Contributions from Geography to Urban Transportation Research

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In recent years there has been an accelerating demand for attack on the problem of urban transportation, with emphasis on the need for interdisciplinary study of all relevant aspects of both the city and the various forms of transportation.

As an integrative discipline that concerns itself, in part, with the way different areas on the earth's surface interact with each other, geography has much to offer toward meeting these needs. Its value is well recognized by urban planning bodies, but much less so by State highway departments, only two of which have geographers on their permanent staffs, doing the sort of work for which they were trained.

No more than a half-dozen papers have been presented by geographers at the annual meetings of the Highway Research Board, and it may therefore be of value to present a brief review of the geographic concepts that are applicable to urban transportation research. These concepts are not necessarily unique to geography, but the insights that arise from them may be. Among them are location theory, central place hierarchy, urban functional classification, regional land-use analysis, simulation models, systems analysis, graph theory, and especially new approaches to cartography, including use of machines in mapping, mathematical maps, and distortions that will clarify the relations between distance, cost, and time.

Many substantive studies have been performed on specific cities and highway problems, and the mass of material accumulated by geography departments in the universities can be of considerable value to local researchers from other disciplines.

• BEFORE the transportation needs of a city can be assessed, it is essential to learn not only the internal characteristics of the city itself but also its relations with the region of which it forms a part, with other cities, with the country as a whole, and in some cases, even with the rest of the world. Thus, for instance, to be able to assess the transportation needs of the city of Seattle, the following factors, among a great many others, need to be considered:

1. The peculiarities of the city's physical setting—its elongated form, its invasion by water bodies, the profusion of hills.
2. The specific climatic conditions, which make for transportation problems very much different from those of, say, Toronto.
3. The marked functional zonation, into central business district, residential and industrial zones, a university district, and the ever-spreading suburbs; and the effect that this zonation has on the pattern of strip generation.
4. The economic base of the city, which rests in large part on the aircraft and forestry industries.
5. Seattle's status as the chief center in the Pacific Northwest, and its relation to the lesser centers in Washington, Oregon, and Idaho, and to the Canadian city of Vancouver.

6. The effect of the mountain barrier that separates it from the bulk of the United States, and from most of its own state of Washington, too.

7. Its dependence on hydroelectric power from the Columbia and Snake Rivers, and the effect of negotiations with Canada on the availability of additional power.

8. Its special relation to Alaska.

9. Its role as a world port on the Pacific, and the competition for its hinterland offered by Los Angeles, San Francisco, Portland, Vancouver, and even Prince Rupert (the last for the Alaska trade.)

By design, this list has almost nothing to say about the factor that must be considered above all others: people, their social needs, their esthetic likes and dislikes, their individual reasons for living in the city and moving about and beyond it. These excluded questions are the domain of the sociologist and the architect, whose skills have been recognized as essential to the solution of the urban transportation problem. The one characteristic the items included in the list have in common is that, in one way or another, they involve relations between places distributed on the earth's surface. To that extent, they are all in the domain of the geographer.

The present paper briefly examines the field of geography and the specific contributions it has made to an understanding of the urban transportation problem.

So brief a survey of so broad a subject can provide few substantive details, nor are such details altogether essential in a paper that is intended merely to put on the record the work that geographers have done, in a place where it will be available to researchers from other disciplines in the field of urban transportation. Reference will be made to a wide range of representative studies, and those who wish to delve deeper will find in the Appendix a short list of bibliographic and review articles that will help them locate other reports in their field of special interest.

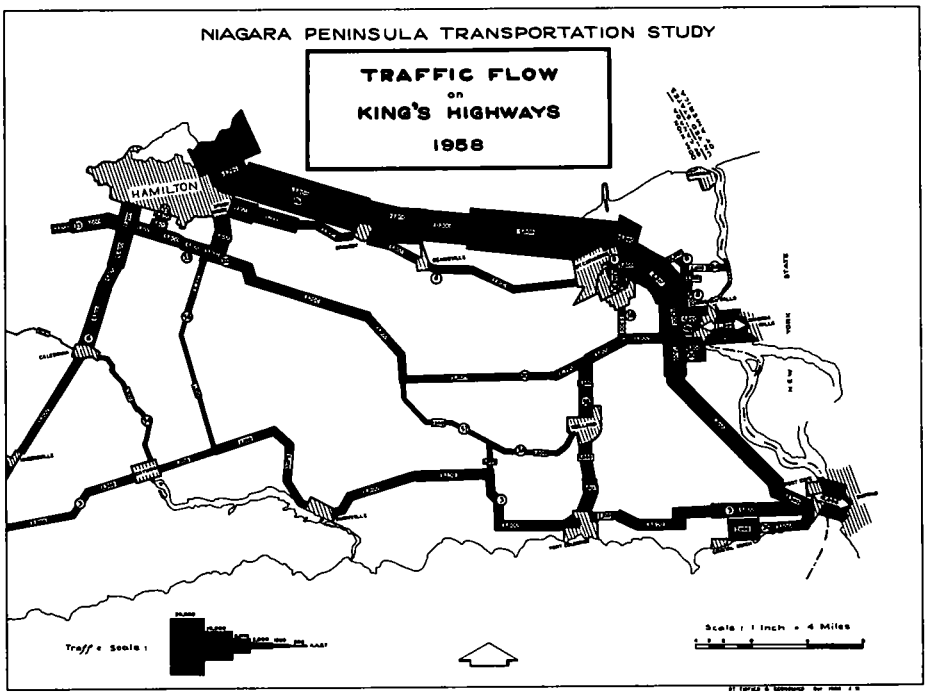


Figure 1. Information about traffic flow shown here used by engineers to help provide efficient facilities for movement. (From "A Highway Plan for the Hamilton-Wentworth Area," Dept. of Highways, Ontario (1961).)

THE FIELD OF GEOGRAPHY

Geography does not have a subject matter exclusively its own. What is unique to geography is its point of view, and nothing else. It is an integrative discipline; it tries to bring together all the phenomena that find an areal expression on the earth's surface, to discover and classify any uniformities that exist, and to clarify the causal relations between phenomena. In so doing, geography draws on a host of other disciplines for their special insights, thereby gaining a synoptic view of the problems that it examines.

As with other disciplines, there is no universally agreed on definition of the limits of the field. Engineers are familiar with the dictum, "Engineering is what engineers do"; similarly, "Geography is what geographers do." It does little good to define engineering in this way to geographers, or geography to engineers. But an example from each may help clarify at least some of the distinctions between the disciplines.

Figures 1 and 2 show two flow plans; the first is the flow of motor traffic on highways in a highly urbanized area, and the second, the flow of certain goods between one specific area in the United States and all others. The engineer uses maps such as that in Figure 1 to learn how much traffic each road in the area is expected to carry, so that he may make such changes in the road system as are necessary to allow the system as a whole to work efficiently; the geographer uses maps such as that in Figure 2 to learn something about the spatial interactions between the area under study and other areas. There is a very important distinction here, the distinction between the engineer's primary interest in the facilities for movement and the geographer's primary interest in the areas between which movement takes place.

Engineers will notice other differences between their ways of dealing with the problems of urban transportation and those of geographers, particularly academic geographers, in the discussion that follows.

Ullman's Concept of Spatial Interaction

Appropriately, the previous geographic example is taken from the work of Ullman (1),

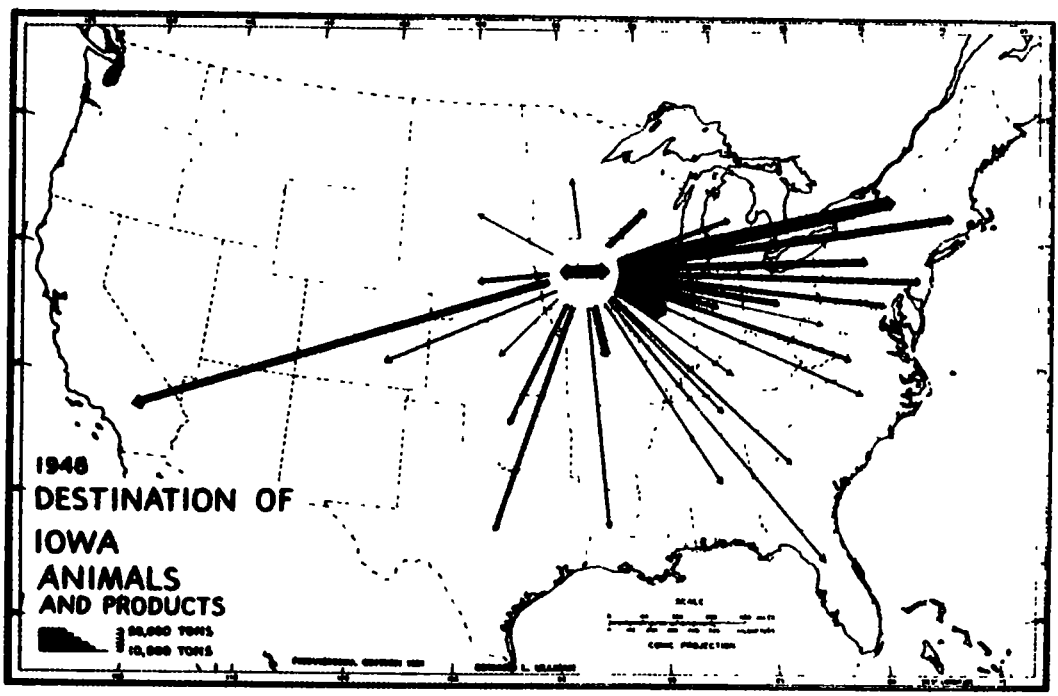


Figure 2. Information about commodity flow shown helps geographers gauge spatial interaction between areas. (From Ullman (1).)

for it is his conception of the primary concern of geography, as the study of spatial interaction, that may be suggested as a most fruitful theoretical foundation for the geographic study of urban transportation.

According to Ullman, there are three concepts that together are sufficient to explain the interactions between any two areas: the first is complementarity, the lack of something in one area that the other can supply; the second is intervening opportunity, which must be absent, otherwise the lack may be made up from this more convenient source; and the third, transferability, the sheer possibility of movement between the two areas taking place (1). It might be well to add a fourth concept, to take into account the action of the human will, which may disregard or change any or all of the other three. Because it may be peculiar to a given place or situation, perhaps it may be called idiosyncrasy.

These concepts are of direct relevance to the problem of urban transportation. For movement to take place between any two zones of a city, there must be complementarity between them; each must have something that the other needs; one may have workers, the other factories, one shoppers, the other stores. A newly created intervening opportunity may reduce the number of trips that formerly took place between two zones; for example, the building of a regional shopping center may cause fewer shoppers to travel from a nearby suburban residential area to the downtown districts. Of most direct concern to transportation planners are transferability and idiosyncrasy—planners may do their best to make convenient movement between two areas possible, by providing mass transit services, and yet these may go relatively unused, as people continue to overload the city's roads with single-occupant cars.

The field of geography, then, may be taken as the study of spatial interaction, which in turn involves a careful examination of the way specific areas differ from each other, and of the forces that these differences generate, which result in movement between the areas.

General Remarks on Geographic Techniques

The two techniques of which geography has traditionally made the most intensive use are the making of field trips and the compilation of maps. Indeed, these two activities fairly well sum up the popular idea of what geographers do—or did while they still had the chance. They went out to explore unknown places and came back with maps showing what they had seen. Of the two, it is the map that is most characteristic of geography.

Field trip and map, however, cannot by themselves tell the whole story. To them must be added the facts that can be gained only by the gathering of statistical information and its analysis. As with any other science, once masses of facts about a great many areas and their interactions have been gathered, the difficult tasks of generalization and the formulation of meaningful concepts must be undertaken. In this process there is necessarily a great deal of borrowing from other disciplines, such as geology, meteorology, geophysics, and especially with respect to the study of the city and of transportation, from sociology, economics, and history.

In geography, as in all sciences, there has been a prodigious leap forward in the last ten years. The solid foundation of direct, empirical observation is still there, as is the painstaking gathering of facts, but there has been evidenced an increasing sophistication in the analysis of these facts. Above all, a new school has emerged, the school of quantifiers, who are seeking to take advantage of recent advances in mathematical statistics, in operations research and linear programming, and in electronic computation, by use of which they hope to establish a set of geographic laws having a generality that has so far been impossible to achieve.

APPLICATION TO URBAN PROBLEMS

Internal Structure of the City

Some years ago the Wenner-Gren Foundation brought together scientists and scholars to discuss "Man's Role in Changing the Face of the Earth," of whom fully one-third were geographers (2). As students of the face of the earth, geographers are of course very

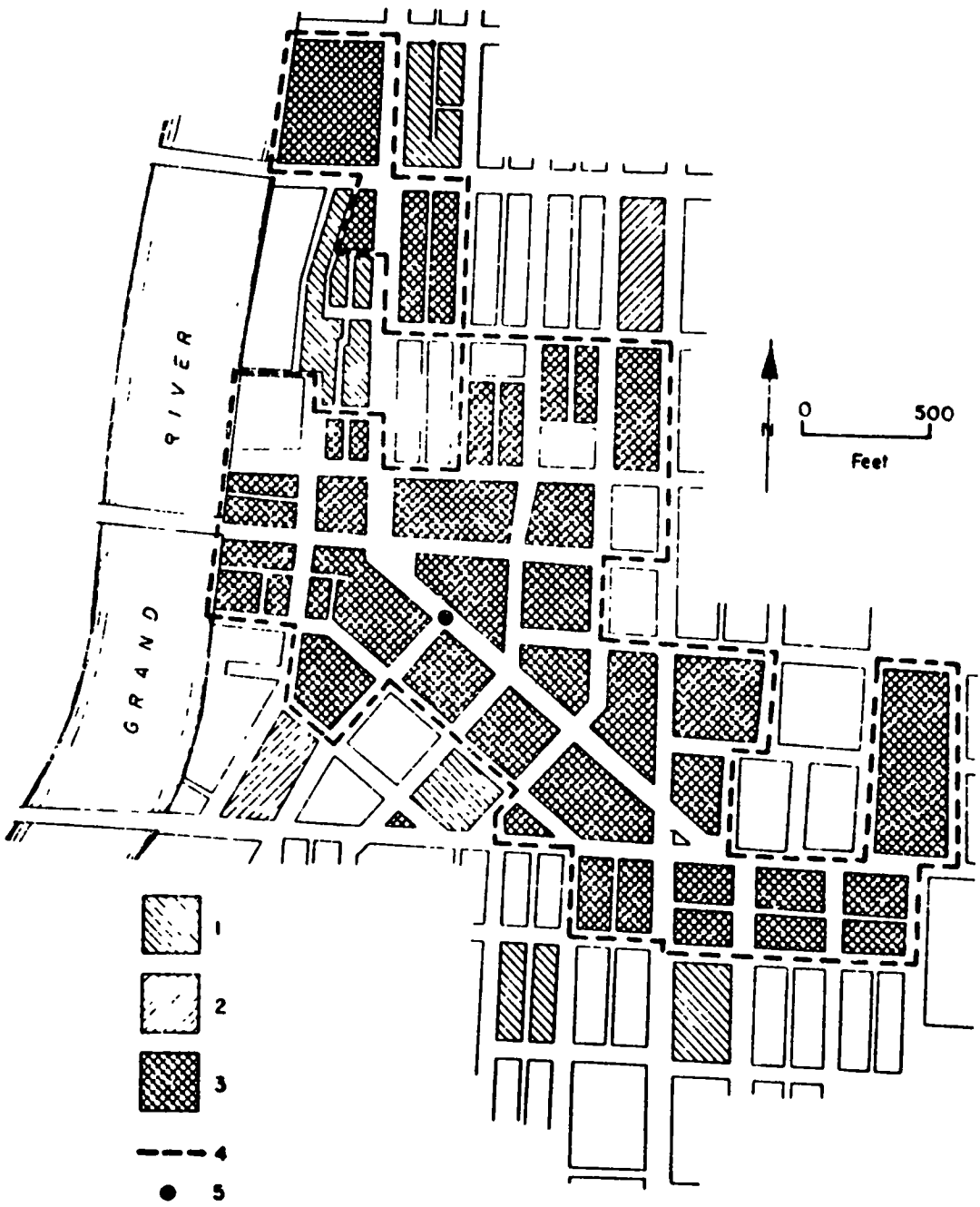


Figure 3. City blocks that make up CBD specified according to levels reached by their Central Business Height Index and Central Business Intensity Index. (From Murphy and Vance (5).)

much interested in the way man changes it, and in no way does he change it so radically, or in so readily observable a form, as in the construction of cities. Therefore, geographers have for a long time directed their attention at the city itself, the complexity of its organization, and the way different parts of it take on different physical qualities that correspond with their different functions.

There is a vast literature devoted to describing the growth and functional zonation of individual cities, and over a period of time the specific types of variations recurring in city after city have become recognized.

Too much attention need not be given here to this aspect of geographic work; all students of the city are aware of its functional zonation, and how much of their knowledge is attributable to the work of geographers, or of sociologists, is of little significance to them.

Two types of study, have concentrated on the very edge and the very center of the city, for in the interaction between these two parts of the city rise the most intractable of all problems in urban transportation.

The Rural-Urban Fringe. —On the edge of the city occurs the conflict between antithetical types of land use, with blocks of houses and factories pushing suburban development out onto once rural acres. Representative of such studies is the work of Krueger (3), who has become the recognized authority on the fruitlands of the Niagara Peninsula in Ontario, where some of the most valuable of the scarce tender-fruit acreage of this continent is fast disappearing under houses. In the United States, a similar phenomenon is occurring on a much vaster scale in Southern California, and it has been made the subject of a special supplement of the Annals of the Association of American Geographers (4).

The Central Business District. —Perhaps no single piece of geographic research has had so direct a bearing on all work on urban transportation as the study of the central business district by Murphy, Vance, and Epstein (5). Here, in a series of three papers, are presented exact quantitative methods for delimiting the CBD, a comparative study of CBD's in nine cities, and some conclusions about the internal structure of the CBD, based on the results of the comparative study (Fig. 3).

Murphy and Vance set themselves the essentially geographic task of defining a recognizably discrete region on the surface of the earth, a man-made region with characteristics of land use that are specific to it and are repeated over and over again in the landscape. Most important, they were determined to define the boundaries of that region in quantitative, objective terms, so that no matter who used the procedures they developed, the resulting conformation of the region should always be, within reasonably close tolerances, the same. They decided to use as the unit for describing this region, this central business district, not the lot, as had been usual before their time, but the whole city block. And the two criteria for measurement that they developed were the Central Business Height Index and the Central Business Intensity Index. The former is the number of floors devoted to the types of business characteristic of the central city, and is obtained by dividing the total floor area of all central business uses by the total ground floor area of the block. The latter is the percentage that the total floor area devoted to central business use makes up of the total floor space at all levels. Then they set up special rules by which they could designate entire blocks as being either in the central business district or outside it. They recognize the existence of a "core" area, an area that has since been intensively investigated by Horwood.

Horwood cooperated with Boyce in a program of studies that have materially advanced understanding of the effect of urban freeways on the city center. The results of their investigations were first presented before the Highway Research Board in January 1959 (6), and later the same year published in expanded form by the University of Washington Press (7, 52).

Durden and Marble (8) have pointed out that, although planners of the CBD have sought for a coherent body of ideas and concepts to provide perspective for their daily work, they have ignored theoretical developments in contemporary social science. They thereupon bring to the attention of planners a number of theoretical approaches from social science that the latter may find useful.

Location Theory. —Economists are paying increasing attention to that aspect of their

field that closely approaches the bounds of geography—the economics of location. Geographers have been happy to make use of the results of their labors, and location theory is becoming a recognized field of geographic study.

Building on the foundation laid by Lösch (9), they have developed new techniques and

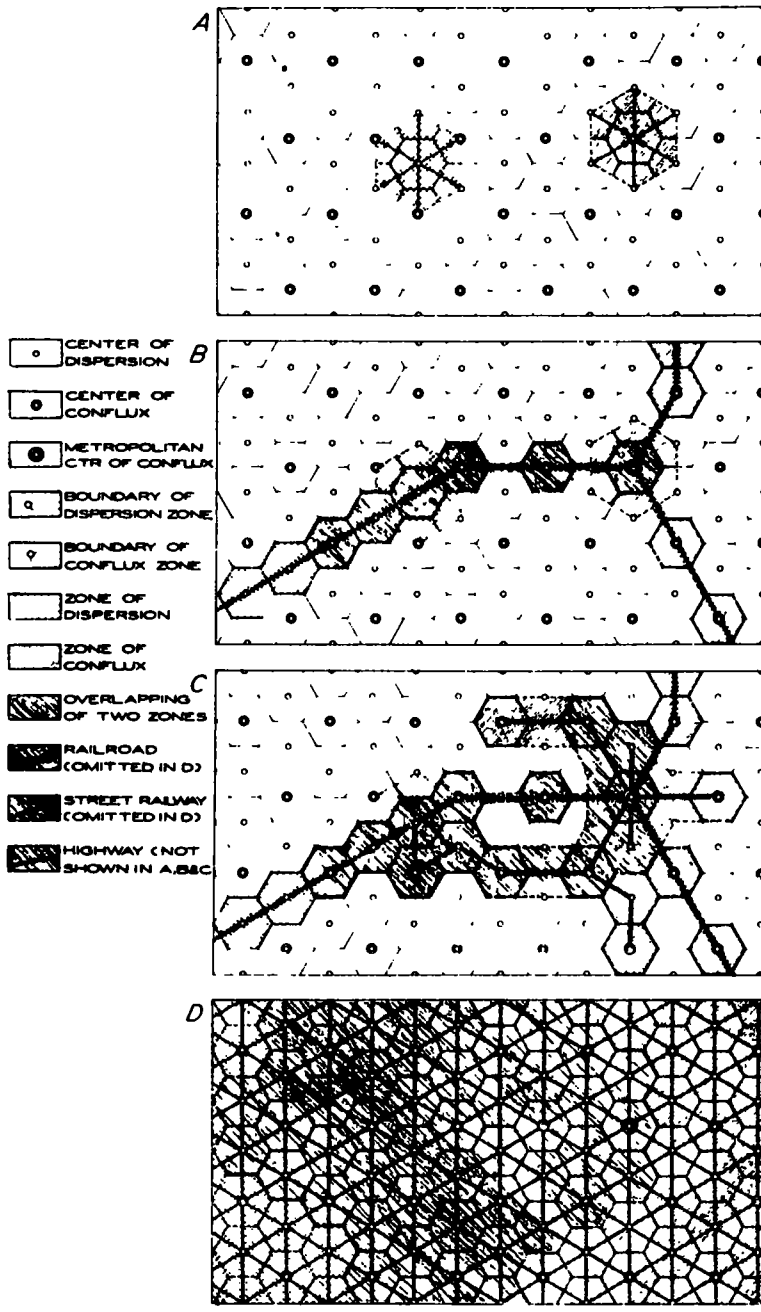
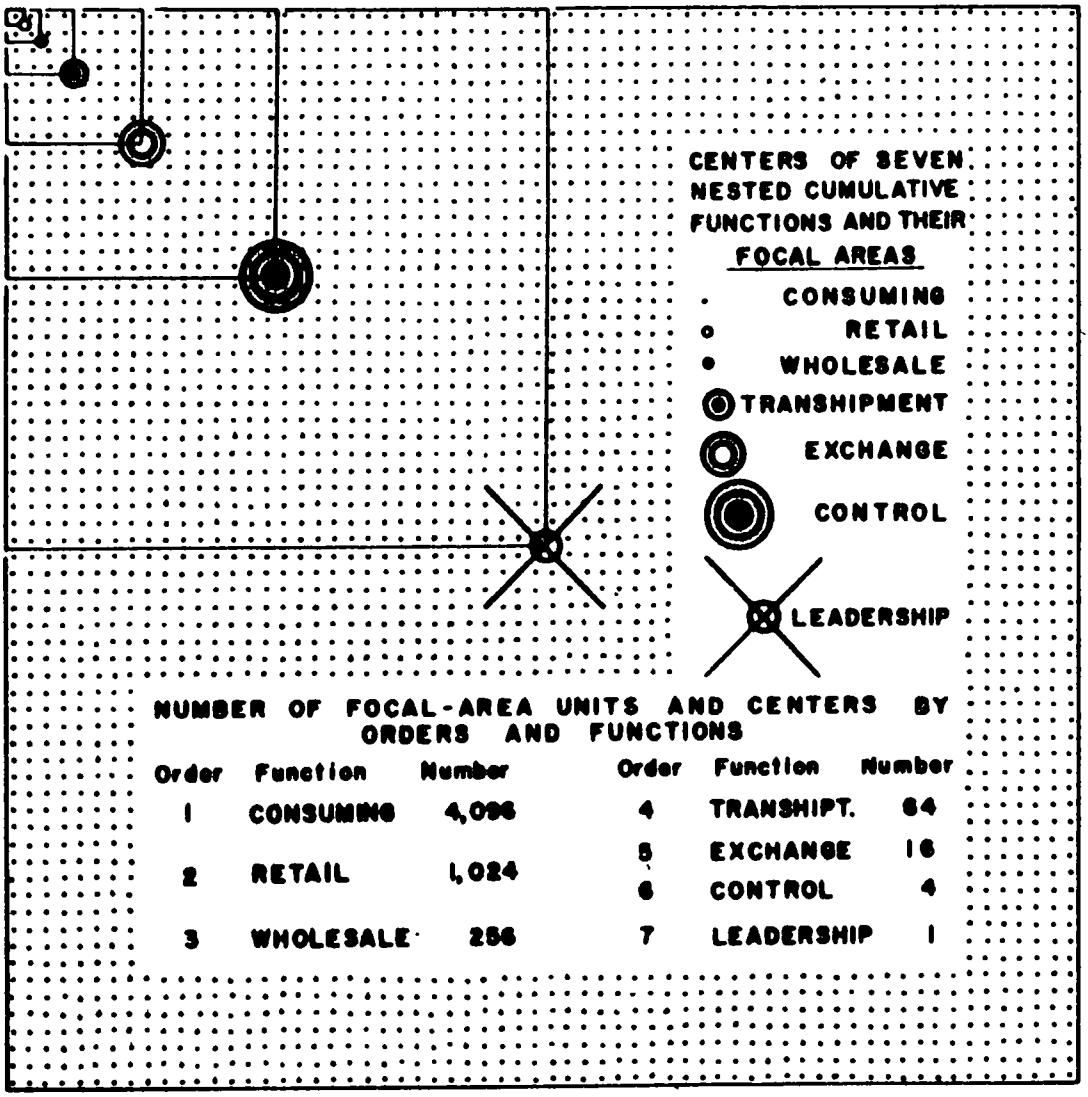


Figure 4. Christaller's hexagons used here to help lay theoretical foundation for empirical study of effects of changing technology of transportation on urban hinterlands. (From Vance (36).)

arrived at new theoretical concepts. Only a small part of location theory deals with the internal functional zonation of the city, but it is interesting and can lead to stimulating results. For example, if on a city map that gives nothing more than the distribution of population and of disposable income—nothing about the street pattern, functional distributions, residential areas, industry, or commerce—purely from theoretical considerations, exactly the right number of supermarkets, with each no more than a few hundred feet away from its actual location, can be exactly placed, then such results are something worth paying attention to. This is exactly what Getis (53) accomplished in his doctoral work on retail location in the city of Tacoma. If his results can be repeated for other cities, his technique should find ready application in urban transportation research.

External Relations of the City

The transportation needs of a city are determined not only by its own extent and the



NUMBER OF FOCAL-AREA UNITS AND CENTERS BY ORDERS AND FUNCTIONS

Order	Function	Number	Order	Function	Number
1	CONSUMING	4,096	4	TRANSHIPT.	64
2	RETAIL	1,024	5	EXCHANGE	16
			6	CONTROL	4
3	WHOLESALE	256	7	LEADERSHIP	1

Figure 5. Nested hierarchy of central places. (From Philbrick (14).)

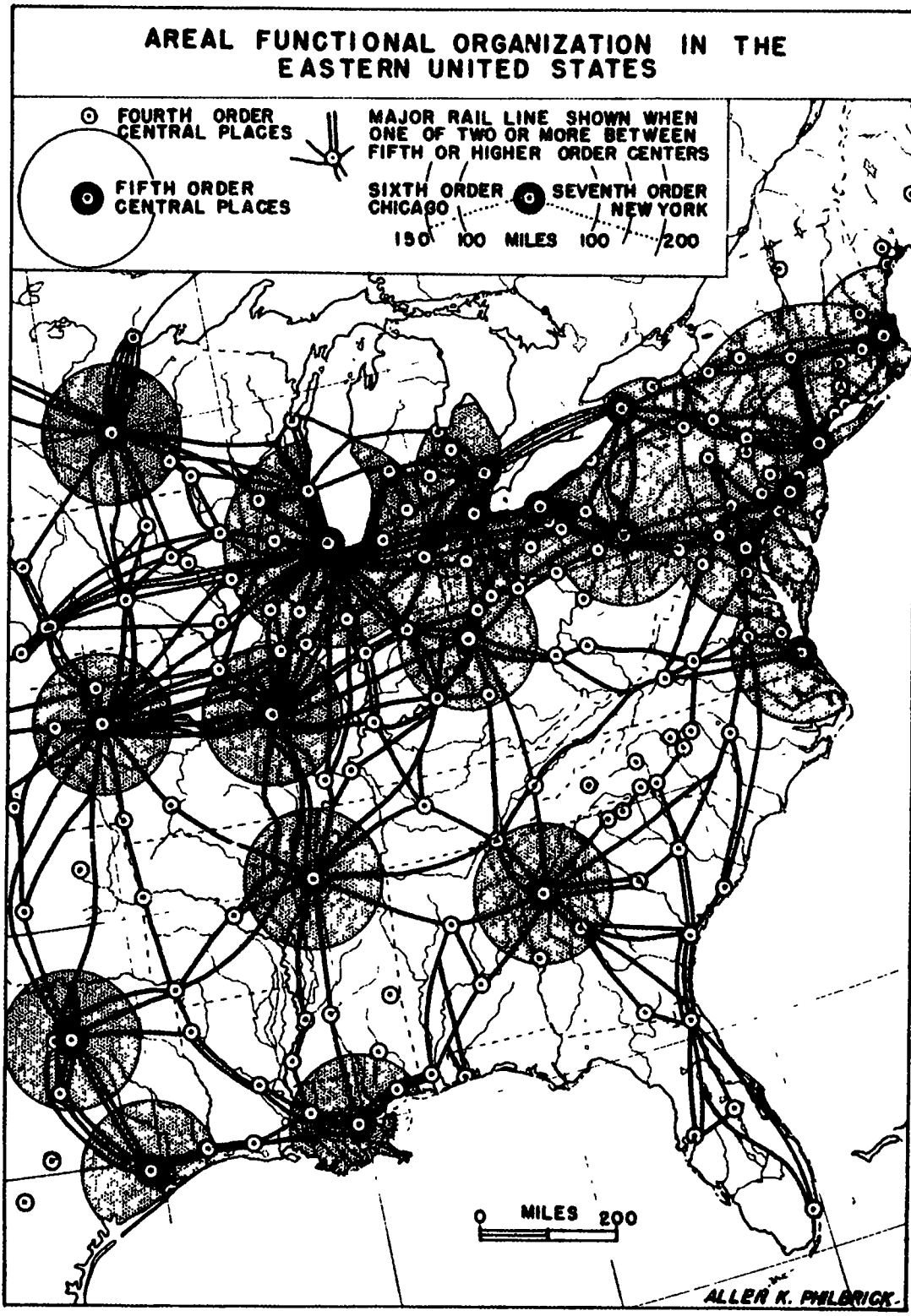


Figure 6. External transportation needs of cities conditioned by relations between these cities and others in hierarchy of central places. (From Philbrick (15).)

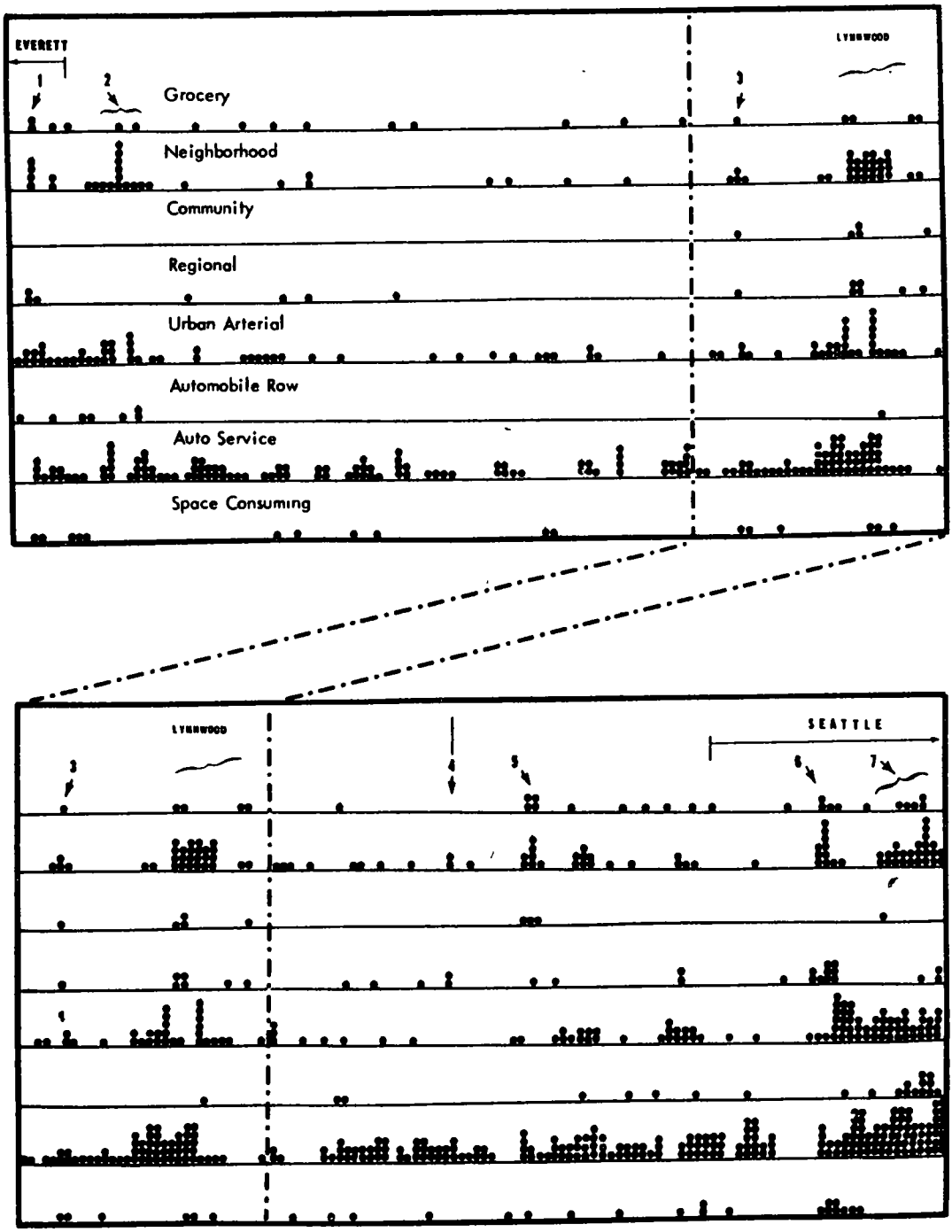


Figure 7. Problem of ribbon development along highways on outskirts of towns and cities related to those of urban sprawl and of premature obsolescence of highways. (From Berry (20).)

complexity of its own organization but also by the relation in which it stands to the surrounding countryside and to other cities. Indeed, its extent and complexity are themselves functions of its external relations; this is the subject of central place theory.

Central Place Hierarchy. —What causes a city to become great? Why does it inexorably arrogate to itself a greater and greater concentration of a country's or a region's population, wealth, industry, and cultural life? In what relation do the lesser cities of the country or region stand to this great city, and to each other? And what of the still lesser cities, towns, and villages: why are they where they are, of the size that they are, offering the precise services that they do? When all these questions are examined, a definite pattern begins to emerge, a pattern to which has been given the name "central place hierarchy."

The great city has been examined in such studies as Jefferson's "The Law of the Primate City" (10), which stimulated much subsequent research as, for example, by Stewart and Warntz (11), who separately and together have subjected the pattern to mathematical analysis. By far the greatest impetus to the study of central places has come from Christaller (12), who claimed to have discovered, in south Germany, a rigidly ordered hexagonal pattern (Fig. 4), to which he thought that the nested hierarchy of urban places everywhere would be found to conform. Further, there was not a gradual increase in population from the smallest place to the largest, but, instead, the places could be grouped in definite, discrete classes, and there were what might be called quantum jumps in population from class to class.

Christaller's work was first brought to the attention of American geographers by Ullman (13). Much work has since been done to test the validity of Christaller's ideas, and the results, though they have in no case confirmed the rigidity of his ordering, have been fruitful in pointing out other suggestive relations. Among the most interesting of such studies are those from which Figures 5 and 6 have been taken, by Philbrick (14, 15). Philbrick has ranked the central places of the United States in an ascending series of orders, from first to seventh (Fig. 5). All places in the eastern United States from the fourth order up, and the amount of railroad service each receives, are shown in Figure 6. This schematic presentation shows with great clarity how the amount of railroad service is related not only to the ranking of each place but also to its spatial position, and emphasizes the density of the rail network in the area contiguous to Lake Michigan and Lake Erie.

The conglomeration of cities on the eastern seaboard has received special attention. Jean Gottman (16) uses the term "megalopolis" to describe the coalescing of the spreading individual cities into this huge conglomeration. Jones (17) took a theoretical concept of Gottmann's and used it to reach an important insight about the city. Gottmann, interested in the development of political entities, has suggested that they come into being through the action of two somewhat opposed forces, circulation and iconography." The first term refers to both transportation and the communication of ideas; the second describes the whole system of symbols in which a people believes. Circulation is (in part) a system of movement, iconography of resistance to movement. The one makes for change, the other for political stability. Jones (17) suggests that:

> Many of the problems of a growing city arise from the fact that its circulation expands faster than its iconography. The metropolitan district outgrows the political limits, and vested local interests and loyalties make political expansion difficult. A sort of "metropolitan idea" may develop, leading usually to functional authorities rather than to political integration. There are a number of choices possible such as annexation of suburbs, city-county consolidation, metropolitan districts, functional authorities, state assumption of local functions.

Other concepts that have a bearing on the "metropolitan idea" are those of the "threshold" and the "range of a good," both of which have been given intensive study by Berry and Garrison (18, 19). The first deals with the size a city must achieve before it can support a given level of service (e.g., three doctors or five service stations), and the

second, with the distance that people are willing to travel to purchase the good, whether a physical object or a service. In the application of these concepts to individual places a broad range of tools is brought into use: location theory and central place theory, the writing of Lösch and Christaller, the economic tools familiar to urban planners,

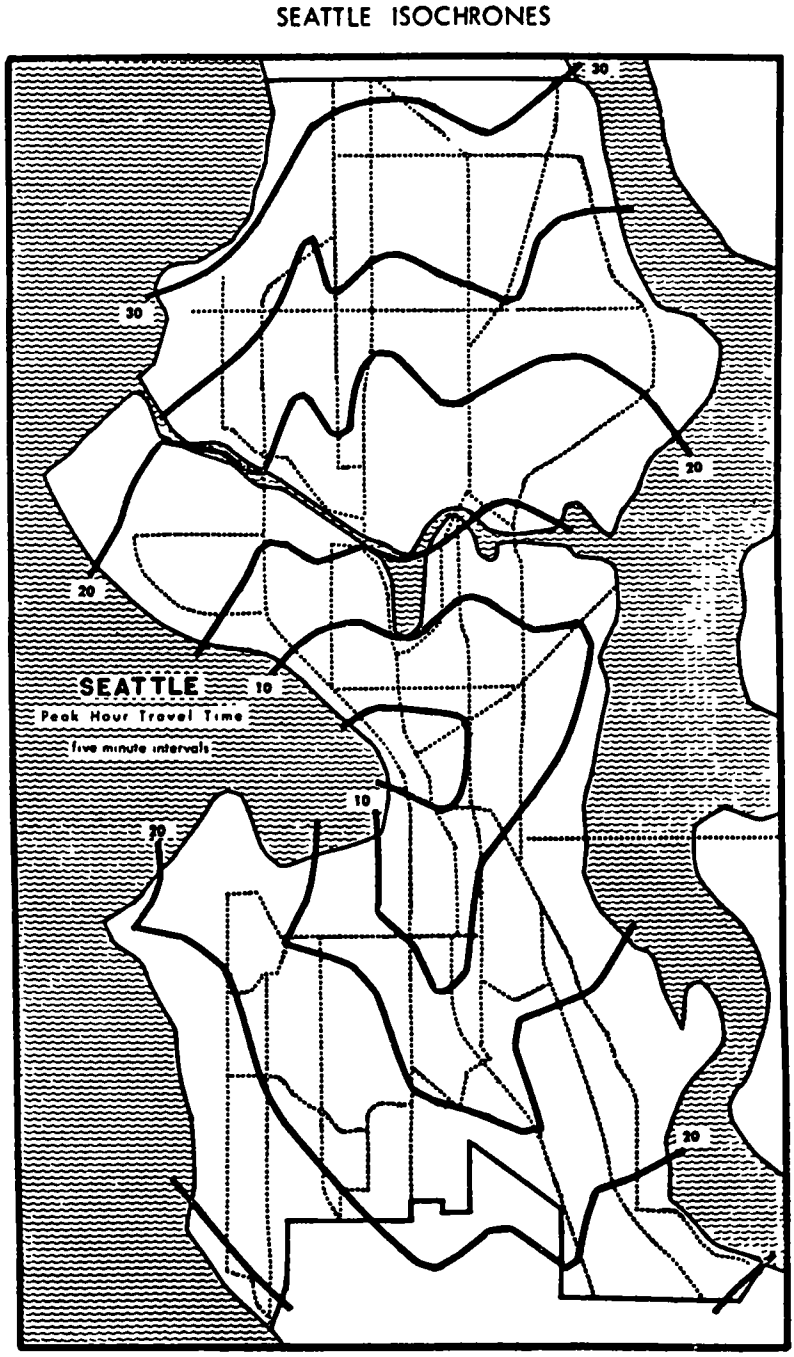


Figure 8. Together with Figure 9, a possible application of cartographic techniques of distortion to urban time-distance studies. (From Tobler (30).)

such as the basic-nonbasic concept and Leontief's input-output analysis; and this work in turn is used as the foundation for studies of urban transportation problems, as Berry (20) has done in his examination of ribbon development on the highway between Seattle and Everett (Fig. 7), and as he, Garrison, and others have done more comprehensively in their book, "Studies of Highway Development and Geographic Change" (21).

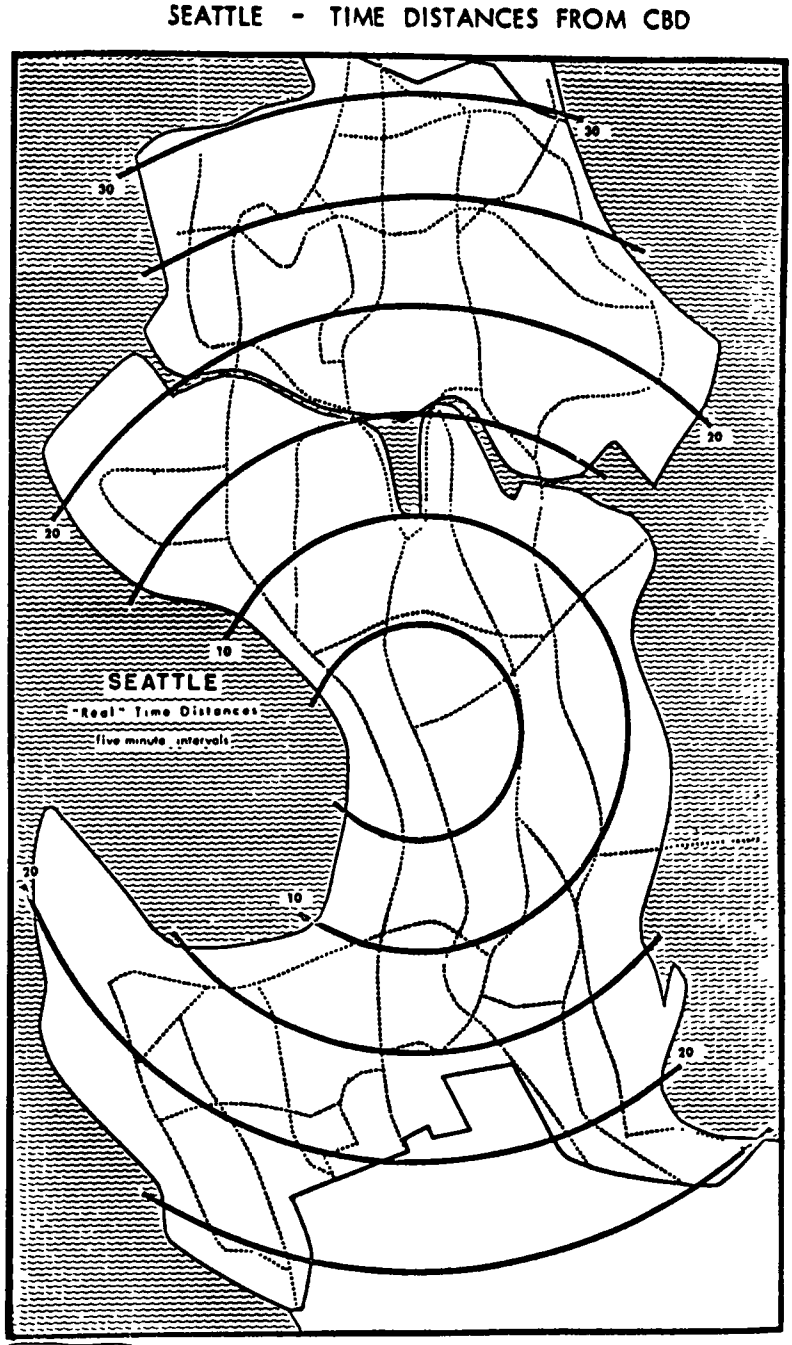


Figure 9.

Finally, there is the class of studies that groups cities in other ways, such as the functional classification by Harris (22) and the service classification by Nelson (23).

Quantitative Techniques

Although other geographers are making use of quantitative techniques of ever growing sophistication in attacking geographic problems, application of these techniques to urban transportation research is chiefly associated with two definite schools, that of the Swedish Royal University of Lund, and that of the University of Washington. Perhaps it is more appropriate to call the latter after its leader, William Garrison, for most of its members, including Garrison himself, have moved to other universities in the United States.

Over the last decade the Lund school has produced an exceptionally interesting body of work, much of it based on rigorous mathematical analysis. Merely to list a few of the titles is to suggest the relevance of this work to urban transportation research: "Bus Services, Hinterlands, and the Location of Urban Settlements in Sweden" (24); "An Analysis of Automobile Frequencies in a Human Geographic Continuum" (25), and "The Journey to Work from the Statistical Point of View" (26).

The school has been especially prolific in studies of migration, in which the journey to work, urban sprawl, and commutation take a prominent place. Special mention must be made of the work of Hägerstrand, in whose "Propagation of Innovation Waves" (27) and "Migration and Area" (28), original cartographic techniques are developed to help explain, respectively, the diffusion of (among other things) the ownership of motor vehicles among a population, and the relation between the distance separating two places and the number of people migrating from place to place.

As for the Garrison school, its pioneering work in location theory and on central place hierarchy has already been referred to. However, these by no means exhaust its range; members of the group have produced papers in which the latest tools of quantita-

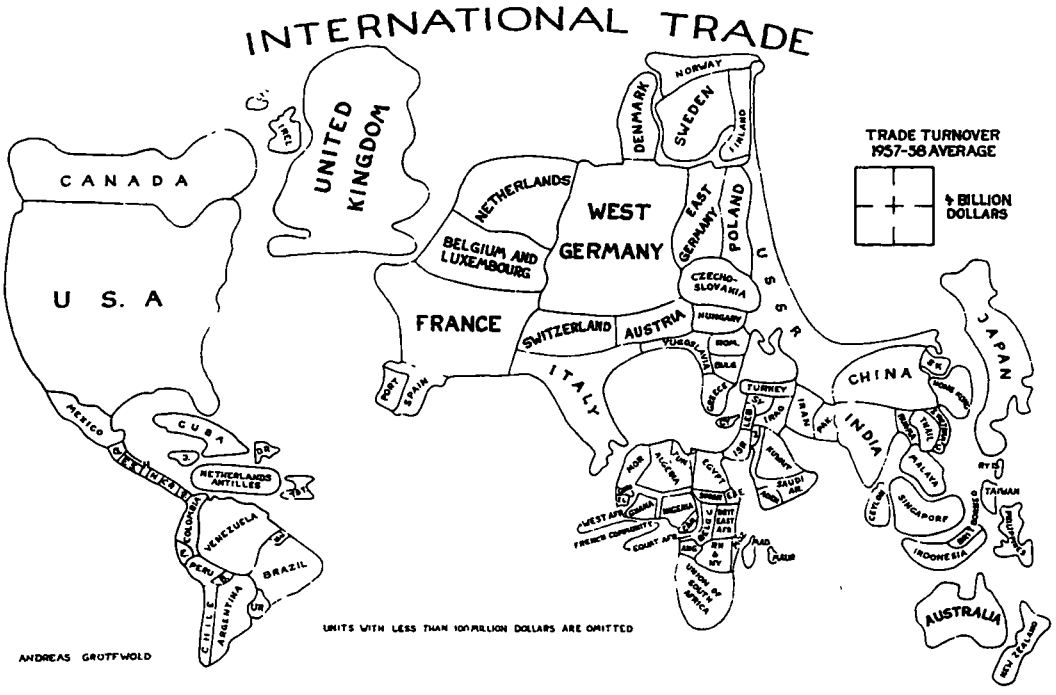
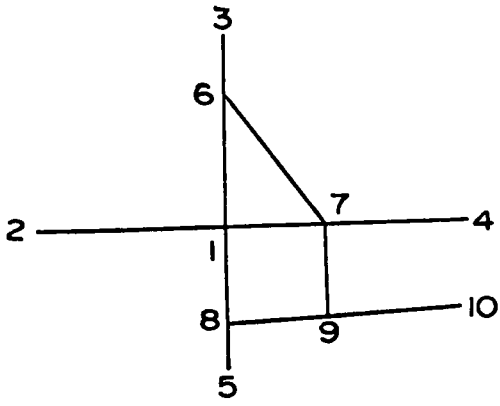


Figure 10. Map distortions used to highlight world relations in international trade. (From Andreas Grotewold, "Some Aspects of the Geography of International Trade." Economic Geography, p. 314 (Oct. 1961).)

TOPOLOGICALLY EQUIVALENT LINKAGES ·



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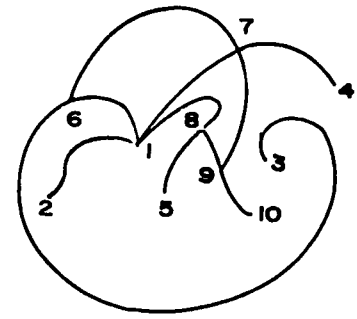

B

	1	2	3	4	5	6	7	8	9	10
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8	1				1				1	
9							1	1		1
10									1	

C

Figure 11. Graph theory, used in conjunction with map distortions, to facilitate use of electronic computers in mapping transportation networks. As long as connections between nodes and links remain the same, shape of map may be changed at will. (After Bunge (29),)

tive analysis—operations research, linear programming, regression analysis, simulation models, and graph theory—have all been put to use.

Cartographic Techniques

In urban transportation, time is of much more significance than distance. Maps usually give only an idea of the number of yards or miles between one point in a city and another, but are less exact in telling about the number of minutes or hours it takes, under given conditions, to move between these points. Mathematical techniques have been developed by Bunge (29) and Tobler (30), for example, for constructing map projections that tell about the time relations between points. Figures 8 and 9 show what happens when such a projection is made. In Figure 8 the shape and the street pattern of the city of Seattle are drawn to scale; at the peak travel hour, movement along some of the streets is faster than along others, so that the lines joining points of equal travel time are very irregular. In Figure 9 these lines of equal travel time, or isochrones, have been smoothed out into concentric circles centering on the CBD, with a resulting distortion of the shape and street pattern of the city. The areas nearest the CBD where travel is slower, are shown as enlarged (taking up more space, as it were, in the time dimension), whereas those further away are foreshortened.

Maps have been constructed on the same principles to show cost relations between points.

Map distortions can be used to highlight other urban relations (Fig. 10). Though their total land area is four times that of the United States, in this map the Soviet Union, China, and India together do not even equal the United States. Here at a glance is seen the relative importance in international trade of these four countries. Similar maps would be useful in emphasizing the internal relations of cities that have their effect on transportation, perhaps by eliminating such factors as topographic irregularities,

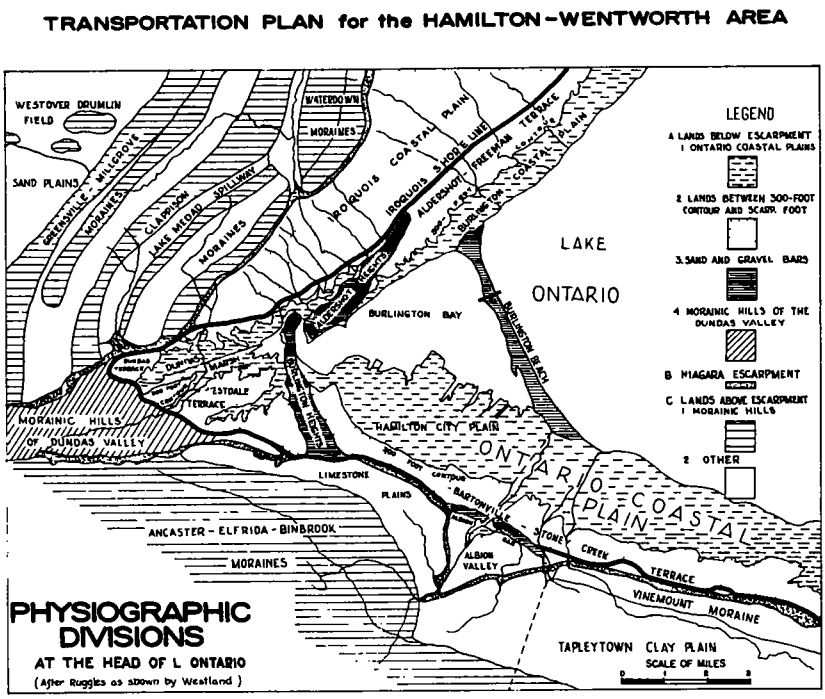

Figure 12. Map taken from thesis helped transportation planners understand physiographic problems. (After Westland (50).)

or unevenness of population density, or differences in suitability for different types of land use, which themselves bring distortions to the transportation pattern.

Map distortions might be used in conjunction with still another new cartographic technique, the use of electronic computers in mapping, to which Tobler has given a great deal of attention. Graph theory can be used to describe the system of nodes and links that makes up a city's street network, and these can then be readily translated into computer language. The simple street pattern in Figure 11 is topologically the exact equivalent of the seemingly more complex pattern in Figure 11, and the relations between the nodes and links of both are exactly reproduced in Figure 11. Because the topological equivalence is exact, no distortion of the shape of a city will affect its street network, as long as the pattern of nodes and links remains undisturbed. This procedure may find useful application in the setting up of a system of zones for origin-destination surveys, and the feeding of the necessary information into a computer.

The Commuting Problem

Mention has already been made of the Lund studies on the subjects of the journey to work and migration, both of which are aspects of the commuting problem. In Sweden great emphasis is placed on bus service, and this emphasis is paralleled in other European countries to a far greater extent than on this continent. Thus, the British geographers, Green (31) and Dickinson (32), use commuting by bus as a criterion for examining the relations between cities and their hinterlands in England and Germany, respectively. Dickinson has further discussed the problem of commuting by all transportation media available in a German industrial area (33). German geographers too have studied the public transport system; for example, the German study of the public transport system in Berlin before and after World War II (34). The destruction caused by war, the division into two sectors by a wall that has since become a physical fact, and the loss of many of the city's functions, have caused a shift in vitality from the central to the peripheral areas of Berlin. This shift is well illustrated in two traffic flow plans: whereas before the war the usual pattern obtained, of heavy traffic in the city center becoming progressively lighter as the outskirts are approached, after the war the pattern was reversed, and the heavier traffic is now found away from the central area. Studies such as this might well be brought to the attention of people working on civil defense plans.

On this continent, geographic work on mass transit is conspicuously meager. To be sure, there is a study on streetcar traffic, which appeared as long ago as 1917 (35), and which appears to be the only paper that discusses climatic effects on urban transportation from a geographic point of view. Finally, there is a paper by Vance (36), from which Figure 4 was taken, that may turn out to be as influential in the field of urban transportation geography as the previously mentioned series on the CBD, with which Vance was also involved. Vance uses what he calls "dynamic analysis," a stage-by-stage comparison of various conditions over time, to discover the effect of the changing technology of transportation on sources of labor supply, on the journey to work, on the shape of the city, and on its relations with satellites and suburbs. He makes the value of his work to planners explicit by discussing the application of his findings to the problems of urban planning.

Miscellaneous Transportation Studies

Waterways, railways, and airways have all received attention from geographers, but no very great proportion of their work has any direct relevance to urban transportation research. Indirectly, of course, almost any study of transportation has its bearing on cities, which are nodal points in all transportation networks.

Chicago, as a great transportation center, has received a commensurately detailed examination from this point of view. Representative studies that may be mentioned are those by Mayer on Chicago's relation to the St. Lawrence Seaway (37) and on its railway facilities (38); and by Taaffe on its air passenger hinterland (39). On ports in general, Weigend is among the chief authorities (40); and, though he restricts himself to European cities, Beaver (41) has some valuable comments on railway patterns near and within great cities.

The present catalogue of transportation studies may be rounded out by adding two that deal respectively with highways on the outskirts of cities and the streets within. The first, by Grotewold (42), examines one of the most difficult problems that highway planners have to contend with—the proliferation, on the highways passing through the rural-urban fringe, of commercial establishments that adversely affect the quality of traffic flow. The second, by Borchert (43), uses the density of the street network in an urbanized area (the number of street and road intersections per square mile) not only to discover the pattern of development in the past and in the present but to extrapolate that development into the future.

Geographers have been just as prone as other students of transportation to concentrate their attention on one or two transportation media, but with less excuse. As practitioners of a discipline that is, in its essence, an integrative and correlating discipline, they might have been expected to approach the problem of transportation, and particularly of urban transportation, on all its manifold fronts. Fortunately, geographers are becoming no less concerned than other scientists over the fragmentation that has so far characterized their work on transportation, and many more studies, such as that by Vance, will probably appear that examine urban transportation as a whole.

GEOGRAPHY AND THE HIGHWAY RESEARCH BOARD

Only within the last five years have highway planners been given the direct opportunity, at the meetings and in the publications of the Highway Research Board, of learning what geographers have been doing in their field. Although in all the highway departments of the United States there are only two geographers permanently employed at present, others have from time to time been brought in as consultants, or have served on such bodies as the Twin Cities Area Transportation Study, two of whose four top positions were occupied by geographers. Much more numerous are geographers associated with urban planning boards. But by far the greatest amount of geographic research on the city and on transportation is done in the universities.

The papers that geographers have presented before the Highway Research Board in the period beginning in 1957, when the first one appeared, have necessarily had a direct bearing on the interests of practicing planners, though in fact all but one of them were prepared by academic geographers. The exception was the very first to appear, which was presented by two geographers on the staff of a Canadian highway department, in conjunction with a highway engineer, on the subject of highway classification techniques (44).

The two state highway departments that have had the closest association with geographers in the universities have been those of Washington and Minnesota. These departments have collaborated with the Bureau of Public Roads and the state universities in conducting many economic impact studies, which have resulted in the publication of numerous papers under the joint auspices of all the bodies involved, among them such papers as that by Garrison and Marts on the influence of highway improvements on urban land (in Washington) (45), and by Borchert on commercial-industrial development along highways in the Minneapolis-St. Paul area (46).

The Highway Research Board has been informed of some of the results of this research; e.g., in a paper from Washington on application of linear programming techniques to analysis of highway networks (47), and one from Minnesota on the Twin Cities Study (48).

Only one paper to the Highway Research Board has been presented by a geographer who was not in any way involved with practical planning, but it was perhaps the most significant of all (49). For in it Murphy brought to the attention of highway workers the important insights that he and his colleagues have brought to the study of the central business district.

Thus, a beginning has been made towards acquainting highway workers with the results of geographic research on the city and on transportation problems.

STUDENTS' THESES

One last source of information must be mentioned, but this is perhaps the most valu-

able to local planners. Students preparing for undergraduate and graduate degrees are frequently assigned problems in urban and transportation research, and sometimes their reports contain information of great value. Geography departments in universities across the continent have great numbers of such reports, in the form of bachelor's, master's, and doctoral theses, which, because they are unpublished, seldom come to public attention, but which in many cases are well worth consulting. The map in Figure 12 comes from just such a thesis (50), and helped planners to familiarize themselves with the physiographic problems that had to be solved in laying out the future street and highway network of the city shown. The Ontario Department of Highways makes constant use of geographic theses prepared in universities throughout Canada and even abroad. Most assuredly, planners elsewhere can gain equal value from research done by university students on the cities in which those planners are interested.

INTERDISCIPLINARY COOPERATION

In the planning of transportation facilities for cities, voices from many disciplines must be heard, but it is the engineer who must have the last word, for his is the ultimate responsibility of providing the physical facilities themselves. Appropriately, therefore, the last words in the present paper will be given to two engineers, both eminent leaders in transportation research.

In his foreword to a report on the Woods Hole Conference on Transportation Research, Davis (51) wrote:

> Transportation affects, and is affected by, many economic, social and institutional factors. The competence of those engaged in the engineering and the physical sciences can be brought to bear on only a few of the aspects that are involved in the functioning of transport. It was recognized at the outset of this undertaking that adequate appraisal of the transportation situation would require the insights not only of the engineers and physical scientists, but also social scientists, economists, urban planners, lawyers, and others intimately familiar with the practical aspects of providing transport facilities and operating the services.

And here, from a personal communication written by John C. Kohl, are the words that best end this paper:

> [There is a need to] reinforce the currently hesitant approach by our own geographers who are lacking in conviction about their role in transportation planning. As a transportation engineer, I have long felt the need for geographers in planning activities.

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Appendix

BIBLIOGRAPHICAL MATERIAL

The fields of both urban and transportation geography are advancing so rapidly that bibliographies and collections of articles, no matter how painstakingly compiled, rapidly become out of date. Nonetheless, the book of readings in urban geography edited by Mayer and Kohn, in which many of the items referred to in the present paper are included (see footnote references), remains valuable, in that it gives an overview of the whole field of urban geography. The fact that no articles on urban street and highway problems are included indicates how recently these problems began to attract the attention of geographers.

For the relation of urban and transportation geography to the field of geography as a whole, see "American Geography: Inventory and Prospect," edited by Preston E. James and Clarence F. Jones (Syracuse Univ. Press, 1954). This compilation was published five years earlier than the book edited by Mayer and Kohn, and is due for revision. Still, it retains the permanent value inherent in any undertaking on which a group of first-rate authorities have cooperated.

Geographers depend to a very high degree on work performed in disciplines other than their own. The catholicity of their reading is illustrated in "An Annotated Bibliography of the Geography of Transportation," the largest part of which deals with urban transportation, compiled in 1961 by the author, with the help of Beverly Hickok, librarian of the Institute of Transportation and Traffic Engineering, University of California at Berkeley, and issued by the Institute as Information Circular 29.

More specialized, but still covering other disciplines besides geography, are a number of bibliographic studies conducted by Berry and by Garrison. The most ambitious of these is "Central Place Studies: A Bibliography of Theory and Applications," compiled by B. J. L. Berry and A. Pred, Bibliography Series 1; Regional Science Research Institute, Philadelphia, (1961). Berry has also published a paper on "Recent Studies Concerning the Role of Transportation in the Space Economy," Annals, Assoc. of American Geographers, pp. 328-342 (1959). Also W. L. Garrison surveyed the literature on "Spatial Structure of the Economy" in a series of three papers, also in the Annals, pp. 232-239, 471-482 (1959) and 357-373 (1960).

Finally, an invaluable source of bibliographical information for those interested in the whole field of location and central place theory, in simulation models (especially the gravity model) and other quantitative techniques, is W. Isard's "Methods of Regional Analysis," Technology Press of Mass. Inst. Tech. and John Wiley (1960).

Two geographic contributions of significance to urban transportation research have appeared since the present paper was delivered before the Highway Research Board. Each is by an established authority in the field.

The first, by Allen K. Philbrick, is on the subject of "Analyses of the Geographical Patterns of Gross Land Uses and Changes in Numbers of Structures in Relation to Major Highways in the Lower Half of the Lower Peninsula of Michigan," Michigan State Univ. Highway Traffic Safety Center and Department of Geography, East Lansing (1961). Philbrick's concept of the "dispersed city," which he prefers to that of "conurbation" or "megalopolis," as having none of the value judgments inherent in either, is here applied to research on the effect of highways on the use of the land that they serve. He demonstrates the existence of "zones of highway impact" of varying depth, and accurately and strikingly maps them by means of original techniques. Of exceptional value is the description of field methods that allow for extremely rapid and comprehensive taking of inventory of land use over large areas.

The second, by Edward J. Taaffe, is "The Urban Hierarchy: An Air Passenger Definition," Economic Geography, 38:1-14 (Jan. 1962), which describes the manner in which four cities in the United States (New York, Chicago, Los Angeles, and San Francisco)

have achieved dominance with respect to air passenger traffic over all others. A distinct hierarchical pattern has emerged; thus, the cities of the Pacific Northwest focus on Seattle, which focuses on San Francisco, which focuses on Los Angeles. "For further empirical evidence as to the specific configuration of the urban hierarchy," Taaffe concludes, "it would seem profitable to examine the highway and rail linkages of individual cities through time, and to attempt to fit them into the broader spatial context of air passenger linkages." Of special interest is Taaffe's use of the gravity model to give a theoretical foundation to his empirical observations.

Both of these papers may be expected to lead to widespread research programs that will give planners valuable insights into the developing transportation needs of growing cities.