A THEORY OF URBAN STRUCTURE

including an application of
certain aspects of the theory
to the relationship between
land use and transportation
in Providence, Rhode Island

by

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ABSTRACT OF THESIS

Title: "A theory of urban structure, including an application of certain aspects of the theory to the relationships between land use and transportation in Providence, Rhode Island.

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Abstract:

A theory of urban structure that describes the relationship between the patterns of urban land uses and transportation systems is postulated in this thesis. The theory describes urban land uses as being of four general types: residential, commercial, industrial, and open recreational. Each of these is shown to be located in the city in similar-sized areas, herein termed "use-districts." The urban pattern is then described in terms of these use-districts and the transport interactions between them.

An application of the theory is made to the city of Providence, Rhode Island to test the applicability of the theory and to illustrate its meaning.

A more abstracted hypothesis of the "use-district" is then put forward in an attempt to develop a geometrical framework for the land use pattern. A pattern of hexagons in a three-axis grid is shown to have certain advantages in this respect. A second application is made to the test city.

Finally, possible uses of the theory are advanced and the direction of further research indicated.

Thesis supervisor: John T. Howard
Title: Associate Professor of City Planning

22 Irving Street
Boston 14, Massachusetts

August 24, 1953

Professor Frederick J. Adams, Head
Department of City and Regional Planning
School of Architecture and Planning
Massachusetts Institute of Technology
Cambridge, Massachusetts

Dear Professor Adams:

The accompanying thesis, entitled "A Theory of Urban Structure," is herewith submitted in partial fulfillment of the requirements for the degree of Master of City Planning.

May I express my deep appreciation to you and to the staff of the Department of City and Regional Planning for the cooperation and encouragement you have given me throughout my course of study.

Sincerely yours,

David A. Grossman

DAG:MG

TABLE OF CONTENTS

LIST OF FIGURES

INTRODUCTION

The objective of this thesis is to develop a theory of urban structure that will be of use in the study and physical planning of modern urban areas. While this may seem a large subject to be dealt with in a master's thesis it was my feeling that, on occasion, it is better to err by aiming too high rather than by setting one's sights too low.

Urban structure, as the term will be used in this thesis, refers to the complex of physical relationships resulting from interactions between the various uses to which land is put. It is in this sense, I believe, that urban structure has the most meaning for physical planners. The urban structure of modern communities is directly affected by the particular ways in which land is used and by the existing technological and economic framework. In this thesis the existing "state of the art" will be accepted as given. Further limitations on the general objective of the thesis will be mentioned in the body of the text.

In Part One the theory of urban structure is stated. As will become apparent from the statement of the theory it is not of a form that is easily susceptible of a direct testing of validity. In an attempt to compensate for this lack, Part Two provides an application of the theory to the City of Providence, Rhode Island. From this application an idea of the meaning of the theory can be drawn. This is in the direction of a test of the usefulness of the theory, rather than a direct test of validity itself. It does not seem likely that a test of the validity of the theory will be possible until the hypothesis has been further developed and its implications have been made more precise.

Part Three is a further extension of the theory along even more tenuous lines. Stated in the form of an assumption, it is an attempt to develop geometric implications from the theory. A second application, using the City of Providence once more, is presented in this section.

The Conclusion summarizes the possible uses of the theory and suggests lines of further study.

PART ONE

THE THEORY

1. Conditions of the theory

The hypothesis that will be advanced below is intended to describe and explain the urban structure of contemporary American cities. The sense in which the term "urban structure" is used here conveys not only three-dimensional aspects of the city, such as buildings, bridges, and highways, but more particularly those aspects of the city dealt with by physical planners such as land use and transportation. The hypothesized theory is not intended to explain such non-physical aspects of the city as its sociological or economic basis. These aspects must, of course, be included in any complete theory of urban structure (or, more generally, urbanism) but they lie beyond the scope of this particular hypothesis, even though factors that are economic and social in nature will be utilized in its derivation.

This hypothesis is restricted to the contemporary American city, not only in an effort to reduce the number of factors involved in its formulation, but also because one of the tenets of the hypothesis is that the contemporary American city is, or is becoming, a different type of city from any that have existed in the past. By the term "contemporary American city" is meant a reasonably large-sized (population above 50,000) metropolitan area.

A successful physical theory of urban structure must include both an explanation of why the structure has developed and a description either of what the development has been or what it is tending to become. For these reasons, it appears that such a theory must provide a descrip-

tion of the city which will enable physical planning to proceed more successfully than it could in the absence of the theory: a theory which cannot be applied to the real physical city is of little value to physical planners.

In summary, then, the theory that is sought is one that will describe the disposition of the physical elements of the city and the inter-relationships between them in such a way as to provide a guide to the physical planning and replanning of the community.

2. Postulation of the theory

The theory which I wish to propose in this thesis was originally formulated partly from observation of land use maps, and partly as a result of intuitive reasoning from them. Two types of support will be offered for the theory: the first is simply an explanation of what it implies, given in the hope that the (to me) apparent correspondence of this theory with the real city will also become apparent to others; the second is by an illustration of the theory as applied to a reasonably typical American city.

Briefly stated, the theory is: that because of past developments in the nature of urban land uses, and especially because of the increasing differentiation and specialization that has arisen among them, the land use pattern of the contemporary American city is, or is tending to become, a pattern of four basic types of land use; that these ~~three~~ four basic types of use are residential, commercial, industrial, and recreational; that as a result of the increasing nucleation of these land uses

into districts the movement of people within an urban area can be explained in terms of interactions between use-districts; and lastly, that the pattern of use-districts and of the transport interactions between them is the basic pattern, or structure, of the city.

3. The separation of uses

The clearest difference between the American city of today and that of thirty years ago is the increasing separation of different land uses that has come about because of the increased specialization and compartmentalization of urban life. This specialization of urban life is only a part of the general trend in all world civilization since the industrial revolution. Our economy, founded as it is on production, makes use of cities as instruments of production. It appears to be that as cities become more efficient instruments of production their land use patterns become more specialized.

This specialization first takes the form of separation of land uses into residential, commercial, industrial, and recreational zones. More functionally described, these four basic zones are where people live, and play, where they exchange goods and services with one another, where they produce goods or exchange them with other cities, and where they relax. The separation of these three functions occurs because each of the three has different environmental requirements and these requirements are usually in conflict with one another.

Living areas, where people reside, play, and go to school require unobstructed sunlight, and air free from such nuisances as smoke, dust, noise, and odors. A pleasant residential area, where people will want

to live, should have open space for parks and playgrounds and should be free from high-speed, high-volume traffic. It needs, besides dwelling units, such ancillary uses as local shopping facilities, schools, and community centers. The amenities necessary to healthful urban life can be achieved in different ways and at different densities, but in order that they may be achieved the residences must not be admixed with industrial or commercial uses. Where this admixture has occurred in the past, in the larger American cities, the quality of residential life has suffered and often the result has been the creation of slums.

Shopping and office-building areas require good transportation facilities and must be closely built to provide maximum accessibility to customers, as well as to the workers in the area. Reasonable freedom from industrial nuisances such as heavy trucking, smoke, odor, and excessive noise are also necessary. Generally, the land values in commercial areas are the highest in the city, too exorbitant for most residential or industrial uses.

Industrial areas, especially modern ones, have been found to operate most successfully on large open tracts of land served by rail or truck lines. Since for the most part, they deal either with market centers dispersed throughout a metropolitan area or with other metropolitan areas, they need little or no direct access for customers but only for workers and freight. Some industrial uses can operate successfully in environments that would be considered unhealthy for residence or commerce, although this is not true for all industrial uses.

These conflicting requirements of these three basic urban uses do not mean that there are no uses that do not act as "bridges" between

different uses; rather they are norms toward which most elements of each of the three uses tend. Uses such as hotels combine some aspects of both residential and commercial uses; uses such as warehouses combine some aspects of both commercial and industrial uses. Other types of "bridging" uses, such as the tenement house with a store on the first floor, have proved undesirable and are no longer built, although many of them continue in existence. The stratification is not complete, it may never be, but the tendency is clearly in the direction of the separation of these three uses. In fact, not only has the separation tended to come about naturally, but, recognizing its value, society has made possible the establishment of such instruments as zoning regulations to hasten its achievement. Land use planning, as it is now practiced, has as one of its major objectives the attainment of use separation.

Before I go on to describe the further configurations of the three basic land uses it may be well to insert some mention of the fourth basic use, which seems to me to be less important than the first three. This last use is large park or recreation areas. These occur infrequently inside the otherwise built-up parts of American cities but are spatially important uses of land. Further mention of this fourth basic use will be found below.

4. The pattern of use-districts

There is a second observable physical pattern of land use separation, wholly consistent with the separation of the basic uses, that occurs in conjunction with the general spatial separation. This is a further separation, or nucleation, of each of the uses into a series of sub-districts. This formation into districts occurs in each of the

three uses for somewhat different reasons, but the overall pattern is similar for all.

Urban residential uses, for instance, do not flow on indistinguishably in obviously concentric or radial patterns from the urban center. Groups of residences within the general residential pattern have certain common functions. One of these common functions is the elementary school around which the well-known "neighborhood" planning unit has been centered. As a functional nucleus, however, the elementary school district has as its key drawback the fact that its functional effect is largely on the elementary schoolchild who is in the minority in almost all residential areas. A more important functional center is the local shopping center, because it is a common focus of interest for most of the adult population of an area. In somewhat the same way as the central commercial area is a common focal point for an entire metropolitan area, the local shopping center is the focus for a residential use-district. It must be pointed out here that by "local shopping center" is not meant a grouping of two or three corner stores but rather a local community center that may contain, in addition to a number of basic stores, some recreation uses such as theaters and some local governmental functions.

Examples of the residential area centered around a local commercial core spring readily to mind. One such area is that around Harvard Square in Cambridge. Located around the localized shopping center is an area primarily devoted to residences. The area extends toward Central Square along Massachusetts Avenue in one direction and towards Porter Square the other way along the Avenue. Watertown center is the next important local center along Mt. Auburn Street. With this example one fact about

the use-district becomes apparent: the center is more easily defined than is the boundary between districts. The precise line where the influence of Central Square leaves off and that of Harvard Square begins is impossible to locate, but the approximate location of this line is not too hard for a person familiar with Cambridge to locate.

Other residential use-districts in the Boston Metropolitan Area could also be cited as examples. The Morton Street-Blue Hill Avenue retail development is the center of such an area in Dorchester. Its influence borders on yet another, the Mattapan Square center.

The residential use-district is an area of general residential development situated around, and dependent for many services upon, a local shopping center. The local shopping center can be defined as the point of highest access for the people living in the use-district. It is the single spot easiest to reach for the greatest number of them.

The commercial use-district is more commonly known as the central business district. A city may have one or more business districts that are large enough and have a sufficiently great radius of influence on surrounding areas to deserve the classification of commercial use-district. In districts of this type are centered one or more of the major institutional activities of the metropolitan area: retail business, offices, government functions and commercial recreation. The influence of the commercial use-district extends to a number of residential use-districts. Usually in large cities there is one location of prime importance that is the center of the entire city and others of lesser importance which, while of a smaller size and importance than the central

district, still serve groups of residential use-districts. These secondary commercial use-districts rank between the local centers serving a single residential district and the city-wide central district.

In the Boston metropolitan area downtown Boston is the central district while Salem and Quincy centers can be ranked as secondary commercial use-districts. The new Shoppers' World at Framingham may well be an example of the development of a new type of second-rank commercial use-district.

The phenomenon of a center and a dependent area occurs internally to the commercial use-district in much the same way as the commercial use-district acts as a center for the city-periphery that it serves. The point of highest access in the commercial use-district, otherwise known as the "100% district" and usually occupied by department stores is the functional center of the commercial use-district. Around it are dispersed the other functions of the commercial use-district, usually at distances from the center inversely proportionate to their ability to pay ground rent.

The industrial use-district, where such activities as wholesale commerce, warehousing, and industrial production are located, is commonly dispersed about a transportation facility such as a rail line or a good truck road. This is due to the heavy dependence of these activities on shipment and receipt of goods. It is also important for them to be easily accessible from the residential use-districts where the people who work in industry live. One other factor that tends to cause industrial

and general commercial uses to congregate together is the benefit in internal exchange that can be derived from such agglomeration.

Thus, industrial use-districts are similar to commercial and residential use-districts in their possession of the two features of a high-access point (in this case a rail line or truck terminal or port facility) and a dependent area. An example of an industrial use-district is the area in South Boston centered around both Commonwealth pier and other port facilities and the railroad line that serves the piers.

The fourth major use of urban area, parks and other large recreation uses, is different from the first three use-types in that they are most utilized on weekends or in the evenings when the commercial, industrial, and residential districts are least active. Activity, in this case, is defined as movement between districts. Developed open recreation areas, such as Franklin Park in Dorchester, seem to operate like commercial use-districts in drawing people to them. As will become evident in the discussion of transport patterns, the fact that park areas are utilized when other areas are not makes them rather less important as a daily factor in the interaction between land use and transportation than the other three use-types.

5. <u>The generalized use-district</u>

Thus far the separation of general urban land uses into three major and one minor use-types has been shown to be proceeding in American cities and the nature of the separation (into use-districts) has been indicated. In this section the general characteristics that these use-

districts have in common will be discussed.

The most important characteristic shared by the residential, commercial, and industrial use-districts is their general structure. All three have what can be termed a nucleus: the local shopping center in the residential area; the "100% district" in the commercial area; and the rail, truck, or port facility in the industrial area. All three also possess a dependent area which is distributed around this center. By that I mean that the relationship between the center and the area of the use-district is such that the center is the most easily accessible point of importance to the periphery. In both the residential and commercial use-district the center is quite small in area compared to the area of the entire use-district; in the industrial use-district the "center" may be linear in nature, such as a rail line serving a number of plants along it. In all three cases the center, or nucleus, can be located quite definitely and precisely; the boundaries of the dependent area, on the other hand, are quite vague and often can be located only approximately. Where use-districts of different types abut on one another, such as a residential area adjacent to an industrial area (as occurs in South Boston, for example) the boundary seems to be clearer and easier to locate than when two residential use-districts, for example, abut on one another. The "line" where the influence of one local shopping center leaves off and another begins is bound to be vague and more like a zone of influence than a line.

Use-districts appear to vary in size in proportion to their distance from the center of the city. A rough indication of this is

available from Figure 1 in Part Two, which shows the City of Providence laid out in use-districts. In Providence, at least, inner use-districts appear to vary from about one-half a square mile to one square mile in area. In the outer reaches of the metropolitan area where densities are lower and development more scanty many districts seem to range upwards of two square miles in area.

6. The pattern of journeys

In addition to the simple existence of the land use pattern composed of districts, the theory postulated in the beginning of this thesis is concerned with the interactions between the land use districts. These interactions can be represented as the movement of people from one district to another inside the metropolitan area. (The problem of goods shipment has not been considered in the course of this thesis.) Due to the size of the use-districts it appears that it is unlikely that much traveling between districts is by foot. Also the boundaries are where settlement is least concentrated. Instead, commuting between districts seems to be mostly by private automobile or by one of the many forms of public transit. Bicycles are used for this type of travel in Europe, but are not usually so used in America.

The total amount of traveling done by automobile or public transit can be described in terms of a pattern. This is due to the fact that the movements of people in a city have both a secular and a short-term stability. This is especially true when all journeys are taken into account.

The secular stability of the journey-pattern comes about because

use-districts change slowly and only over periods of years. As long as a use-district is residential, for example, the number of people living in it will not change drastically over short periods of time, nor will the location of the work-places or shopping-places to which they must travel daily. The most rapid changes will occur in the periphery of the city where population growth has been most rapid in the past decade. The location of the great mass of people, however, and the location of most of their daily destinations, will change very slowly over time. Small parts of the pattern change continually, but the whole pattern of movement remains quite constant.

The short-term stability occurs from day to day, with the exception of Saturday and Sunday. For the five weekdays most people's daily travel is habitual and invariant. People go to work in the same places at the same time every day. Others go to shop at the same places and while the same people do not shop in the same place every day, the statistical result is that about the same number of people do shop every day in the various centers of the community. People visit one another at random, but the result of many people doing this, or of many people going to theaters or other recreation places, is that the total daily traffic remains constant and repetitive within quite close limits.

This double stability makes it possible, by finding where people go to on any one day, and then testing to find the expected daily variations from the pattern, to describe the total complex of journeys. This information will be statistically valid for a sufficiently long time so

that it can be used for planning purposes.

7. Summary of Part One

Thus far there has been presented a general theory of urban land use structure and an analysis of the transport interconnections between the various areas of which the contemporary American urban area is composed. The land use structure has been indicated to be made up of use-districts, each of a single predominant use-type, distributed about the central business district. The various journeys between these use-districts have been shown to be of a relatively stable, repetitive nature.

In the two Parts that follow are illustrations of how these two factors (land use pattern and journey-pattern) relate to one another in a typical city. These two phenomena, acting and interacting on one another, constitute the urban structure postulated in this thesis. In the remainder of the thesis two methods for examining this interaction will be considered.

PART TWO

An Application of the Theory

1. Method of application

In order to test the applicability of the theory that was formulated in the preceding part an application of the theory to a particular city will prove useful. While this application will not necessarily prove that cities are what the theory describes them as - i. e., complexes of interacting use-districts of various types - it seems sufficient to my present purpose to show that a city can be laid out in use-districts and that a measure of the interaction between these use-districts can be developed.

For the sample city I have chosen Providence, Rhode Island. The reasons for this specific choice were as follows:

(a) Providence and its metropolitan area have 438,000 inhabitants. This population size indicates a city quite large enough to have developed a complex urban pattern but not yet so large as to have developed a pattern which, like that of New York, is so immense and complex as to introduce too many complicating factors.

(b) Providence is a city about which there was much data available. In particular there is good data concerning both land use and traffic flow.

(c) My own knowledge of Providence, while slight, seemed sufficient to keep me from making any gross mistakes of interpretation in regard to it.

The first task, once the City of Providence had been chosen, was to lay out the city in terms of use-districts. The Providence Metropolitan Area used in the 1954 origin and destination study of Providence[1] was selected as determining the extent of the city, since it was from this study that I was enabled to obtain figures on traffic movement from place to place within the city. For this study of origins and destinations, the Providence Metropolitan Area was divided into tracts. These tracts generally were census tracts within the city proper and local town boundaries outside. The tracts did not coincide with use-districts since they were formulated in another way entirely. In order to group the survey tracts so as to form close approximations to use-districts I had to call upon the services of a fellow student, Mr. Robert Rowland, who very generously devoted his time to grouping survey tracts into use-districts. He was able to do this by virtue of the intimate knowledge of Providence he has gained while working for the Providence Redevelopment Agency. I am indebted also to Mr. Donald Graham, Executive Director of the Redevelopment Agency who also gave generously of his time and experience in the laying-out of the use-district map which appears here as Figure 1.

The fact that Rowland and Graham were able to develop such a use-district map using, substantially, the definitions of use-districts given in Part One of this thesis, serves as an indication that these districts are, in large part, natural divisions of the city, and also that people engaged in laying-out a city into use-districts should arrive at quite similar results. The requirement that use-district boundaries must coincide with survey tracts introduced some error.

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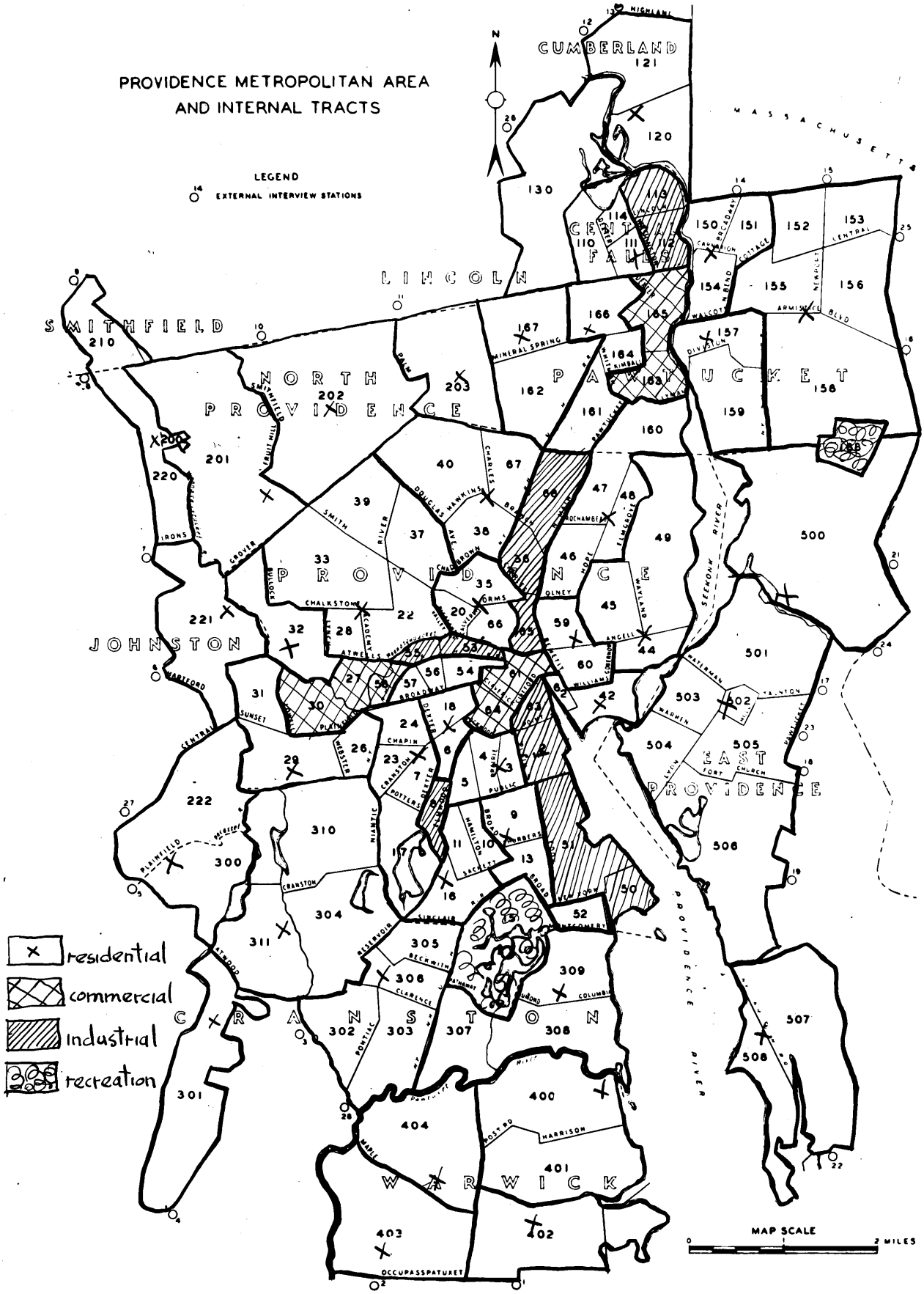
[1]Department of Public Works, State of Rhide Island, "A Traffic Survey of the Providence Metropolitan Area," Providence, 1945.



USE-DISTRICTS FIGURE 1

In the case of a few of the use-districts as shown on Figure 1, the district does not have all of the features it should. Especially in the peripheral area of the city, lightly settled use-districts have no clearly definable centers. In the case of certain centrally-located residential districts, the local shopping center of the district seems to be replaced by a major business center. This type of district is like the Central Square, Cambridge, area which is both a regional sub-center for shopping and the local shopping center for a residential area.

2. The origin and destination survey

Before proceeding with the description of how traffic data was applied to the use-district map, I have felt it desirable to insert a brief description of how origin-and-destination surveys are made and the uses to which they can be put. The origin-and-destination survey, as it has been developed for use in American cities by state and city highway planners and by the federal Bureau of Public Roads, consists of two parts: a statistical sampling of a population of automobile drivers and sometimes of rapid transit riders also, and a presentation of these results in a graphic form so that they can be used in highway and street design. The general procedure used in the surveys has been as follows: First a metropolitan area is divided into a number of tracts, usually bounded by important thoroughfares. Then a cordon of inspection points is established around the periphery of the metropolitan area. Inspectors are stationed at the points where roads into and out of the city intersect the periphery to question drivers as to the places where their journeys began and the places where they are going. At the same time other inspectors are sent to a number of

homes and offices inside the metropolitan area to ask the same questions of residents and workers. These are selected on the basis of a statistically representative sample since the task of interviewing all potential drivers and riders is too large. The questioning is usually done over a reasonably short period of time so as to obtain a nearly simultaneous picture of the pattern of movement.

After the material is gathered it is tabulated and the sample is expanded to fit the entire statistical population. A table can then be prepared in which the expected number of trips between every pair of sectors or between every sector and every cordon point is listed. This table is the first result of the study.

One common form of graphic presentation of the results of the survey is as follows: all of the combinations of possible trips are stratified by size and each size class is plotted onto a map of the metropolitan area by drawing a line of appropriate thickness as determined by the number of trips between the sectors or cordons. Depending on the complexity of the information involved a greater or lesser number of maps may be drawn. Maps showing trips between external points and internal sectors or between internal sectors may be presented separately. Frequently transparent overlays are used in an attempt to provide greater clarity. Often, maps showing the pattern of trips between the central business area or areas and the rest of the metropolitan area are shown as well. These maps are known as "desire-line" maps since they show the desire of the people to move from place to place, not the actual routes that they take. This latter information can be obtained from traffic-flow maps which show the actual

amounts of traffic on the streets of the metropolis as determined by electronic counters or by human tabulation.

Figure 2 is a desire line map for all tract-to-tract relationships of under 200 cars per 24 hours. From it the greatest drawback of the desire-line method becomes apparent: it is not an easy map to interpret. The criss-crossing, many-directional pattern gives a fairly good general impression, but the great complexity makes for difficulty of specific interpretation. This difficultyin the presentation of the survey data does not vitiate its usefulness however. There remain at least two other conventional methods of rendering the data, each of which seems more valuable than the desire-line technique. One of these methods is to lay out the data on a map of the existing street pattern of the city, thereby giving an approximation of the existing traffic flow situation. This is done by connecting origins and destinations by the most logical street route and assigning the desire-flow to the proper streets. This method can serve either as a check of the survey data against existing traffic counts, or, if some manipulation of the data is done in an attempt to correlate it with future population growth and location, a picture of "future traffic flow" on existing streets can be obtained. A second alternative method of using the survey data is to apply it, in the same way as is done in the first method, to one or more proposed new street or highway designs. In this way the efficiencies of various designs can be compared.

3. Application of data to the use-district map

Because of the superior clarity of the presentation wherein origin-and-destination data is applied to existing roadways as opposed to the


INTERCHANGE OF TRAFFIC HAVING BOTH ORIGINS AND DESTINATIONS WITHIN THE METROPOLITAN AREA, VOLUMES FROM 100 TO 199 PER DAY
N
MAP SCALE
0
2 MILES
HIGHLAND
MASSACHUSETTS
CUMBERLAND
LINCOLN
NORTH PROVIDENCE
SMITHFIELD
PROVIDENCE
JOHNSTON
CRANSTON
WARWICK
NORTH KINGSTOWN
EXETER
RICHMOND
HOPKINTON
WESTERLY
CHARLESTOWN
SOUTH KINGSTOWN
NARRAGANSETT
NEW SHOREHAM
BLOCK ISLAND
WOONSOCKET
CENTRAL FALLS
PAWTUCKET
EAST PROVIDENCE
BARRINGTON
WARREN
BRISTOL
TIVERTON
LITTLE COMPTON
DARTMOUTH
FALL RIVER
SWANSEA
SEEKONK
REHOBOTH
ATTLEBORO
NORTH ATTLEBORO
NORTON
MANSFIELD
EASTON
FOXBORO
SHARON
CANTON
STOUGHTON
RANDOLPH
HOLBROOK
BRAINTREE
WEYMOUTH
MILTON
QUINCY
BOSTON
HINGHAM
HULL
COHASSET
SCITUATE
MARSHFIELD
DUXBURY
PEMBROKE
HANOVER
NORWELL
HANSON
ABINGTON
ROCKLAND
HINGHAM
WEYMOUTH
BRIDGEWATER
WEST BRIDGEWATER
EAST BRIDGEWATER
BROCKTON
WHITMAN
HANSON
PLYMOUTH
KINGSTON
DUXBURY
PEMBROKE
HANOVER
NORWELL
HANSON
ABINGTON
ROCKLAND
HINGHAM
WEYMOUTH
BRIDGEWATER
WEST BRIDGEWATER
EAST BRIDGEWATER
BROCKTON
WHITMAN
HANSON
PLYMOUTH
KINGSTON

FIGURE 2

"desire-line" rendering of the same data, it is this former method that I have chosen for the illustration of the use-district theory. In order to apply the Providence data to the use-district map, certain simplifying assumptions were made. These assumptions were necessitated by the form in which the data was available.

First, there were over 5,000 combinations of tracts. To reduce this number to workable size all tract-to-tract relationships under 200 auto trips per 24 hours were eliminated. Figure 2 serves the additional purpose of showing the reasonably even distribution of this size group of figures, thus indicating that little meaning was lost by this decision.

Secondly, it was necessary to group tracts into use-districts and to determine district-to-district figures. The elimination of the smaller numbers did not reduce the magnitude of this task. To change the Providence table, which consists of 35 pages of closely-printed numbers from tracts to use-districts would be simple if some mechanical punch-card system ~~was~~ were available. Unfortunately, this was not the case. Therefore I chose to compute only those district-to-district relationships that seemed most important. For business use-districts these included all relationships with other districts; for industrial districts the relationships with the two surrounding "rings" of tracts; and for residential districts only the relationships with contiguous tracts were used. This decision reduced the problem to manageable size, but at the cost of some accuracy. Without it, however, the necessary mathematical manipulation would have been immense.

Figure 3 was arrived at by a combination of the use-district map with the data from the Providence origin-and-destination survey, simplified in the manner already described. If the theory outlined in Part One is valid, then this drawing represents the basic pattern of urban movement and inter-relationship for the city. Similar drawings for other cities could be made, and by comparison, some of the ways in which the Providence pattern is unique or typical could be seen.

4. Description of the Illustration

Some measure of the accuracy of the illustration can be obtained by comparison of it with Figure 4 which shows the traffic flow as measured on the same principal streets at the time of the origin-and-destination survey. The overall patterns appear to be quite similar, granting that the illustration of the theory has been simplified greatly. Thus, the least that can be said for the illustration is that it seems to retain considerable accuracy, while simplifying and abstracting the situation. One important difference that must be noted between Figures 3 and 4 is that while the theory illustration shows only internal district-to-district traffic, the Traffic Flow map shows all traffic, including that originating in and destined for areas outside the Providence metropolitan area.

In the next part of the thesis, Part Three, a further extension of the theory will be made with the objective of developing an even more abstracted diagram of use-district interactions. The similarities between Figure 3, the first theory illustration, and this later geometrical abstraction will be quite interesting.

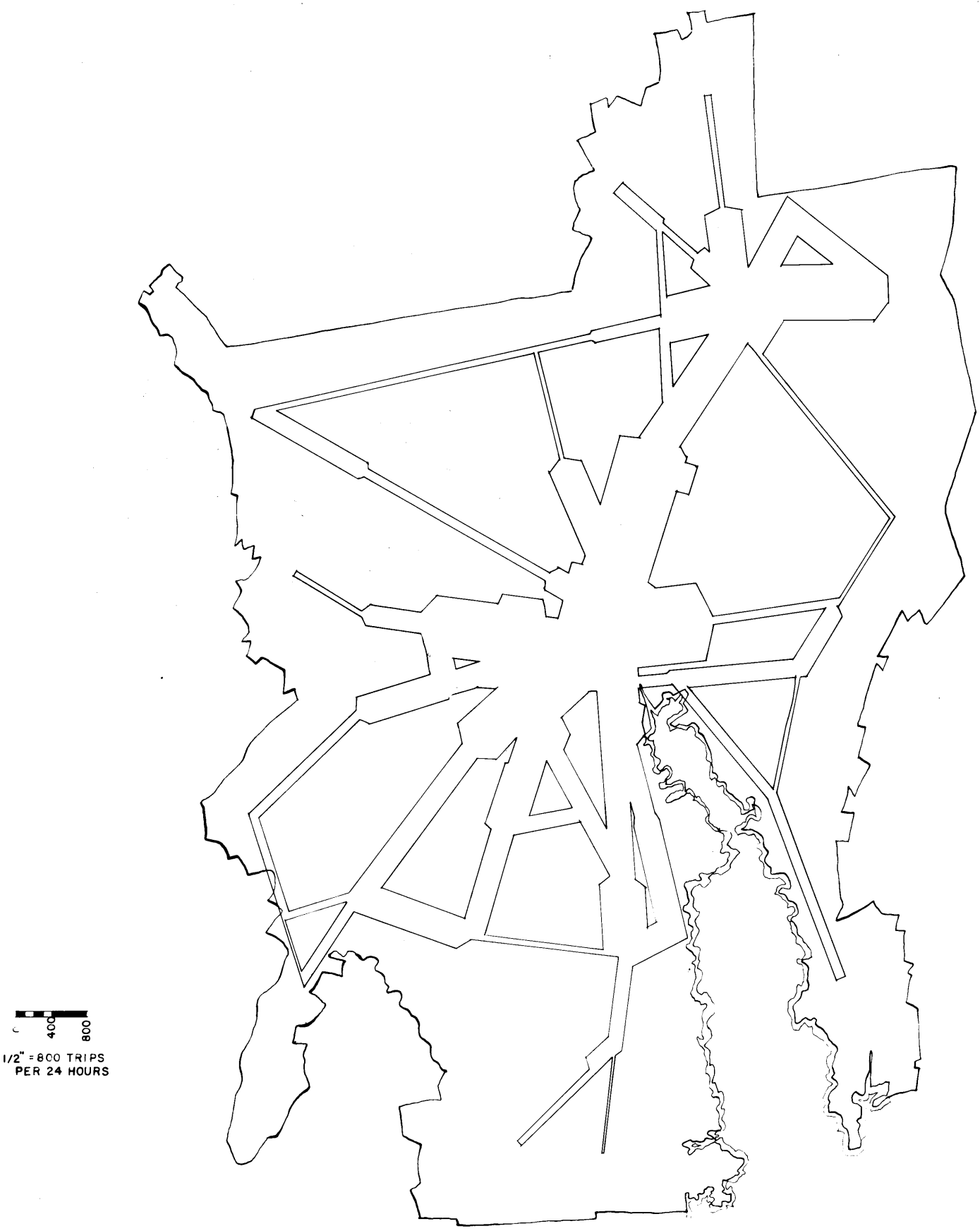


ILLUSTRATION I

FIGURE 3

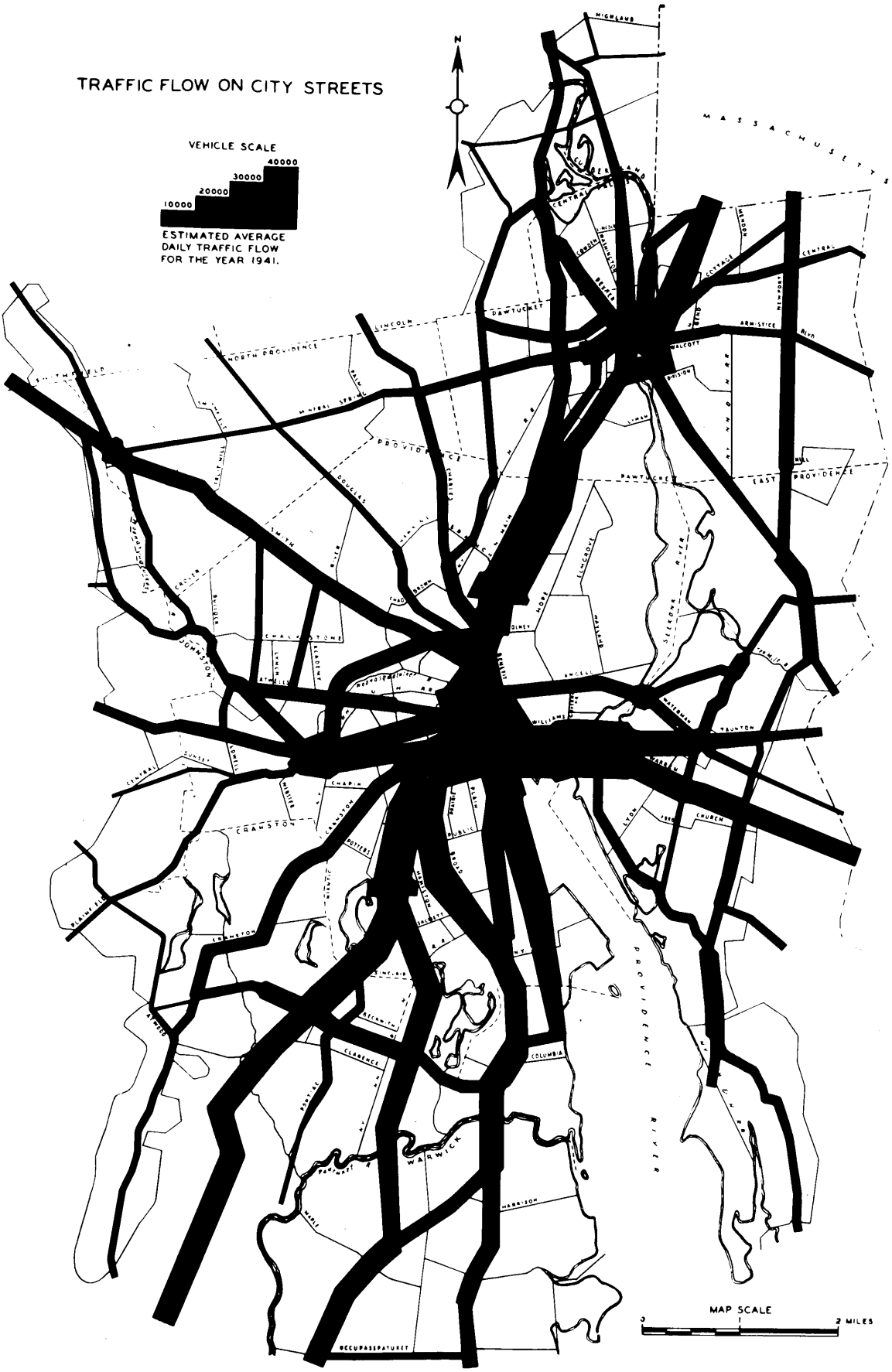

TRAFFIC FLOW ON CITY STREETS
VEHICLE SCALE
10000
20000
30000
40000
ESTIMATED AVERAGE DAILY TRAFFIC FLOW FOR THE YEAR 1941.
N
MASSACHUSETTS
PROVIDENCE
PAWTUCKET
CRANSTON
WARWICK
NORTH PROVIDENCE
EAST PROVIDENCE
CENTRAL FALLS
LINCOLN
JOHNSTON
CUMBERLAND
NORTH SMITHFIELD
SMITHFIELD
GLOCESTER
FOSTER
SCITUATE
COVENTRY
WEST WARWICK
EAST GREENWICH
NORTH KINGSTOWN
EXETER
RICHMOND
HOPKINTON
WESTERLY
CHARLESTOWN
SOUTH KINGSTOWN
NARRAGANSETT
NEW SHOREHAM
BLOCK ISLAND
MAP SCALE
0
2 MILES

FIGURE 4

PART THREE:

A GEOMETRIC HYPOTHESIS

The theory developed in Part One of this thesis is based on the idea of use-districts as they actually exist in real cities. The example in Part Two uses use-districts as they actually exist, or are coming into existence, in the City of Providence, Rhode Island. In the following section a further extension of the idea of the use-district will be made in the direction of abstraction and generalization. In the course of the hypothesis that will be developed a number of quite broad assumptions, some of which are more justifiable than others, will be made. While I realize that this hypothesis can be no more valid than its most tenuous part, nevertheless I offer it because of the promise it seems to offer of a clear, geometric analysis of urban structure.

The hypothesis follows in large part reasoning similar to that used by the economist, August Lösch, in an article he wrote about the nature of economic regions.* For this reason I feel that it may be helpful to insert a brief resumé of the Lösch analysis at this point.

1. Lösch on the economic region

The Lösch analysis begins with an assumption of a flat plain on which farmers and consumers are scattered at random. Since the only production in this system is assumed to be that of beer grown on each farm, no one farmer has any particular production advantage over his fellows. His only advantage lies in the fact that he can sell his beer to the areas close to his farm more cheaply than any other farmers since

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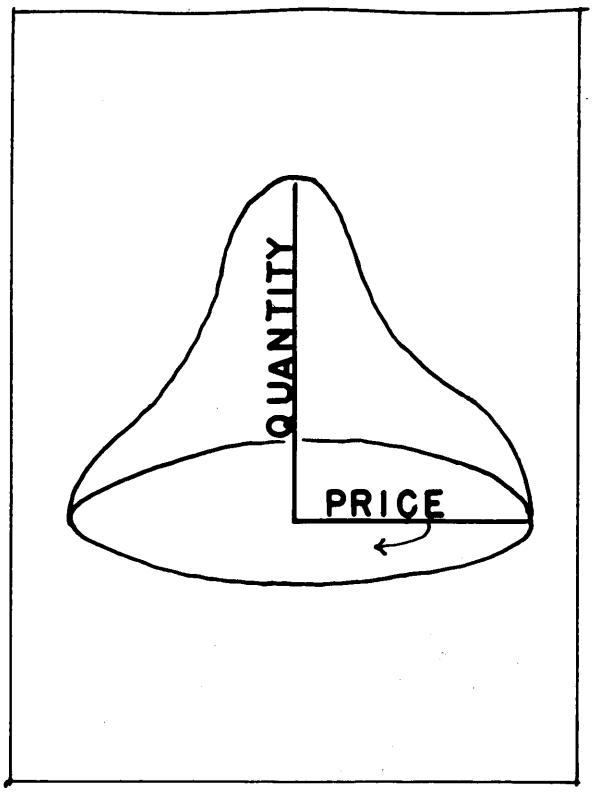
* August Lösch, "The Nature of Economic Regions," Southern Economic Journal, Vol. V, July 1938, p. 71 ff.

they, having to bring the beer farther, will have higher transportation costs. Lösch reasons that in this way a price-quantity relationship is set up such that the price of beer is lowest at each farm (no transportation) and highest at the edge of the farmer's market area. Quantities sold at any distance from the farm go down with the distance since the price must go up. Diagram A in Figure 5 shows the situation where the circular area is the market area that the farmer can control, the height of the cone at any point represents the quantities he can sell, and the radial distance out from the center of the market area is a measure of the price of beer at that point.

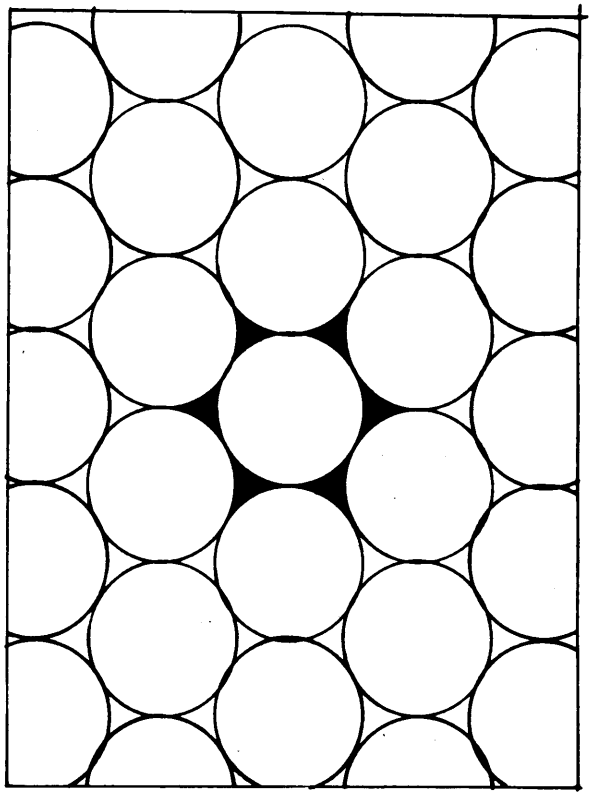
Since every farmer in the plain is in the same situation, each one has a circular market area of the same size. The size of the areas will be such that the farmer can just sell enough beer inside his area to keep him in business, since if there were more business than this other farmers would spring up and take the additional area away from him. This leads to the situation shown in Diagram B, where the plain is covered by circular market areas.

The circular situation is unstable, though, since it leaves interstitial areas (and therefore consumers) unserved. The farmers must expand to cover all the area, and in the expansion must depart from the circular market area. The nearest polygon to a circle that will cover a surface with no interstices is a hexagon, and therefore this becomes the new shape of the market areas, as shown in Diagram C.

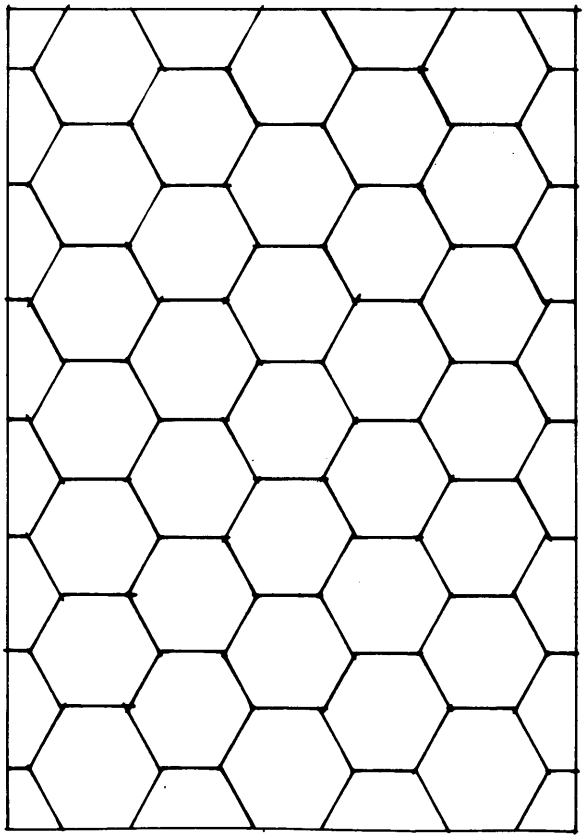
Lösch carries the argument further to develop larger sets of market areas (belts) that include the basic areas and even larger sets that



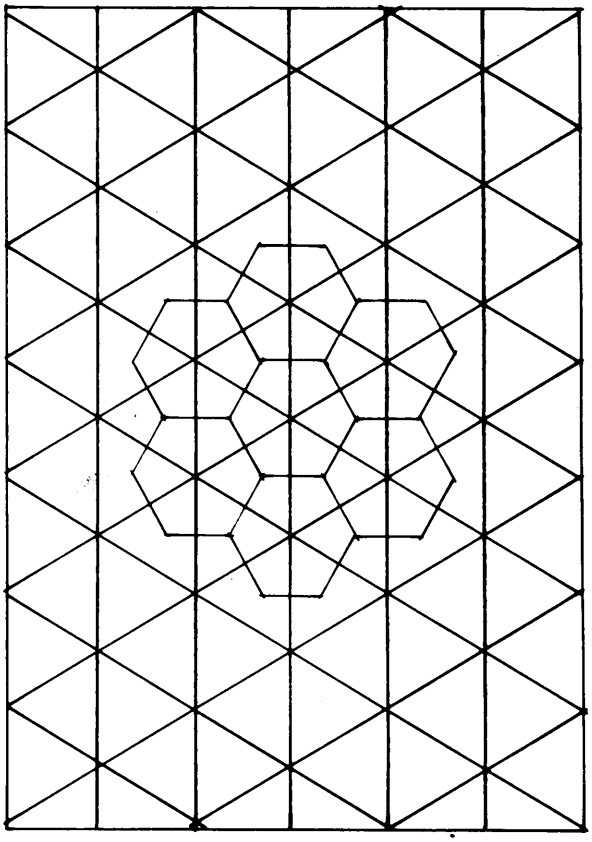
A



B



C



D

GEOMETRIC DIAGRAMS

FIGURE 5

include these (nets). The remaining point in his article pertinent to this thesis is the application of his system to a "metropolitan area." He shows that the formation of the centers of the market areas grouped around a single "city-center" is that of six radial sectors that contain many market centers, and six radial sectors that contain very few centers. He describes these as "community-rich" and "community-poor" sectors respectively. An empirical application of this to the city of Indianapolis, Indiana, (showing the location of community centers in the metropolitan area) gives a very close parallel to the theoretical situation.

2. Geometry of the use-districts

In attempting to abastract the structure of the city it is necessary to make the same assumption that Lösch does about the nature of the terrain: that it is a flat, featureless plain with no single spot holding any natural advantage over any other. In this terrain, for reasons which shall not be discussed here, a city can be assumed to have grown up. What form will it take?

The first answer to this question must be that it will tend to take the most efficient form to serve the purposes of the people of the city. This implies, at least for a people whose technical level is that of the American people that land uses will tend to separate themselves into use-districts in the way described earlier in this thesis. These districts, with the possible exception of the industrial use-districts, had two features in common: a center and an area dependent on the

center for the efficient satisfaction of certain needs. The center, or nucleus, is the single point in the use-district that is visited most often, either from other parts of a use-district, or from other use-districts. In the absence of topography or history it seems that the people or activities in a use-district would tend to distribute themselves symmetrically about the center. The density of settlement would be proportional to the "cost" of reaching the center, i. e., proportional to the distance from the center. The geometric figure that the use-district would tend to become, therefore, would be similar to that in Diagram A, Figure 4 where distance horizontally would represent the distance of any point from the nucleus (price) and the vertical height at any point would represent the density that would tend to be formed at that point (quantity).

Diagram B of the same figure shows the pattern that would be created by use-districts that covered the entire plain, leaving only the interstitial areas between the circles. When these interstices are eliminated, as in Diagram C, the remaining pattern of use-districts has become a pattern of hexagons.

Movement between hexagons, since settlement of people or activity within them is symmetric, can be treated as movement between hexagon-centers. This gives rise to the triangular grid of Diagram D. A certain error (added length of movement) is caused if all movement is said to occur on the triangular grid instead of anywhere in the plain. This error increases the distance of a journey from one center to another by a maximum of 16% of the length of the trip. The next most efficient simple

grid with straight axes is the rectangular grid and in this the added length varies up to 42%. Clearly the triangular grid provides a close approximation to straight line movement while at the same time greatly simplifying the pattern of movement.

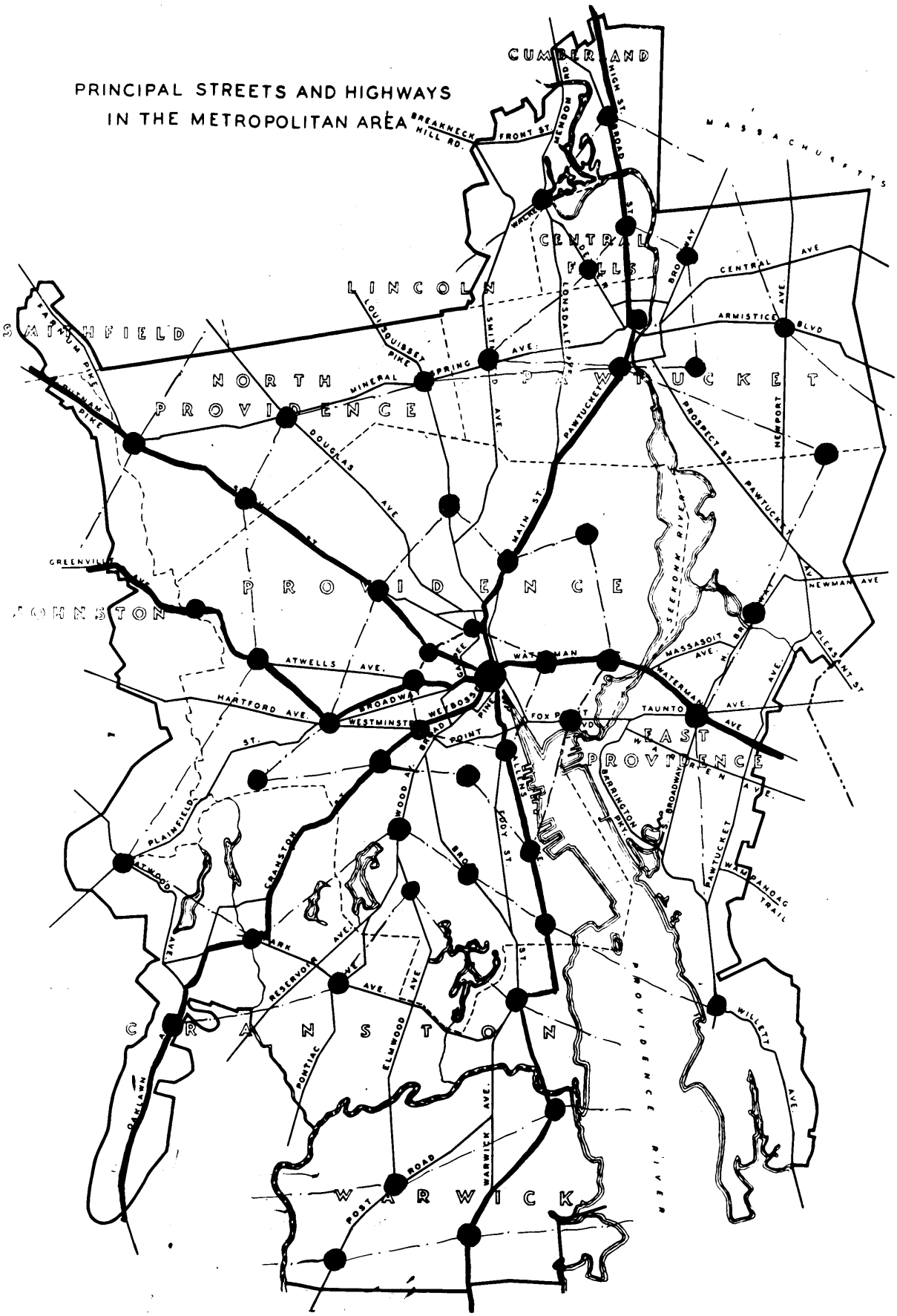
3. Application of the data to the grid

In the foregoing section a triangular grid has been developed which is an abstract representation of the connections between hexagonal use-districts. To compare this abstracted pattern to the use-district movement pattern of Part Two (Figure 3) the following was necessary. The use-district map of Providence was re-arranged in hexagonal form. That is, it was assumed that the Providence districts were hexagons arranged around the downtown Providence business center. To do this a traffic flow map of Providence (Figure 4) was used to discover which the main Providence radial routes were. Accidentally or otherwise, the number of these routes seems to be six. This fits the triangular pattern very well. Figure 6 shows the amount of distortion that was introduced in the process of "hexagonalizing" the Providence use-district map (Figure 1). Each of the concentric rings about point "0" should be a hexagon.

Then the same data as was used in Part Two was applied to the triangular grid of hexagon-centers. Figure 7 is the result of this operation.

4. Discription of the illustration

Thus Figure 7 is Illustration II, an abstract, geometrical version of Illustration I (Figure 3). Direct comparison of the two reveals general similarities. The most easily apparent difference is the clarity of Illustration II, based on the triangular grid. It is not possible,



GRID DISTORTION

FIGURE 6

of course, on the basis of this single illustration to state that comparison of triangular grid patterns for different cities would reveal significant facts about their similarities and differences. Were this so the technique might prove quite valuable.

The advantages of Illustration II are that the regularity introduced by its geometry eliminates small details and leaves only the broad and basic features. As such it could hardly be used in its present form as anything other than a very general planning tool or an instrument in further theoretical research.

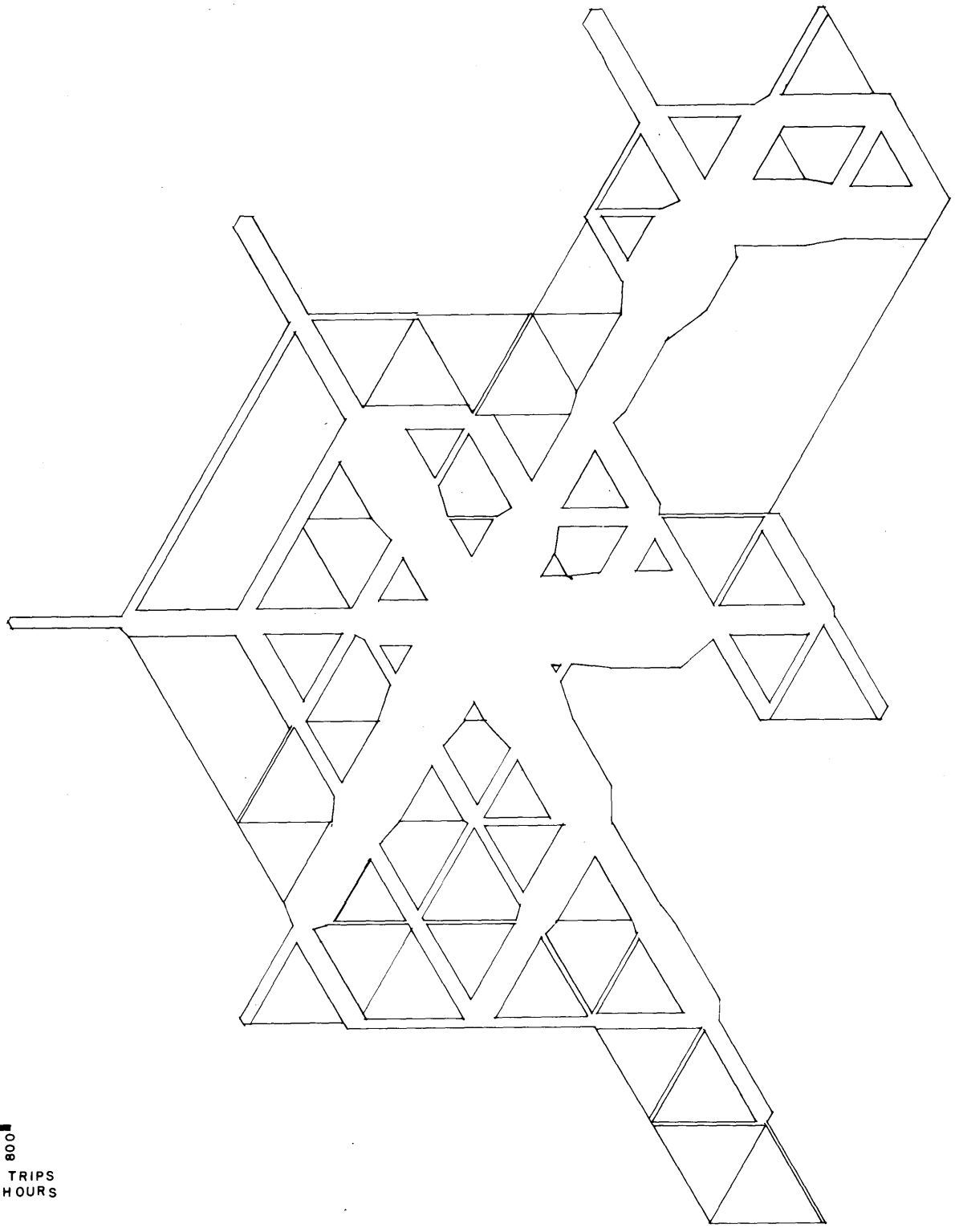


ILLUSTRATION II

FIGURE 7

CONCLUSION

In this thesis the hypothesis has been set forth that the land use structure of cities is composed of a series of districts of four different primary uses. These districts, all of which have certain important common aspects, are the basic land use areas of the city. Within the framework of these districts urban life goes on, and in movements between these districts the basic pattern of movement in the city is created. In addition to the presentation and definition of the theory in Part One, an illustrative application of the theory was made, using the city of Providence, Rhode Island, in Part Two. While the theory is as yet still so broad and non-specific as to be difficult of proof, the meaning of it and, to some extent, its validity, was measured in Part Two.

In Part Three a more tenuous extension of the theory was made in an attempt to create a geometric framework within which the theory might operate. This extension was based on assumptions about the nature and operation of cities that cannot as yet be considered to be proven. For this reason the geometric hypothesis of Part Three cannot yet be validified.

While it would be gratifying to be able to state in this conclusion that a theory has been formulated, tested, and either validified or found incorrect, such is not the case. The spirit in which I worked on this theory was speculative: it is perhaps more in the nature of an essay in the direction of a theory of urban structure than a statement of a theory itself. The field of urban structure or of land use pattern theory is a rich, but ill-defined one. I did not expect that with this one blow I should lay bare the mysteries of the city; I did expect, and believe that I have fulfilled my expectation, that I have made a start in a promising direction. To make

this direction clearer and to develop a precisely stated, verifiable theory is the work of many years. I am satisfied if I have made a worthwhile start.

The reasons for undertaking a study such as this on the theoretical basis of urban operation and pattern, in addition to the academic argument for the pursuit of knowledge for curiosity's sake alone, are several in number. The most immediately practical uses of this theory or its extensions are in land use planning and highway design. In land use planning an important consideration is the delineation of natural areas and their relations to one another. Use-districts as defined in Part One, would seem to be quite valuable as planning sub-areas of metropolitan areas. The inter-dependency of the use-district and its local center is as simple and usable a concept as the "elementary school" neighborhood with its more arbitrary concept of local shopping.

In traffic and highway planning the theory may prove useful as an additional and revealing method of presentation of the results of origin-and-destination surveys. Urban highways and freeways can be treated as high-speed connections between use-districts, for example.

A third possible use of the theory is for purposes of comparison and analysis of the land use and traffic patterns of existing cities. In order to compare the differences and similarities among the basic patterns of cities and thereby learn more of the nature of urban areas, it is essential to have a framework for their comparison. The use-district pattern, together with the traffic pattern among use-districts is just this sort of framework. This last use of the theory may well be its greatest potential value.

As stated and explained in this thesis, the theory of urban structure

is hardly a polished and definite accomplishment. It is, rather, a statement of direction and intent. It suggests, to me, the possibility of further work along the same lines to clarify definitions, tighten concepts, and by further applications and illustrations, to test further its validity. The possibilities of an extension and amplification of the hexagonal hypothesis of Part Three are especially appealing to me.

In this thesis, therefore, I have presented a method of looking at cities and the ways in which they operate that offers some promise, I believe, of future development and use. If this is so, I am content.

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