SPATIAL REORGANIZATION: A MODEL AND CONCEPT[1]

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ABSTRACT. Travel-time connectivity is a key factor in defining a process of the spatial reorganization of man's functional establishments. A case study relating highway development with the growth in wholesale activity for selected cities in the upper midwest of the United States indicates that, aside from being a good surrogate of transport efficiency, travel-time connectivity is also a good measure of the relative advantage of a given place in attracting to itself the centralization and specialization of human activity.

A functional framework which includes a measure of the friction of distance, such as time or cost of travel, seems essential in a study of central place development. Furthermore, as Blaut noted, structure (the areal arrangement of earth-space phenomena) and process (the rearrangement of these phenomena over time) are one and the same thing—that is: " . . . structures of the real world are simply slow processes of long duration."[2] Inherent in Blaut's view is the implicit existence of a temporal pattern in each and every spatial pattern.[3] Thus, these two factors, the friction of distance (measured in travel-time) and historical development,

have been incorporated into the following statement of a model of spatial reorganization.[4]

A MODEL OF SPATIAL REORGANIZATION

In this study, the concept of spatial reorganization identifies a process by which places adapt both the locational structure and the characteristics of their social, economic, and political activities to changes in time-space connectivity (the time required to travel between desired origins and destinations). As an example of such areal reorganization, Fox noted how, for the food retailing industry, spatial adaptations to advances in transportation have tended towards fewer, larger, and more distantly spaced establishments—an abandonment of the corner grocery store in favor of the supermarket.[5]

A model has been designed to depict a normative process of such areal development. Later this model (the basic model) will be

[2] J. M. Blaut, "Space and Process," The Professional Geographer, Vol. 13 (July, 1961), p. 4.

[3] This notion, first recognized by the physicists and physical philosophers, has been acknowledged by many geographers and other social scientists, including W. J. Cahnman, "Outline of a Theory of Area Studies," Annals, Association of American Geographers, Vol. 38 (1948), pp. 233–43; A. H. Hawley, Human Ecology: A Theory of Community Structure (New York: The Ronald Press, 1950), p. 288; W. Isard, Location and Space-Economy (Cambridge, Mass.: The Massachusetts Institute of Technology Press, 1956), p. 11; F. Lukermann, "The

Role of Theory in Geographical Inquiry," The Professional Geographer, Vol. 13 (March, 1961), p. 1; and R. L. Morrill, "The Development of Spatial Distributions of Towns in Sweden: A Historical-Predictive Approach," Annals, Association of American Geographers, Vol. 53 (1963), pp. 2–3.

[4] The term "spatial reorganization" is not new. It has been used by W. L. Garrison. See "Notes on Benefits of Highway Improvements," in W. L. Garrison, B. J. L. Berry, D. F. Marble, J. D. Nystuen, R. L. Morrill, Studies of Highway Development and Geographic Change (Seattle: University of Washington Press, 1959), p. 23. This and other impact studies of the post-1956 period suggests that although the term has not seen wide use, the concept is one of immediate concern.

[5] K. A. Fox, "The Study of Interactions Between Agriculture and the Nonfarm Economy: Local, Regional and National," Journal of Farm Economics, Vol. 44 (February, 1962), pp. 1–34.

expanded so as to present a more comprehensive view. Although these models are intended to be applicable to urban-exchange economies typical of the United States and Western Europe, the writer believes that they may have some predictive value in forecasting the areal development of areas which have only recently begun progressing through the industrial-commercial revolution. Before describing the models, a concept which is central to the overall process of reorganization needs to be considered—this is the notion of *locational utility.*

Locational Utility

Very simply, utility is a measure of value. However, the term locational utility used in this study should be distinguished from *place utility* as defined by Wolpert.[6] Wolpert recognized in his discussion on the decision to migrate that utility is inherently individualistic. Thus, place utility is an individual's subjective measure of the degree to which the opportunities at a particular place permit his perceived or actual achievement level to be in as close as possible accordance with his aspiration level. By integrating this individualistic concept with information on the life cycles, life styles, and life spaces of specific socioeconomic groups, Wolpert developed an aggregate measure of the utility of specific places relative to the mover-stayer decision.

In contrast to place utility, locational utility is defined in a context which, in part, overlooks the individualistic and subjective connotation of value. It is a measure of the utility of specific places or areas, which in this case is defined by the aggregate time-expenditure (cost or effort) in transport required for that place or area to satisfy its operational needs.[7] Operational need refers to those natural and human resource requirements which permit the place or area to fulfill its functional roles in the larger spatial system of places and areas. The alternative possibilities of a place, either to decrease, maintain, or increase its existing competitive

[6] J. Wolpert, "Behaviorial Aspects of the Decision to Migrate," *Papers, Regional Science Association,* Vol. 15 (1965), pp. 159–69.

[7] The terms place and area are used as designators of areal scale. In this study they are used interchangeably.
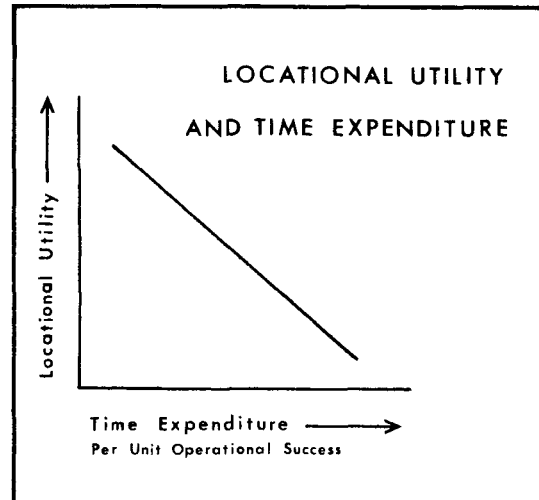
FIG. 1. Locational utility and time expenditure per unit operational success. Some curvilinear function might express the reality of this relationship better than the linear function represented in this graph.

status within the bounds of either its present spatial system of socioeconomic activities or in an expanded sphere of influence, are here considered to be functions of its locational utility. Thus, as shown in Figure 1, the locational utility or value of places and areas increases as travel-time expenditure per unit of operational success (profit or some other form of amenity benefit) decreases. Whereas

FIG. 2. The increase in locational utility for time period t_1 through t_2 resulting from the introduction of a transport innovation in time t_2.

a first degree linear function is used to express this relationship, it is likely that a second, third, or higher degree function would be more appropriate.

In reality, the spatial variance in the locational utility for a system of places may be characterized by surfaces of utility. In a given spatial system there exists one surface 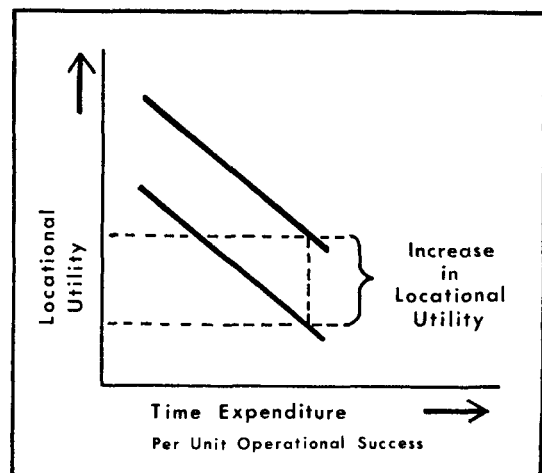for each of the many possible functional roles to be performed. Theoretically, with possible loss of much information, it might be feasible to treat these surfaces in an additive sense and to arrive at a surface of composite locational utility for the system.

Once the surface of utility has been described, one can then focus attention on a more significant problem—the dynamics of surface change. For example, the depletion or the discovery of a resource which is an operational need for the success of a given economic activity would alter the utility surface for that activity, and could necessitate the selection of a new production site.

In that locational utility is defined as a function of time-expenditure, it is evident that innovations which speed transportation will also lead to changes in the utility surface. Thus, for a given place, the increase in locational utility from time t_1 to time t_2 that is derived from a transport innovation at time t_2 is indicated in Figure 2. Such changes pose many questions of practical relevance. For example, are these innovations and certain distributive forces leading towards greater equilibrium in the utility surface and, thus, possibly towards a more homogeneous distribution of man's socioeconomic activities? Or, do transport improvements and certain agglomerative forces lead to increasing spatial variance in locational utility and, thus, to-
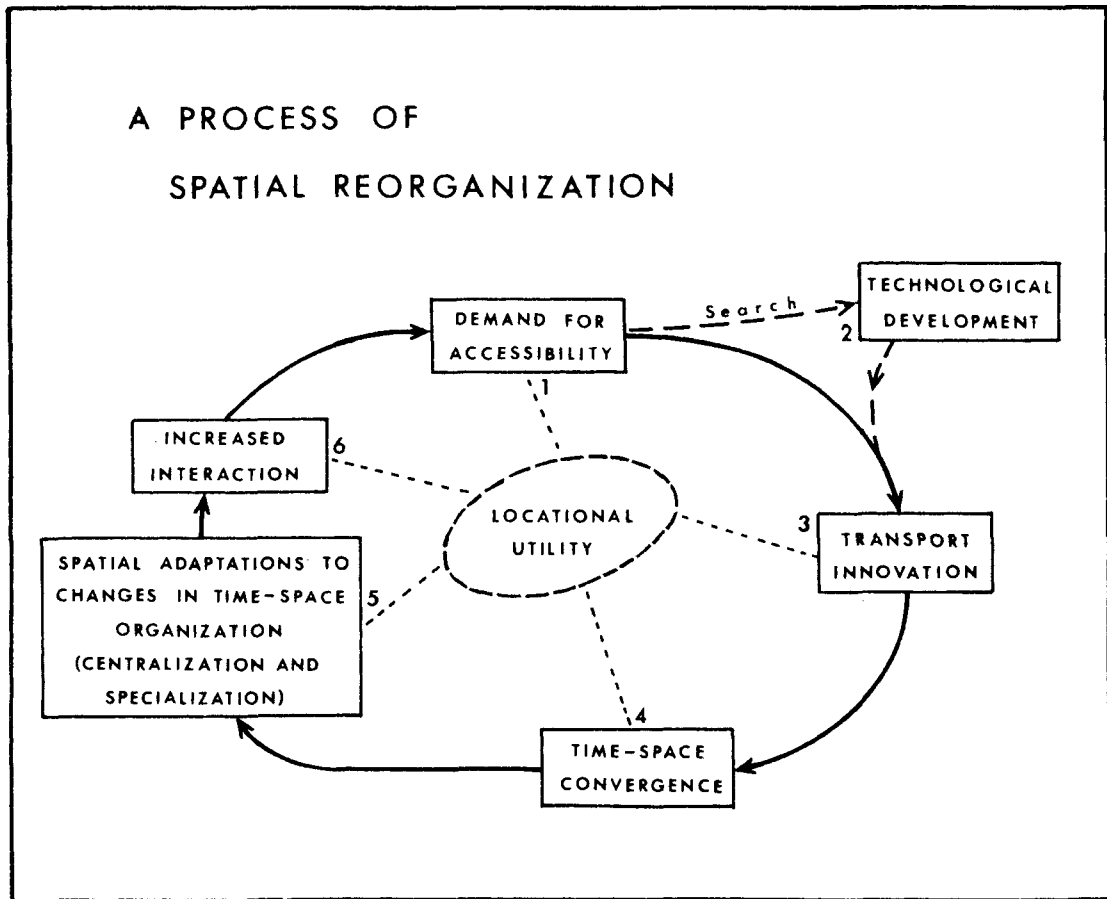

FIG. 3.

wards greater place-concentration of human enterprise?

These questions, along with the process of spatial reorganization will be clarified as the concepts integrated into the model in Figure 3 are defined. These concepts include:

1) Demand for accessibility;
2) transport innovations;
3) time-space convergence;
4) spatial adaptations—centralization and specialization; and
5) spatial interaction.

Demand for Accessibility

Accessibility is a measure of the ease (time, cost, or effort) in which transfer occurs between the places and areas of a system. The demand for accessibility, then, is really a quest to decrease the transport effort expended per unit of operational success or, very simply, to augment locational utility. A useful and more objective measure of accessibility (not used in this study) is provided by the graph theoretic approaches employed by Garrison, Kansky, and others.[8]

Transport Innovations

In this study, transport innovations are any technologies or methods which serve to increase accessibility between places or which permit an increase in the quantity of goods or the number of passengers that can be moved between these places per unit of time. Thus, a transport innovation may be a new and faster type of carrier, improved traffic routing procedures, better gasoline, improved lighting for night travel, the straightening of angular routes, and so forth. All such introductions are likely to result in what the author describes as time-space convergence (step 4 of the model).

Time-space Convergence

By time-space convergence, the writer is implying that, as a result of transport innovations, places approach each other in time-space; that is, the travel-time required between places decreases and distance declines in significance.[9] An example of this phenomenon is illustrated in Figure 4 for travel between Detroit and Lansing, Michigan. As a consequence of such convergence, man has found that it is possible and practical to adapt the spatial organization of his activities to their evolving time-space framework (step 5 of the model).

Spatial Adaptations to Changes in Time-space Organization

In the basic model under consideration, the spatial adaptations of man's activities to their changing time-space framework will lead to the centralization and specialization of secondary and tertiary economic activities in specific places and, as is frequently the case, to the specialization of primary economic activities in the resource-oriented hinterlands of these places. Centralization (of which urbanization is a form) refers to the increasing focus of human activity upon a particular place; it results in the growth of an economically, culturally and, sometimes, politically integrated area over which this particular place is dominant (its hinterland). The economies that result when the scale of an economic, political, or cultural endeavor is increased at a particular place or in a particular area are generally considered to be the motivating forces behind centralization. As a rule, increased scale permits lower per-unit production or operation costs —unless diminishing returns set in.

Specialization (of which industrialization is a form) develops when places or areas concentrate their efforts on particular activities at the expense of others. Many regional economists and economic geographers note that the most intense concentration of any given economic activity will (or at least should) be in a locale having a comparative advantage relative to other places and areas. On the other hand, a less favored place should choose to specialize in that activity for which it has (relative to the rest of the

[8] W. L. Garrison, "Connectivity of the Interstate Highway System," *Papers and Proceedings of the Regional Science Association,* Vol. 6 (1960), pp. 121–37; K. J. Kansky, *Structure of Transportation Networks* (Chicago: Department of Geography Research Paper No. 84, University of Chicago Press, 1963).

[9] For a more thorough discussion of time-space convergence, see D. G. Janelle, "Central Place Development in a Time-space Framework," *The Professional Geographer,* Vol. 20 (1968), pp. 5–10.
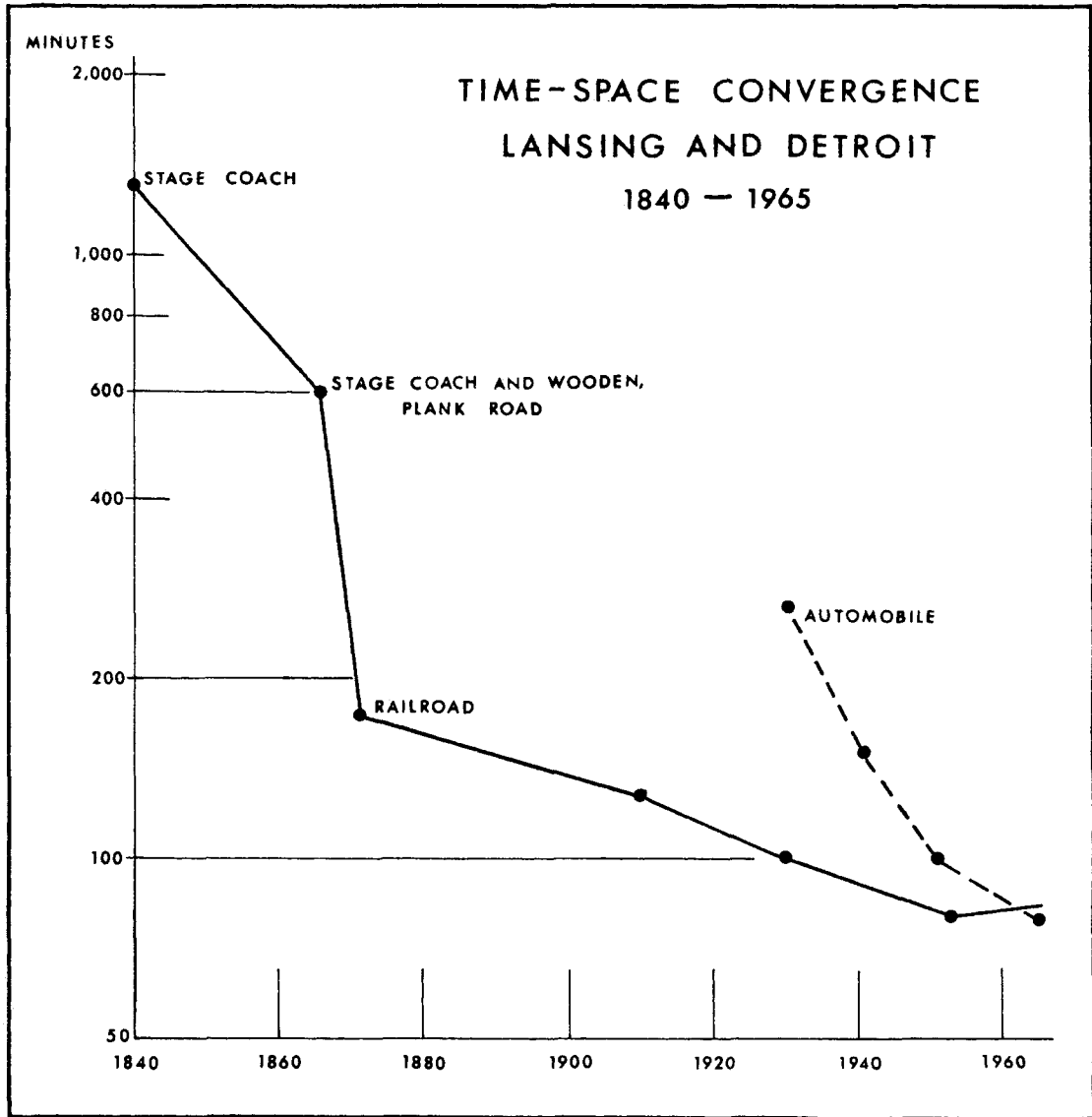
FIG. 4.

system) a least comparative disadvantage.[10] For the mechanistic model in question, the surfaces of locational utility dictate the specialties of places and areas.

The greater the centralization and specialization of man's activities, the greater is the need for efficient transport and increased locational utility (steps 1–4 of the basic model). As man speeds up his means of movement, it becomes possible for him to travel further in a given time, to increase his access to a larger surrounding area and, possibly, to more and better resources. This idea is in line with Ullman's concept of transferability.[11] Likewise, secondary and tertiary functions can serve more people; and the

[10] For a discussion on the law of comparative advantage, see P. A. Samuelson, "The Gains from International Trade," *Canadian Journal of Economics and Political Science,* Vol. 5 (May 1939).

[11] E. L. Ullman, "The Role of Transportation and the Bases of Interaction," in W. L. Thomas, Jr. (Ed.), *Man's Role in Changing the Face of the Earth* (Chicago: University of Chicago Press, 1956), pp. 862–80.

perishable agricultural products and other primary products can be profitably marketed over a larger area. In essence these changes are manifestations of an increasing degree of locational utility (greater operational success can be derived per unit of time-expenditure from a given place) that permits the increasing centralization and specialization of human endeavors. Thus, these scale economies are, in part, both forms of spatial adaptation to an evolving time-space framework.

Unlike centralization and specialization, suburbanization (a form of spatial decentralization) represents an alternative response to time-space convergence which is not treated in this basic model. Improvements in individual mobility have made it possible for some families and for some firms to trade off central accessibility for the amenities associated with suburban life and industrial parks. These adaptations are considered in the expanded model of spatial reorganization (Fig. 5).

tertiary activities centralize within given places, it is necessary for those places to interact in the forms of products, service, and information exchange with their resource-oriented hinterlands. These hinterlands provide the necessities of primary production and they demand the products and services of secondary and tertiary establishments. Similarly, if central places concentrate on a given type of economic activity or, if resource-oriented areas specialize in a specific form of primary activity (e.g., wheat or iron ore), it is necessary for them to trade and exchange with one another so that they can attain those needs or desirable items that they themselves do not produce.

The increasing intercourse that results from the concentration of human activities at particular places is likely to lead to an overextension of man's transport facilities and result in their deterioration from overuse and in the development of traffic congestion. It is, therefore, likely that the operational suc-

FIG. 5.

Interaction

Step 6 of the basic model indicates that an increase in interaction results between places and areas that experience increasing centralization and specialization.[12] As secondary and

cess of these places can only be continued through increased costs. Consequently, the increasing interaction that results from centralization and specialization leads to further demands for increased accessibility, greater degrees of locational utility, and transport innovations (steps 6, 1–3 in basic model). Thus, the spatial reorganization of human activities is perpetuated in what, theoretically,

[12] For a more complete treatment of this notion, see Ullman, op. cit., footnote 11.

is a never ending and accelerating cycle. This notion of a multiplier effect or positive feedback[13] implies that the state of a system (that is, the degree of convergence between interacting settlements, their demands for accessibility, and so forth) at a given time is determined completely from within the system and by the previous state of the system.[14] Thus, the positive feedback system, as indicated by the completed circuit in the basic model, is self-perpetuating.

Support for the notion that a transport improvement, in itself, encourages increased interaction is also available. Studies by Coverdale and Colpitts show that improvements in highway facilities result in traffic volumes greater than the number accounted for by the diverted traffic.[15] That is, many new facilities (i.e., bridges and freeways) will attract considerably more traffic than would be expected had the previous facilities continued to operate alone. This increase is frequently termed induced traffic. The volumes of induced traffic encouraged by bridges replacing ferries have ranged, in many instances, from sixty-five percent to seventy-five percent of that before the improvement. For the Philadelphia-Camden Bridge it was seventy-eight percent, and for the San Francisco-Oakland Bay Bridge it was about sixty-four percent. This finding lends additional support for the inclusion of a positive feedback system in the basic model of spatial reorganization.

AN EVALUATION OF THE BASIC MODEL

Changes in the time-spatial and spatial organization of human endeavors present places and areas with possibilities for greater

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[13] The application of the feedback concept in this context was suggested to the author by James H. Stine, Department of Geology and Geography, Oklahoma State University.

[14] An excellent discussion on both positive and negative feedback systems is provided by M. Maruyama, "The Second Cybernetics: Deviation-Amplifying Mutual Causal Processes," *American Scientist*, Vol. 51 (1963), pp. 164–79; also, see L. von Bertalanffy, "General System Theory," *General Systems*, Vol. 1 (1956), pp. 1–10.

[15] Coverdale and Colpitts, Consultant Engineers, *Report on Traffic and Revenues, Proposed Mackinac Straits Bridge* (New York: Coverdale and Colpitts, January 22, 1952), p. 18.

scale economies and with problems of developing more efficient means of transport. It is man's awareness or perception of these possibilities and problems that enables him to take advantage of the changes in the time-space structure of his activities. In reality, however, the process that has been described is not so simple—not all men will perceive the changes described in the model nor will they see the implications of these changes in the same way. Furthermore, some of the assumptions of the model lack complete accord with reality.

Varying Conceptions of Utility and Time

Whereas the basic model is based on an objective measure of locational utility (time-expenditure), it was indicated earlier that utility is inherently individualistic; that is, it is perceived according to one's values, goals, and technical and institutional means of living. At the level of places and areas it is likely that the criteria for utility are based on factors other than just the expenditure of time.

It is also apparent that man's perceived value of a given unit of time has increased as the tempo of his activities has increased. A component to represent this change is not included in the model. Yet, by sole reason of the tremendously greater commodity, passenger, and information flows today as compared with past periods, man is motivated to seek greater utility for his expenditure of time. Imagine the magnitude of storage that would be necessary if New York City had to store food for its population to meet their needs over the winter months. With faster transport, the city can rely on more distant sources. Food can be moved to the city when it is needed, thus reducing its storage costs and increasing its operational success.

There is the additional likelihood that a person's perception of the utility of time will differ for various travel purposes. For example, an individual may be willing to spend an hour in travel to receive the medicinal services of an eye specialist; but, he may only grudgingly give up ten minutes to purchase a loaf of bread. No model of the process of spatial reorganization could account for all of the multitudinous goals and criteria of all persons, places, and areas, and the

changing value of time for each. Therefore, in the development of the model, a standard pattern of human place-behavior has been assumed.

A Basic Assumption: Rationality in Human Place-Behavior

The principal assumption upon which the spatial process model is based is that man is rational. This concept of a rational man or the economic man has been well developed elsewhere and only the implications relevant to this discussion are presented.[16] These include the following:

1) Man has perfect knowledge. Thus, in an aggregate sense, places and areas show complete awareness of all factors operative in the areal reformation of their activities; they are aware of all their operational needs and of all the possibilities for fulfilling these needs.
2) Man has no uncertainty—he has perfect predictability. Thus, the rational place foresees the time-space convergence that will result from any transport innovation; it foresees the degree of increased interaction that will be derived from greater centralization and specialization of its activities.
3) Man is interested solely in maximizing the utility of time at a given place. This permits the necessary spatial reorganization to augment the operational success of places. Net social benefits, inclusive of all possible benefits—whether economic, political, or cultural—could be substituted for operational success.

Limitations and Omissions of the Model

Although the inclusion of the rational place concept may limit the correspondence of the basic model with reality, it does permit one to consider the process of reorganization under controlled circumstances with a mini-

mum of conflicting factors (i.e., changing criteria and varying degrees of rationality that have to be accounted for). Other factors which are, in part, attributable to a lack of perfect rationality may be summed up as perceptive, responsive, and technological lags. Spatial change is not necessarily characterized by a smooth flow through the six-step process identified in the basic model.

There may be lags or delays in the process resulting from man's inefficient behavior—his slowness in adapting the spatial organization of human activity to its changing time-space framework, or his slowness in introducing more efficient forms of transportation. It is also possible that improvements in transfer technology will lag behind the need for such development. It will be noted from Figure 3 that the development of technology, although intimately related, is considered exogenous to the system depicting the process of spatial change. Such development may take place independently of any need present within the system—innovations developed for an entirely different purpose may be readily applicable to transportation.

AN EXPANDED MODEL OF SPATIAL REORGANIZATION

If the restraints of rationality, as defined above, are relaxed, and, if another factor, the demand for land, is introduced, then the mechanism of the basic model breaks down. In reality, places and areas do not always seek to maximize their degree of locational utility and, in many cases, they find it impossible to do so. Thus, if there is no demand for increased accessibility in response to increases in interaction or if there is no technology available for meeting demands for greater accessibility, then it is likely that either traffic congestion, route deterioration, or both will occur. This, in turn, would lead to time-space divergence (places getting further apart in time-space). This is indicated by steps 7 and 8 of the expanded model depicted in Figure 5.

The demand for land or space (step 9) is a form of decentralization which is a direct consequence of the centralization and specialization associated with time-space convergence. Factories, warehouses and so forth, which seek to augment scale economies, find

[16] R. M. Cyert and J. G. March, *A Behavioral Theory of the Firm* (Englewood Cliffs, N. J.: Prentice-Hall, Inc., 1963); J. H. Henderson and R. E. Quandt, *Micro-Economic Theory, A Mathematical Approach* (New York: McGraw-Hill Book Co., Inc., 1958); H. A. Simon, "Some Strategic Considerations in the Construction of Social Science Models," in P. F. Lazarsfeld (Ed.), *Mathematical Thinking in the Social Sciences*, (Glencoe, Ill.: The Free Press, 1954), pp. 388–415.

land scarce and expensive in the central areas of cities and, thus, move to the peripheries of the built-up areas where it is available and comparatively cheap. Jobs created by this expansion may increase the population attraction power of places and lead to further demands for land. Additional factors accounting for a demand for land peripheral to the built-up areas include the population holding power of the urban area itself and the amenity goal to gain more elbow room—to get out of the noisy, crowded city. This demand to leave the central city results as interaction accelerates beyond a tolerable threshold. It seems likely that this demand for land coupled with time-space divergence will lead to a completely different form of areal adaptation than was the case with convergence.

Spatial Adaptation: Decentralized Centralization and the Expansion of the City

Because the land available for expansion is generally peripheral to that portion of the city area which is already developed, the new and relocated establishments (residents, retail and service firms, and so forth) find themselves at a time-disadvantage in attaining goods and services that are only offered in the central core of the city. To obviate this problem these families and firms can either demand greater transport access (steps 1–3), or they can encourage the location of new establishments in the city's peripheral area to serve and to employ them (step 10). Frequently, the demand for new commercial, industrial, and cultural establishments is met prior to any substantial improvements in transport access. The pattern of such development is typified by shopping centers carrying on many retail and service functions and by the nucleation of secondary activities in planned industrial parks.

The decentralized nucleation of man's activities in planned shopping centers and in industrial parks may owe to the desire to reduce the number of trips or the distance of movement needed to attain a given quantity of goods and services.[17] This is made pos-

sible by grouping many functions at one center. Such nucleation of activities within given subregions of the urban area may lead to increased interaction within the subregion and, eventually, to an even greater demand for accessibility (step 1). Thus, in this manner, the subregion finds itself in a new stage of areal rearrangement—it is operative within the basic model of spatial reorganization and will develop greater centralization and specialization (steps 1–5).

With the continuance of this process, it is easily seen how subnucleated secondary and tertiary activities can eventually become a part of the very core of the urban area—the increasing concentration of activities within the urban core and within the subnucleated secondary and tertiary centers leads to further demands for land (step 9). It is possible that they will engulf each other in their expansion and become fused into one highly integrated unit. Without some form of control or planning, this process could lead to one vast urban-society—a megalopolis.[18]

In the absence of planning, it is evident that decentralization is merely an intermediate or lag-stage in the general process (described by the basic model) leading towards an expanded area of centralization and specialization. This model highlights only the basic components of spatial reorganization and clearly expresses the cyclical tendency towards the increasing centralization and specialization of human activity.

An Evaluation of the Expanded Model

Unlike the basic model of spatial reorganization, the expanded model accounts for what happens when the degree of rationality, as defined for the basic model, is lessened or when the criteria of rationality change. This model permits consideration of the spatial consequences to the alternative demands of either accessibility or space (land and air).

In concluding the discussion on the de-

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[17] For information on the multiple nuclei concept of urban growth, see C. D. Harris and E. L. Ullman, "The Nature of Cities," *Annals of the Ameri-*

can Academy of Political and Social Science, Vol. 242 (November, 1945), pp. 7–17; E. L. Ullman, "The Nature of Cities Reconsidered," *Papers and Proceedings of the Regional Science Association*, Vol. 9 (1962), pp. 7–23.

[18] J. Gottman, "Megalopolis, Or the Urbanization of the Northeastern Seaboard," *Economic Geography*, Vol. 33 (1957), pp. 189–200.

velopment and evaluation of the model, one further observation is necessary. Spatial reorganization is not operative everywhere to the same degree and it does not occur simultaneously at all points in earth space. Therefore, it is essential to determine why this process is so selective and why some places undergo a more rapid areal reorganization than others.[19]

THE PROCESS OF SPATIAL REORGANIZATION AND THE CONCEPT OF RELATIVE ADVANTAGE

The concept of relative advantage states that the process of spatial reorganization in the form of centralization and specialization will accelerate most rapidly at those places which stand to benefit most from increasing accessibility.[20] In other words, transport innovations are most likely between those places which will benefit most from a lessening in the expenditure of time (cost or effort) to attain needed and desirable goods and services. Relative advantage is defined in terms of the benefits of operational success (inclusive of all economic, political, and cultural benefits) that can be derived from a particular place with a given expenditure of time. The concept is based on the same assumptions of rationality as were the process models.

Since locational decentralization, as defined in the expanded model, is simply an intermediate or lag-stage in the overall trend towards centralization (given the continuance of the process and the assumption that a point of diminishing returns does not set in), it is possible to confine the evaluation of the relative advantage concept to the basic model of spatial reorganization. The question is, where will this process be likely to accel-

erate most rapidly? Or, where is man most likely to introduce a transport improvement? In seeking answers to these questions, the concepts of relative advantage and spatial reorganization will be applied to a selected set of cities in the northern, midwest of the United States.

Relative Advantage and Spatial Reorganization in the Upper Midwest

Because of their significance as times of automobile and highway innovation, the periods of 1900 to 1925, and 1940 to 1965, were selected for evaluating the real world applicability of the concepts proposed in this study. In the early twentieth century, prior to about 1930, railways and electric interurban lines not only dominated intercity travel in the United States, they also had a definite speed advantage over the automobile. For example, although in 1930 a typical forty-five mile auto trip from Dexter, Michigan, to Detroit took three hours, interurban lines averaging anywhere from forty to sixty miles per hour connected most of the nation's major cities.[21] Nonetheless, people increasingly sought the personal convenience and versatility of the automobile and demanded better roads.[22] The tangible results of this demand are illustrated in Figure 6 by a series of five highway status maps for southern Michigan.

Relative Advantage for Transport Improvement in Southern Michigan

In Figure 7A a closed system of seven major Michigan cities and eleven highway links has been selected to evaluate the concept of relative advantage. The immediate objective is to predict highway status for 1925 on the basis of information for 1900 and, similarly, to project the status of highways in

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[19] The skyscraper is an alternative choice in attaining more space while still retaining central access. The skyscraper, however, is a form of centralization which fosters greater interaction and additional demand for accessibility. Thus, this spatial adaptation also helps to perpetuate the trend towards greater centralization.

[20] Interesting statements on a concept of relative advantage similar to that proposed here are provided by Z. Griliches, "Hybrid Corn and the Economics of Innovation," *Science*, Vol. 132 (July 29, 1960), pp. 275–80; and "Hybrid Corn: An Exploration in the Economics of Technological Change," *Econometrica*, Vol. 25 (1957), pp. 501–22.

[21] G. W. Hilton and J. F. Due, *The Electric Interurban Railways in America* (Stanford, Calif.: Stanford University Press, 1960).

[22] The number of automobiles in Michigan increased from 2,700 in 1905 to more than 60,000 by 1913. See Michigan State Highway Department, *History of Michigan Highways and the Michigan State Highway Department* (Lansing, Mich.: Michigan State Highway Department, 1965), pp. 6–7.

CHANGES IN STATUS
OF MAJOR HIGHWAYS
IN SOUTHERN MICHIGAN
1919 – 1965

Muskegon
Grand
Rapids
Saginaw
Flint
Port
Huron
Lansing
Battle
Creek
Kalamazoo
Jackson
Detroit

1919

1925

1940

1955

1965

----- UNIMPROVED
·········· GRAVEL
==== BRICK
——— PAVED, 2 LANES
≡≡≡≡ DIVIDED, > 2 LANES
▨▨▨▨ LIMITED ACCESS, > 2 LANES
– – – NO DATA (1919)

0   MILES   50
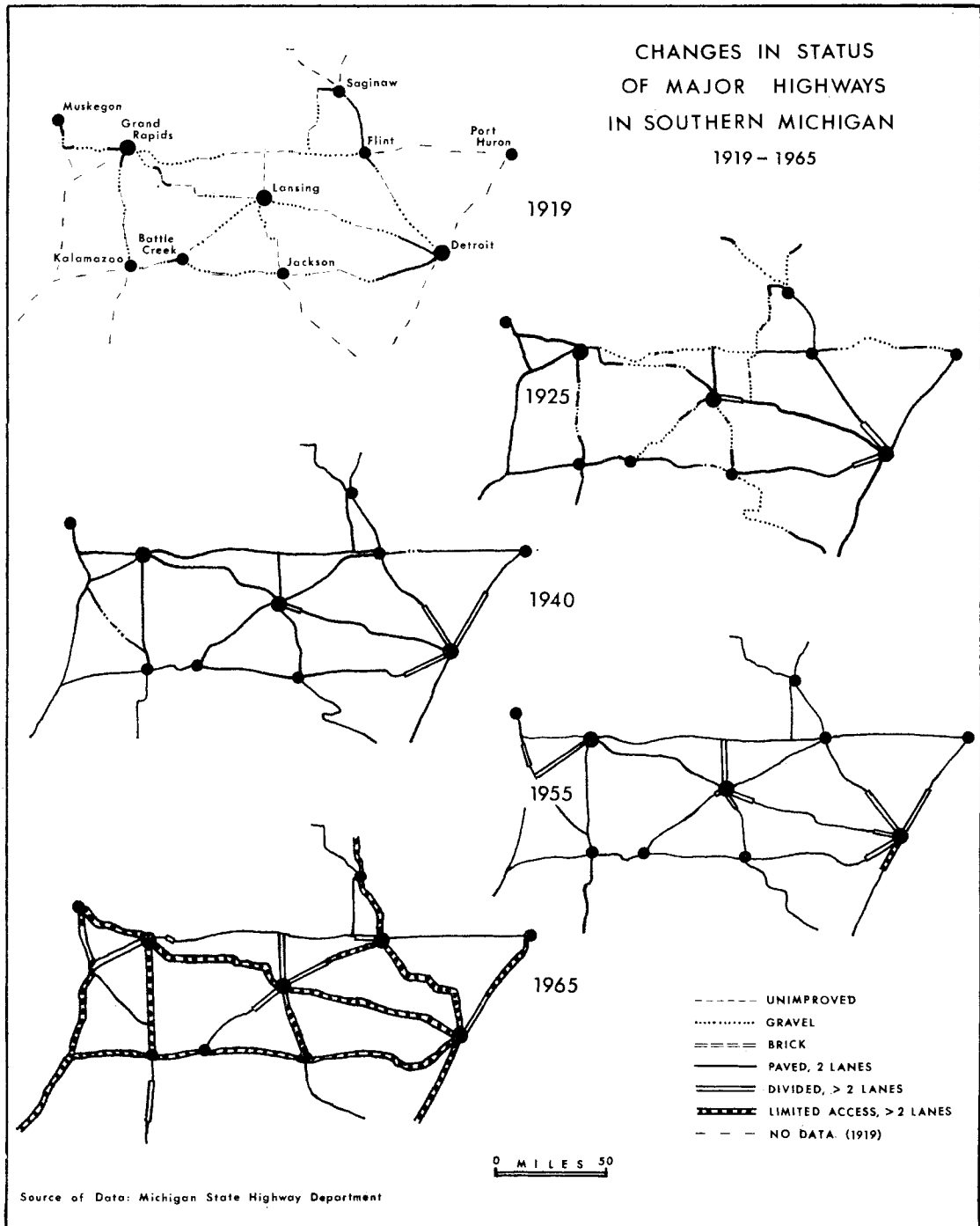
Source of Data: Michigan State Highway Department

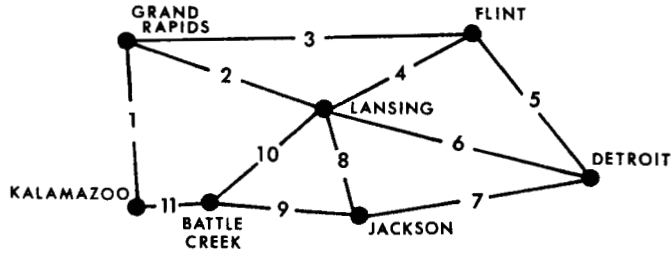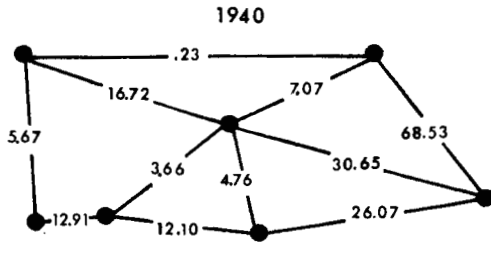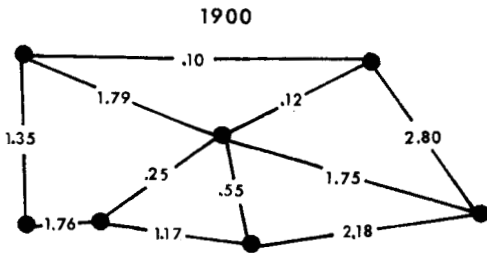FIG. 6.

RELATIVE ADVANTAGE FOR HIGHWAY IMPROVEMENT
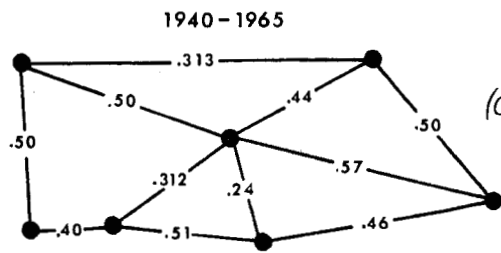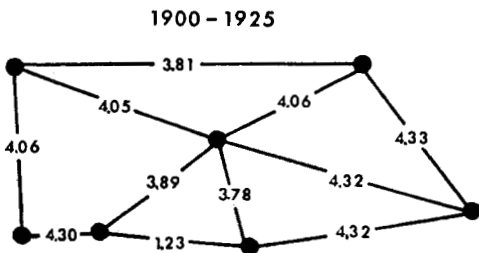AND TIME-SPACE CONVERGENCE FOR MAJOR MICHIGAN ROADS
1900 - 1925 and 1940 - 1965

(a)

Link-Demand (Index of Relative Advantage)

1900

1940

(b)

Minutes Saved Per Route Mile (Convergence Measure of Route Improvement)

1900 - 1925

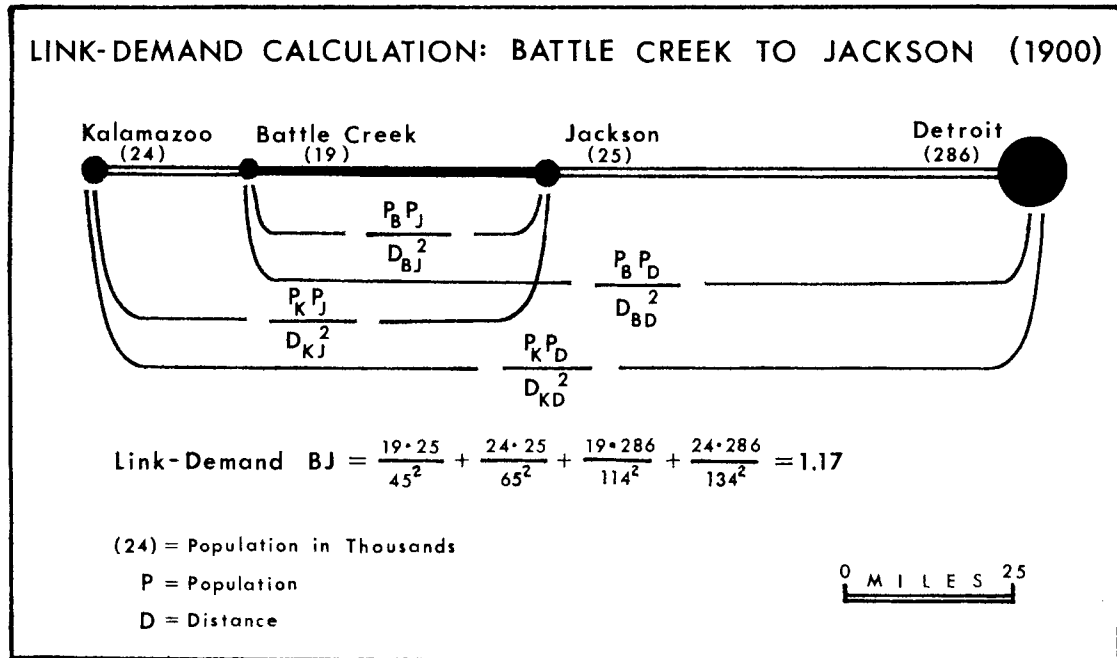1940 - 1965

(c)

0 MILES 50

Fig. 7.

FIG. 8.

1965 from information known in 1940. For the initial years of each period, 1900 and 1940, the principal highway trunklines were nearly homogeneous in quality—mostly unimproved clay and sand roads in 1900 and, as shown in Figure 6, mostly two-lane paved roads in 1940.[23] Thus, the calculation of travel-times between cities for these two years assumes standard speeds of ten miles per hour for 1900 and forty miles per hour for 1940. For the years 1925 and 1965, travel-times are based on the following criteria:

1925—unimproved roads   (10 miles per hour),
    —gravel roads   (25 miles per hour),
    —brick roads   (35 miles per hour),
    —paved two-lane roads   (40 miles per hour).

1965—where possible, actual travel-time

data from the Michigan State Highway Department are used.[24]

Otherwise:

—paved two-lane roads   (45 miles per hour),
—divided highways   (55 miles per hour),
—limited access roads   (60 miles per hour).

Through application of the above criteria in calculating travel-times, a convergence measure of actual route improvement—minutes saved per route mile—is derived for the two periods in question. This convergence measure will be used to evaluate the success of the predictive variable—relative advantage. The hypothesis under investigation is as follows: the degree of innovation will increase as relative advantage increases. The surrogate used to represent relative ad-

[23] Of the 68,000 miles of roads in Michigan in 1905, only 7,700 miles were graveled and only 245 miles were stone or macadam. See Michigan State Highway Department, op. cit., footnote 22, p. 6.

[24] Michigan State Highway Department, Highways Connecting Pertinent Cities with O'Hare Field (Chicago) or Metropolitan Airport (Detroit) (Lansing, Mich.: Michigan State Highway Department, 1963).

TABLE 1.—LINK-DEMANDS FOR 1900 AND TIME-SPACE CONVERGENCE FOR 1900–1925

Linkages (see Fig. 7)	Calculations of link-demand*	Link-demand value (LDV)	Rank (LDV)	Travel-time over link** (minutes)		Route miles	Minutes saved per route mile 1900–1925	Rank (Minutes saved)
				1900	1925			
1 (KG)	KG + BG	1.35	6	288	93	48	4.06	6.5
2 (GL)	GL + GD + GJ	1.79	3	378	123	63	4.05	8
3 (GF)	GF	.10	11	630	230	105	3.81	10
4 (LF)	LF + BF + KF + JF	.12	10	360	116	60	4.06	6.5
5 (FD)	FD	2.80	1	360	100	60	4.33	1
6 (LD)	LD + GD	1.75	5	510	143	85	4.32	2.5
7 (JD)	JD + BD + KD	2.18	2	432	121	72	4.32	2.5
8 (JL)	JL + FJ + GJ	.55	8	222	82	37	3.78	11
9 (BJ)	BJ + KJ + KD + BD	1.17	7	270	84	44	4.23	5
10 (BL)	BL + KL + BF + FK	.25	9	288	101	48	3.89	9
11 (KB)	KB + KJ + KD + KL + KF	1.76	4	120	34	20	4.30	4

* Link-demands for 1900 were calculated as indicated in text and are based on the following city limit populations (in thousands): Battle Creek (B), 19; Detroit (D), 286; Flint (F), 13; Grand Rapids (G), 88; Jackson (J), 25; Kalamazoo (K), 24; and Lansing (L), 16. Source: U.S. Bureau of Census, *Twelfth Census of the United States: 1900, Population, Number and Distribution of Inhabitants,* Vol. I.
** Based on criteria established by author (see text). Source: Compiled and calculated by author.

vantage is an index of link-demand derived from the simple gravity model

$$\frac{p_i \, p_j}{d_{ij}^2}$$

where $p_i \, p_j$ is the product of the populations of the two places joined by the link, and d_{ij}^2 is the square of the route mileage between them.[25]

The above procedure is complicated somewhat when a system has several places

[25] For a good review and appraisal of the gravity model, see G. Olson, *Distance and Human Interaction* (Philadelphia: Regional Science Research Institute, 1965).

demanding travel over the same link. For example, the demand for travel over link 9 in Figure 7B is not only a function of travel-demand between Battle Creek and Jackson, but it is also a function of the demands for travel between Detroit and Battle Creek, Detroit and Kalamazoo, and Kalamazoo and Jackson. Thus, as illustrated in Figure 8, the link-demand for a highway improvement between Battle Creek and Jackson represents the sum of the gravity model indices for each pair of places whose interconnection requires use of link 9. The demand values for the other ten links were determined in similar fashion and are shown in Figure 7B for the

TABLE 2.—LINK-DEMANDS FOR 1940 AND TIME-SPACE CONVERGENCE FOR 1940–1965

Linkages (see Fig. 7)	Calculations of link-demand*	Link-demand value (LDV)	Rank (LDV)	Travel-time over link** (minutes)		Route miles	Minutes saved per route mile 1900–1925	Rank (minutes saved)
				1940	1965			
1 (KG)	KG + BG	5.67	8	72	48	48	.50	4
2 (GL)	GL + GD + GJ	16.72	4	93	62	62	.50	4
3 (GF)	GF	.23	11	158	125	105	.313	9
4 (LF)	LF + BF + KF + JF	7.07	7	75	53	50	.44	7
5 (FD)	FD	68.53	1	90	60	60	.50	4
6 (LD)	LD + GD	30.65	2	126	78	84	.57	1
7 (JD)	JD + BD + KD	26.07	3	108	70	72	.46	6
8 (JL)	JL + JF + JG	4.76	9	56	40	37	.24	11
9 (BJ)	BJ + KJ + KD + BD	12.10	6	68	45	45	.51	2
10 (BL)	BL + KL + BF + KF	3.66	10	72	57	48	.312	10
11 (KB)	KB + KJ + KD + KL + KF	12.91	5	30	22	20	.41	8

* Link-demands for 1940 were calculated as indicated in text and are based on the following city limit populations (in thousands): Battle Creek (B), 43; Detroit (D), 1,623; Flint (F), 152; Grand Rapids (G), 164; Jackson (J), 50; Kalamazoo (K), 54; and Lansing (L), 79. Source: U.S. Bureau of Census, *Sixteenth Census of the United States: 1940. Population, Number of Inhabitants by States,* Vol. I.
** Based on criteria established by author (see text). Source: Compiled and calculated by author.

TABLE 3.—TRAVEL-TIME AND TIME-SPACE CONVERGENCE (1940–65) BETWEEN SELECTED CITIES IN THE NORTHERN MIDWEST

	D	F	GR	J	K	L	M	PH	S	SB	T	Chicago
BATTLE CREEK	170	147	93	68	30	72	146	248	179	131	168	234
	105	114	60	45	22	57	101	230	150	91	135	157
	.58	.34	.53	.51	.40	.31	.46	.11	.24	.46	.29	.49
DETROIT		90	219	108	200	126	276	86	137	272	86	402
		60	140	70	135	78	182	64	91	188	53	268
		.50	.54	.53	.49	.57	.51	.39	.51	.46	.58	.50
FLINT			158	131	177	75	215	100	47	278	162	381
			125	98	135	53	165	80	31	225	115	265
			.31	.38	.36	.44	.35	.30	.52	.29	.44	.46
GRAND RAPIDS				146	72	93	57	258	173	168	246	254
				100	48	62	40	200	145	118	195	180
				.47	.50	.50	.44	.34	.24	.44	.31	.44
JACKSON					98	56	203	193	162	174	100	291
					67	40	150	149	125	135	85	200
					.46	.43	.39	.34	.34	.34	.18	.46
KALAMAZOO						102	123	278	209	100	198	204
						81	82	208	165	70	150	136
						.32	.50	.34	.32	.45	.36	.50
LANSING							150	176	107	203	156	306
							100	140	80	150	130	215
							.50	.31	.38	.39	.25	.45
MUSKEGON								315	192	177	303	263
								252	180	158	240	180
								.30	.09	.16	.31	.47
PORT HURON									147	357	171	488
									120	260	120	333
									.28	.41	.45	.48
SAGINAW										309	209	413
										234	140	300
										.36	.50	.41
SOUTH BEND											219	131
											135	80
											.58	.59
TOLEDO												349
												215
												.58

170
105
.58

1940 \ 1965 / Travel-time in minutes

Minutes saved per route mile (1940–65)

Source: Based on criteria established by author (see text).

years 1900 and 1940. Shown in Figure 7C are the convergence values of actual route improvement for the periods 1900 to 1925 and 1940 to 1965. Data pertinent to these calculations are included in Tables 1 and 2.

Spearman's rank correlation technique was used to measure the statistical association of the rankings of the demand and improvement variables. This technique yielded R values (significant at the ninety-five percent level) of .74 for the 1900–1925 period and .69 for the 1940–1965 period.[26] The results, though not conclusive, are encouraging. It is evident

[26] The test of the significance of R values was based on the use of Student's t as suggested by M. J. Moroney, Facts From Figures (Baltimore: Penguin Books, 1956), pp. 334–36. In this study, findings based on Spearman's rank correlation technique are to be regarded as tentative rather than conclusive.

that the inclusion of places outside the chosen system of seven cities such as Chicago, Toledo, Saginaw, and others might have greatly altered both the rankings of the link-demand and the results. Furthermore, the gravity model used here may be a comparatively crude measure of the relative advantage for transport improvement.

Although a comparison of the rankings of the link-demands for 1900 and for 1940 show a high degree of stability (R equals .87 at the ninety-nine percent level of significance), a similar comparison of the convergence rankings for the two periods reveals some signs of significant change in the time-space connectivity of Michigan's transport network. For example, link 2 from Grand Rapids to Lansing moved from eighth in the convergence ranking for 1900–1925 to fourth during the 1940–1965 period. On the whole, however, the changes for 1940–1965 were consistent with those of the 1900–1925 period of route improvement (R equals .67 at the ninety-five percent level of significance).

In general, this evaluation suggests that highway development in Michigan has varied with the changes in relative advantage. And, owing to the pronounced stability in the rankings of the link-demands, it is evident that transport innovations helped to confirm and to augment the existing advantages in time-space connectivity for dominant places. For example, during both periods, Detroit ranked first among the seven cities in the average number of minutes saved per route mile along each of its radiating links. In essense, Detroit has been favored by a greater increase in locational utility than any of the other six places in the system. Thus, in accordance with the norm of spatial reorganization as outlined in the basic model (Figure 3), Detroit should also be favored by the greatest increase among the seven cities in the centralization and specialization of human activity. This concept will be tested against the background of wholesale enterprise in thirteen upper midwestern United States cities.

Spatial Reorganization: Wholesale Activity in the Upper Midwest

Wholesale activity is a form of economic specialization which, according to Philbrick, shows dominant centralization in places of

TABLE 4.—TIME-SPACE CONVERGENCE (1940–1965) AND WHOLESALE GROWTH (1939–1963) FOR SELECTED
METROPOLITAN AREAS IN THE NORTHERN MIDWEST

Place	Avg. TSC* 1940–1965 (minutes saved per route mile)	Indices of wholesale growth (1939–1963)**									Rankings of Change			
		Wholesale sales (millions of dollars)			No. establishments			No. paid employees (thousands)			TSC	Sales	Estab.	Employ.
		1939	1963	Change	1939	1963	Change	1939	1963	Change				
Battle Creek	.393	18	117	99	107	180	73	.6	1.5	.9	9	12	11	10
Detroit	.513	1,392	9,952	8,560	3,100	5,640	2,540	29.7	65.0	35.3	1	2	2	2
Flint	.391	76	386	310	181	420	239	2.1	7.6	5.5	10	7	6	5
Grand Rapids	.422	91	1,008	917	500	1,000	500	3.6	10.3	6.7	3	4	3	3
Jackson	.403	16	147	131	109	200	91	.9	1.6	.7	7.5	10	10	12
Kalamazoo	.416	23	205	182	134	290	156	1.1	2.6	1.5	4	9	8	8
Lansing	.404	45	411	366	260	440	180	1.7	4.0	2.3	6	6	7	7
Muskegon	.373	16	123	107	113	180	67	.6	1.6	1.0	11	11	12	9
Port Huron	.338	18	62	44	76	130	54	1.3	.7	-.6	13	13	13	13
Saginaw	.349	42	240	198	190	290	100	1.9	2.7	.8	12	8	9	11
South Bend	.411	50	512	462	190	460	270	1.7	4.8	3.1	5	5	5	6
Toledo	.403	137	1,096	959	530	1,000	470	5.7	11.5	5.8	7.5	3	4	4
Chicago	.486	4,150	23,682	19,532	8,200	12,210	4,010	98.3	171.0	72.7	2	1	1	1

* This is the average convergence of each place to the other twelve places in the system. Calculated by author from data in Table 3.
** The values of wholesale indices are for the SMSA's as defined for the 1960 U.S. Census. County data are used for Battle Creek and Port Huron.
    Source: U.S. Bureau of Census, *Sixteenth Census of the United States: 1940. Census of Business 1939, Wholesale Trade*, Vol. II; and *1963 Census of Business, Wholesale Trade Area Statistics*, Vol. V.

third order and above.[27] It seems reasonable to assume that wholesale firms would fare best if they located at those places which are most accessible to their customers. If this is so, then places offering high degrees of locational utility relative to other places should be dominant wholesale centers. However, as indicated for the highway network of southern Michigan, the time-space surface of locational utility is in a state of sporadic flux —differential transportation development induces variations in the relative rates with which places improve their time-space connectivity with one another. Thus, this factor of non-homogeneous transport change is incorporated in the general hypothesis that the wholesale activity in a place will increase as the time-expenditure per unit of operational success decreases. In other words, that place which experiences the greatest degree of time-space convergence, compared to all other places in the system, will be expected to show the greatest absolute growth in wholesale activity.

A system of thirteen metropolitan areas in the Upper Midwest has been selected to test

[27] A. K. Philbrick, "Principles of Areal Functional Organization in Regional Human Geography," *Economic Geography*, Vol. 33 (1957), pp. 299–336.

this hypothesis. Indicated in Table 3 are the travel-times for 1940 and 1965 and the time saved per route mile between each city and the other twelve places in the system. In Table 4 the average convergence of each place to all other places in the system between 1940 and 1965 is included along with various indicators of wholesale growth during roughly the same period—1939 to 1963. These cities were ranked from one to thirteen on the convergence and wholesale variables, and Spearman's rank correlation was used to measure the statistical association of the rankings of time-space convergence with each of the indicators of wholesale growth. The three wholesale measures showed close association with the convergence factor; R values, significant at the ninety-nine percent level, equaled .76 for the increase in dollar sales, .81 for the increase in the number of wholesale establishments, and .77 for the increase in the number of paid wholesale employees. These findings lend cautious support for the notion that, at least for the wholesale function, time-space convergence is a useful surrogate for estimating the centralization and specialization possible at given places.

In this example, convergence was least

effective in suggesting the rank changes resulting from the growth in wholesale activities for Kalamazoo, Flint, and Toledo. Among the thirteen cities, Kalamazoo stood four positions lower in wholesale growth than it did in convergence. In contrast, Flint and Toledo each ranked four positions higher in change of wholesale activity than they did in the ranking of time-space convergence. Thus, relative to the locational utility of other places in the system, it is possible that Kalamazoo has increased, and Flint and Toledo have declined, in status as potential sites for wholesale activity. Interestingly, dollar sales by wholesale firms in the Kalamazoo metropolitan area increased 8.9 times between 1939 and 1963 in contrast to increases of 5.1 and 8.0 for the Flint and Toledo metropolitan areas. The average growth factor for the thirteen areas was 7.5. It appears, therefore, that even in those cases where convergence showed comparatively little rank association with wholesale growth, wholesale activity did gradually shift in association with changes in the surface of locational utility. As indicated in the evaluation of the basic model, there is an inherent inefficiency in human place-behavior and, therefore, such lags in spatial reorganization are to be expected.

CONCLUSION

The objective of this study has been three-fold:

1) To conceptualize the role of transport technology as a key factor in the spatial reorganization of man's activities;
2) to outline the "steps" in the process of spatial reorganization; and
3) to propose a conceptual framework that accounts for the differential operation of this process at various places.

The premise upon which the study was based was that man adapts the areal structure of his activities in response to changes in transport technology which enable him to travel faster and to have access to larger areas and to more resources.

Given the assumptions of rationality as developed earlier in this study, the proposed theses seem tenable: 1) that time-space convergence is a significant factor leading towards spatial adaptation, and that 2) spatial reorganization will accelerate most rapidly at those places which stand to benefit most from increasing accessibility. However, in light of the limitations posed by the assumption of rationality, it is evident that the concept of relative advantage, as applied to the process of spatial reorganization, is not in complete accord with reality. The relative advantage concept seeks to explain man's decisions on the basis of motivation (i.e., desire for net social benefits, locational utility, operational success, and the like). The decisions of man, however, are often conditioned by his lack of information, or non-maxima goals.

In that much of man's areal development is presently directed by various government agencies (at the city, region, state, and nation levels) rather than by the demand for locational utility, it seems that complete understanding of the process of spatial reorganization may rest upon one's knowledge of the decision-making processes of these agencies.[28] Upon what information are their decisions made? By what goals are they motivated? Answers to these questions were beyond the scope of this study. Nonetheless, until answers to such questions are found, the understanding of spatial reorganization will be limited to mechanistic concepts similar to those outlined herein. It is believed that a more refined understanding of spatial reorganization must await efforts to account for lags in the process and to evaluate the significance of both spatially and temporally variant goals. Dynamic programming techniques may hold some promise for the solution of these problems.[29]

[28] For an excellent review of studies on decision theory and their applicability in planning, see J. W. Dyckman, "Planning and Decision Theory," *Journal of the American Institute of Planners*, Vol. 27 (1961), pp. 335–45.

[29] A brief review of dynamic programming is provided by R. Bellman, "Dynamic Programming," *Science*, Vol. 153 (1 July, 1966), pp. 34–37.