as well as ways in which the representation is helpful to the designer occurs in:


(1.13) Manuals are generally available which describe general purpose languages for scientific and commercial application. (eg. FORTRAN, COBOL)

(1.14) The DISCOURSE interpreter permits a wide variety of new instructions to be written by the user. These are called "RCOM files" in this thesis and there are many examples in Chapters IV and V and in the Appendix. Where shorter execution times are demanded, any RCOM file can be written in AED and called as a basic command of the DISCOURSE language.
CHAPTER I: FOOTNOTES

(1.15) ICES System: General Description, Daniel Roos, editor (Cambridge: Department of Civil Engineering, Massachusetts Institute of Technology, 1967)


(1.17) I spent over two years as part of a team working on the planning and design of Ciudad Guayana. For further information about the project see:


(1.18) Minsky's discussion deals with both the notions of algorithms and functional equivalence which are the intuitive basis of the analysis in Chapter II.


(1.19) For the idea to represent DISCOURSE as a range rather than a point on this continuum I owe my thanks to my colleague in the Department of Architecture, Professor Leon Groisser.

  For an explanation of TRANSET, see:


CHAPTER II: FOOTNOTES

(2.01) This work began as a seminar in city design led by Professor Aaron Fleisher in which were John Boorn, Christine Boyer, and Hans Bleiker. There was agreement neither on the analysis nor the direction of research; the interpretation of the work may, therefore, not be shared.

(2.02) The GPS (General Problem Solver) did reproduce the subject's protocol with remarkable fidelity.


(2.03) See FOOTNOTE (1.18).

(2.04) Please refer to the APPENDIX for some of the documentation of this experiment. See also FOOTNOTE (1.17).

(2.06) A great deal has been decided here: "land suitable for industry" is only a small leap forward from "SLOPE615" toward making the description of the environment equal the specification of the design. For experiments of wider applicability it would probably be better to pick environmental descriptions with less commitment.

(2.07) The problem of determining how well the generated design "fits" the designers' pattern is difficult to solve with a rule. A square by square comparison of the generated pattern gives a value no different for values computed from very unsuccessful patterns. Examining clusters of squares may yield values which are different from those compiled from outlandish patterns. These issues seem to be similar to many discussed under the name "Pattern Recognition" where the success of the human pattern recognizer seems to have much to do with the context he is able to provide which helps him to recognize the particular object he is looking at.

O.G. Selfridge and U. Neisser, "Pattern Recognition by Machine"


(2.08) Putnam introduces the notion of "law cluster" in which the status of a law is provisional and depends for its importance upon its degree of connectedness to other laws and upon the meaning of that to which it refers. A new discovery, therefore, affects both laws and the objects of meaning.


(2.09) A particularly creative solution could be defined as one which has a high degree of both novelty and usefulness because of the types of elements and relationships among them both in the solution and the implied problem formulation. No solution can be tested on either criterion without reference to considerations external to the created solution itself. The novelty of a solution may be a product of the surprise elicited by previously remote elements being brought into a new combination. The combination may be achieved because the elements play complementary roles in performing some task; because they are similar in some respect to each other; or because they are joined by some third element which is common to both in either one of the two previous respects. The sense of surprise is often justified by the observers' knowledge that effort in the area of the new solution had consistently met with failure or that the solution represents the filling of a gap in previous knowledge.

Mednick notes that although the creative person may have a relatively higher number of associations in all, the non-creative person may be able to produce more associations at first; this might be ascribed to the high strength of the bonds between elements which the non-creative person has and which prevent him from moving beyond to less strong or more remote associations. Mednick also found a good correlation between high scores on a remote association test and independent ratings of creativity of the same students by their professors.
CHAPTER II: FOOTNOTES


The usefulness of a solution may be judged in part by the acceptance which it is rendered by people to whose advantage it ought to be to accept it. The criteria used by officials granting patents run very much along these lines. The same sorts of problems face administrators when trying to judge relative merits of productive scientists.


(2.10) Some rules, at least for land planning, which would seem to be at about the right level of specificity can be found in:

(2.11) Design of the highway from the observer's point of view yields horizontal profiles for which the reasons may not be obvious in plan view. See:

(2.12) G. Pask, op. cit.

(2.13) Polya suggests "working backwards" as one of the strategies for improving the chances of problem solving.

(2.14) Bartlett's discussion of "artistic thinking" is illuminating in this regard. See also his discussion of "interpolation" (with reference to "working backwards") where the subject has both beginning and end points to work with.

CHAPTER III: FOOTNOTES

(3.01) See FOOTNOTE (1.18).

(3.02) A.N. Whitehead, An Introduction to Mathematics, op. cit., p. 186. "The notion of Law, that is to say, of some measure of regularity or of persistence or of recurrence, is an essential element in the urge towards technology, methodology, scholarship, and speculation."
CHAPTER III: FOOTNOTES

A.N. Whitehead, Adventures of Ideas (New York: The MacMillan

Also, see:
A.N. Whitehead, An Introduction to Mathematics, op. cit., pp.107-120
for a discussion of functions.

(3.03) G. Hodge, "Use and Mis-Use of Measurement Scales in City
Planning," Journal of the American Institute of Planners, Vol. XXVIII,
No. 2, pp. 112-121.

(3.04) Many communities have their own rules concerning land develop-
ment. See:
F.S. Chapin, op. cit., p. 311.

(3.05) F.S. Chapin, op. cit., pp. 383-456.

(3.06) J. Herbert and B. Stevens, "A Model for the Distribution of

(3.07) J. Ruesch and W. Kees, Nonverbal Communication: Notes on the
Visual Perception of Human Relations (Berkeley: University of California

(3.08) Susanne K. Langer, Philosophy in a New Key (New York: Mentor

(3.09) These categories reflect a taxonomy developed by Donald
Appleyard which are partly evident in:
"An Environmental Improvement Program for
Ideal Transportation Systems," (Chicago: Barton-Aschman Associates, Inc.,
1968) (Mimeographed).

(3.10) Filling the gaps and creating the gaps to be filled is dis-
cussed in:
F.C. Bartlett, op. cit.

(3.11) Harvard's Sixth Urban Design Conference, "Designing Inter-City


(3.14) Rusch makes an interesting analysis of Picasso's series of "Bulls" in which are identified two kinds of changes from drawing to drawing: movement toward the final sketch, the larger changes; and movement toward good form.


Some designers seem to work from simple geometric ideas to distortions of these ideas to accommodate the particularities of the site and the program. I carried out several such studies under the direction of Louis I. Kahn, Architect of Philadelphia.

(3.18) The opportunity area as perceived is constrained by a number of factors such as time pressure, and information available; these and more are discussed in:


(3.20) March and Simon discuss "aspiration levels" as being closely related to "criteria of satisfaction"; they propose that "the aspiration level tends to adjust to the level of achievement."

March and Simon, op. cit., p. 182.

If so, this is a strike against the normatively minded for it suggests that the designer will tend to adjust goals or the fit between goals and performance before he adjusts his performance.
CHAPTER III: FOOTNOTES


CHAPTER IV: FOOTNOTES

(4.01) There is an excellent introductory survey of data organization in:

(4.02) In the present version of DISCOURSE there is a core-resident array in which one bit position is assigned to each ATTRIBUTE at a LOCATION (to each ATTXLOC). If the ATTXLOC is there or not there it can be found out very rapidly by searching that array. Thus all logical operations can be performed very rapidly without having to read in the data which are stored on the disk. The pointer structure is reserved for the CHARVARS, the numerical information which is LOCATION specific and which may be changing in its demands upon computer storage. Pointers also serve to gain access to the various parts of the data from the two basic dictionaries of ATTRIBUTES and LOCATIONS.

(4.03) For a precise definition of the use of the features of the language and for further illustration of the use of the language see:

(4.04) An engaging and clear explanation of EDIT can be found in:

CHAPTER V: FOOTNOTES

(5.01) Please refer to the discussion in Chapter IV page 88, "step 6."

(5.02) For further discussion of the uses of simulations see:
CHAPTER VI: FOOTNOTES

(6.01) Examples have been developed by students in subject "11.06" dedicated to the analysis of design at M.I.T. in the spring of 1969. They ranged from making clear the criteria of growth of residential areas in a rapidly expanding city to making obvious but complicated computations of floor-area-ratios parking ratios and the like of a center city district. Michael O'Hare has been working on the development of a residential location simulation which began with Harvard's New Communities Project.

(6.02) John P. Boorn, op. cit.


(6.05) Steven Coons, "Computer Aided Design," Ibid.


The description of the discovery of non-euclidean geometries; the destruction of the point of view that the axioms of geometry are true a priori. Contains discussions of euclidean, non-euclidean and topological spaces; and introduces the idea of "coordinative definitions:"

"They are arbitrary, like all definitions; on their choice depends the conceptual system which develops with the progress of science...Wherever metrical relations are to be established, the use of coordinative definitions is conspicuous. If a distance is to be measured, the unit of length has to be determined beforehand by definition. This definition is a coordinative definition.... If the definition is used for measurements, as in the case of the unit of length, it is a "metrical" coordinative definition."


If euclidean or any other geometry is not inevitably a part of the world which we see, but, instead, part of our conceptual apparatus, it behooves us to choose the geometry which is most convenient for us at the time. The same point of view is expressed by Carnap with respect to with respect to the variables of the description (in DISCOURSE, the ATTRIBUTES, CHARCONS and CHARVARS):

"...the decision to use certain types of variables is a practical decision like the choice of an instrument; it depends chiefly upon the purposes for which the instrument--here the language--is intended to be used and upon the properties of the instrument."

BIBLIOGRAPHY


