Approaches to Three Highway Impact Problems

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● THE ACCELERATED development of highway transportation facilities will most certainly introduce marked changes into urban, suburban, and rural life. One is traveling farther, more frequently, and for more varied purposes than before, so the range of distance over which day-to-day travel occurs is being extended, and activities consuming transportation are organized at larger and more efficient levels. An example of the latter is the growth of specialized services using highway transportation to serve customers dispersed through large areas.

Curiosity is widespread about the results of these accelerated transportation developments. For instance, knowledge is needed for both public and private investment decisions, for the formulation of planning policies to insure orderly development of areas served by new facilities, and the formulation of taxation policies. Competition by government services for tax revenue is very keen and many states are pressed for funds to match federal participation in highway construction. Too, the Federal Government is now participating actively in highway user taxes and this requires consideration of highway tax revenue sources at each level of government.

A number of studies of the economic impact of highway improvements have been made in response to these needs for knowledge. A review of completed studies (1) reveals that greatest interest has been in the impact of improvements on business sales and land values in nearby areas. Some of these studies have supplied general information in local areas. Other studies were intended to assist in right-of-way acquisition (2, 6). Also, it is well known that a number of studies are under-way or have been recently completed relating to Section 210 of the Highway Revenue Act of 1956. These studies emphasize relevant criteria for the evaluation of nonuser benefits from highway improvements and the estimation of such benefits. The ensuing paper reviews research (3) on nonuser benefit questions. There are implications from the research for the topics identified earlier, however, because there is a great deal of overlap among impact questions.

The research is reviewed from the standpoint of objectives, methods, and implications. Research objectives and implications will be discussed in some detail, but methods will be sketched only briefly. Thus, stress will be on the point of view (objectives) and fruitful directions of research (implications) rather than on the technical organization and particular findings of the studies.

By way of introduction, contents of the studies and the questions the studies attempted to answer are described briefly as follows:

1. A study of changes in retail business structure resulting from improvements of highway facilities. Structure refers to the spatial layout of the entire urban retail business activity. The question was: How does a complex competitive activity adjust to changes in transportation facilities?
2. A study of variations in household travel patterns associated with variations in available transportation facilities. Particular attention was given to travel for shopping purposes, and to travel as it relates to the selection of the residential site. Two questions were asked: (a) How does a transportation improvement vary the amount and kind of travel from households and, thus, relate to residential site selection? (b) What are the mutual relations between the complex pattern of travel from households and the structure of retail business?
3. A study of the urban, interurban, and national structures of a service industry. Again, structure refers to a spatial layout of the industry in its entirety, and the study treated structural changes as the availability of transportation facilities varies. The question was: How can the pay-off of a transportation improvement be measured? This question was asked for a single industry and pay-off was measured in terms of the industry and of consumers.

In ensuing sections of this paper the contents and questions listed above are elaborated through discussions of the objectives and methods of individual studies. There are implications from these objectives and methods for economic impact research, and these implications will be merged with the individual discussions. It will be noted that the questions asked in studies 1 and 3 could be answered using the points of view and methods of the studies. The questions asked in study 2 proved intractable. The ability or inability to answer questions has implications for impact research. This is given special attention in the final summary of the paper.

STRUCTURE OF RETAIL BUSINESSES

It is well known that the retail businesses of a modern urban area are arrayed in a complex system of locations. The apex of the location system is the central business district, and the grocery on the corner in a residential district and the isolated gasoline station are at other extremes. The availability of transportation makes possible the aggregation of certain establishments serving many customers, thus achieving significant economies of large size and economies from grouping with other establishments. At the same time, many establishments operate effectively while serving only small tributary areas. These businesses may be located in neighborhoods and communities convenient to the ultimate consumer (that is, isolated stores or stores in small shopping centers). At first glance there seems to be an endless variety of location choices available and resulting location patterns. But this is a competitive system. Businesses compete for customers via the transportation network and patterns of business location represent some sort of spatial equilibrium in terms of location choices available, characteristics of businesses, and the availability of transportation and customers.

Effect of Highway Improvements

The highway transportation system is improved; this improvement would set off a game of "musical chairs" with firms shuffling to new locations in their new location environment (Fig. 1). Eventually, a new equilibrium pattern would result. The difference between the before and after pattern is the change induced by highway improvements, and it is the subject under discussion. (After equilibrium will be more efficient than the before if highway improvements are warranted. Efficiencies achieved represent a pay-off from highway investments to retail businesses.) But the game of relocation is much more complex than "musical chiars" because businesses are set within sets and subsets of shopping centers and trading areas. Regional shopping centers are set within the trading areas of central business districts, community centers are set within a higher order network of regional shopping centers, and so on. The many kinds of retail businesses and possibilities for changes in emphasis on goods or services within each business complicate the question as do variations in the time required for firms to respond to changes in their location environments. Again speaking figuratively, one will have a game of "musical chairs" with many players, each playing at his own speed, with his own rules, and having the possibility of going up and down as well as around.

Speaking less figuratively, the structure of retail business mirrors a highly organized and interdependent system of land uses. The environment of the system is the transportation network and customers that may be served over that network. The impact of a highway improvement is in part in terms of freer flows of traffic over the highways (user benefits) and is in part in terms of changed structure of lay-out of the pattern of business (a type of nonuser benefit). It might be mentioned that the retail business problem is one of a set of problems. Changes in the structures of residential, industrial, and other land uses follow highway improvements.

Research was designed to give explicit recognition to the complexity of the location system. First, a study was made to establish the exact character of the spatial structure of business competition. Second, a study was made of the sensitivity of individual elements in the system to changes in available transportation. Finally, the two approaches were brought together to yield a composite analysis of the sensitivity of structure to changes in highway facilities.

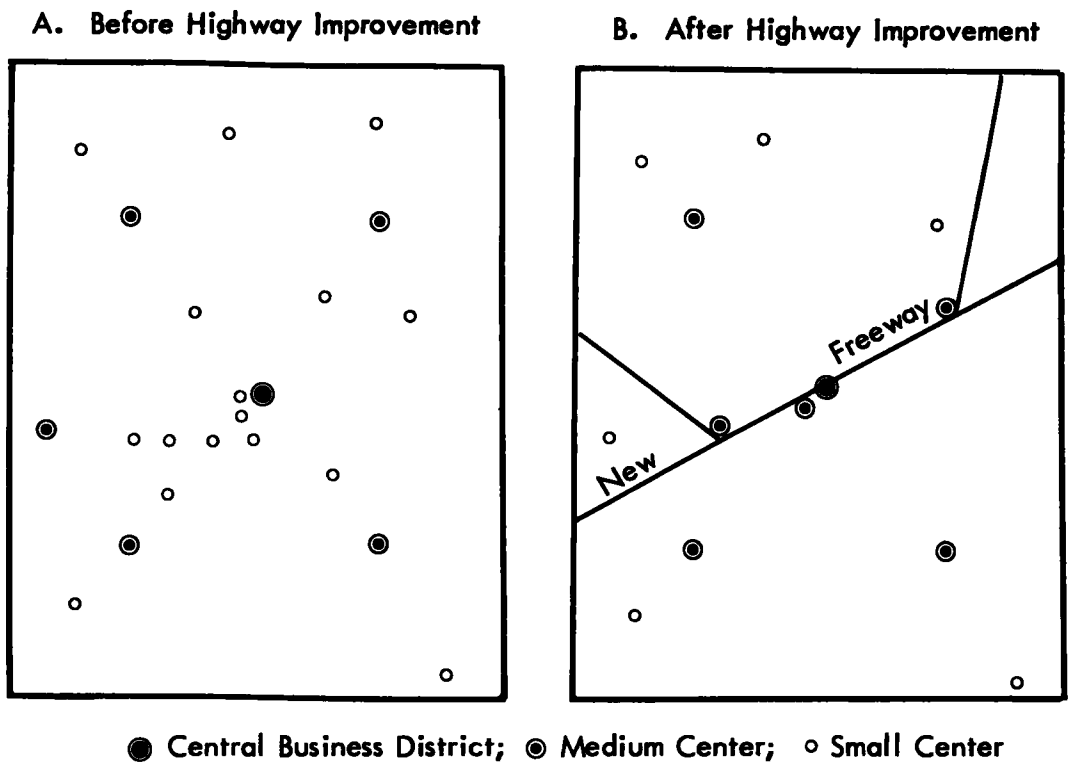

Figure 1. Arrangement of retail business centers before and after highway improvements (hypothetical).

Establishing Structure

The retail structure of urban areas has been analyzed many times and general notions of structure are available in the literature. However, examination of these studies reveals that each uses an a priori classification scheme, details of structure exist by definition and by definition alone. Thus, it was necessary to establish the exact character of the spatial structure of urban businesses.

Detailed data on the location of businesses were available in the case of Spokane, Washington, and in several other comparison areas. The tendency for establishments to associate areally was determined by an ordinary correlation matrix—a correlation coefficient was computed for each pair of businesses in the n locations observed. Next, the tendency for groups to exist was determined by linking correlation coefficients within the correlation matrix. The exact method is too complex to be elaborated here. But it yields business groupings in terms of grouping tendencies and independent of a priori judgments on the nature of groupings.

Finally, continued aggregation using grouping methods yielded systems of nucleated shopping centers and isolated and arterial business locations. Each element in the system was identified as to its composition and as to the strength of spatial associations giving rise to the type. The system included a set of nucleated shopping centers, extending from the isolated grocery store through the central business district. Certain nucleations were also associated with urban arterials including the familiar "automobile row." In addition to these, it was possible to identify a series of highway-oriented businesses of a non-nucleated type.

The validity of the location system identified in Spokane was checked by comparing data from Cedar Rapids, Iowa, Phoenix, Arizona, and Cincinnati, Ohio, and by an examination of data on planned shopping Centers and data on the location of facilities along US 99 in a portion of western Washington.

Sensitivity to Highway Change

The complex business structure identified is subject to change when availability of transportation facilities changes. Just which elements in the system change and in what way is partially evident from variations from place to place in transportation facilities. Another approach to this problem of variations is by examining changes in individual businesses when the highway environment changes over a period of time, and this was the method used to establish sensitivity.

Business sales data were available from a study by Garrison and Marts (2) for establishments in Marysville, Washington, and on a stretch of highway nearby for a period before the construction of a bypass highway around Marysville and a comparison after period. Sales data were also available for a control area which was used to adjust for the influence of general business conditions on the before-and-after data. The problem of observing business sensitivity was quite a complex as that of measuring the spatial system of business land uses. For one thing, the change in highway facilities was more complex than what is implied by simply mentioning a bypass highway. The subject area, Marysville, is on US 99 within a complex of towns and trading areas between Seattle and the Canadian border. The new highway facility decreased congestion in downtown Marysville and also increased the ease of traveling from and to Marysville from other places in the area. This means that the amenity qualities of the business facilities changed as did the competitive position of the businesses versus larger towns and versus other towns which had been competing along the borders of the Marysville trading area.

Other complexities of the analysis included the well-known difficulties of analyzing time series data. Although tax reports on sales were used as the primary data and the data were presumably "good", errors were present. Too, it was necessary to make comparisons with the control area and resolve variations in business classification from one area to the other.

As a result of the study it was found that some businesses had increased in volume of sales, others had decreased and still others remained essentially unchanged. Too, it was found that the seasonality of businesses had varied from the before to after period.

Changes in Structure

Given knowledge of the geographic structure of business activities and knowledge of the sensitivity of individual firms within that structure to highway changes, it was possible to make prognostic statements regarding changes in structure. At the level of technical operations, the temporal analysis was merged with the cross-section analysis, that is, the temporal data were grouped in a manner compatible with the spatial groupings of businesses. Statements could then be made regarding the changes expected in the whole spatial pattern.

But many technical and more general problems could be solved only crudely. In particular, the sensitivity data were restricted to a limited number of types or retail businesses and to the reaction of these types to a particular type of highway change. The rich variation in types of highway changes, retail businesses, and locations that would appear in the course of widespread highway improvements was simply not observed for the observations were fragmentary at best. Another limitation was that the data were strictly short run because only a two-year period after highway improvement was used to compute sensitivity to change. The length of the observation period was not long enough to observe actual business relocations; only changes in business levels were observed. There is no assurance that relocation patterns will correspond exactly to changes in business sales.

On a more general level, there were difficulties in anticipating the pattern of sites available for relocation choices as well as the distributions of markets which might affect these location choices. It was found, for example, that certain of the arterial type businesses were extremely sensitive to changes in highways. However, location choices available to businesses of this type are strictly limited by planning and highway engineering and design policies and procedures. Widespread development of limited-

access highways limits the available sites for such establishments as do zoning ordinances in many urban areas. Nucleated establishments are extremely sensitive to the distribution of households (their markets), and business relocation will depend upon evolving patterns of residential land uses as well as the technical and zoning restrictions on possible location choices mentioned earlier. In other words, it is not known to what degree relocation will be technically possible and to what degree redistributions of customer population will influence the pattern of location choices.

HIGHWAY UTILIZATION FROM RESIDENTIAL SITES

It was just mentioned that questions of the rearrangement of shopping facilities are closely related to problems of the relocation of households subsequent to transportation improvements. The continued development of transportation facilities has seen the dispersion of residences into urban and suburban areas as regular trips over long distances become practicable.

This problem of changes in the arrangements of residential areas could be treated in a manner similar to the approach used in the study of retail businesses. The researcher would establish the present structure of residential areas and, by observing changes in particular parts of the structure, make statements regarding the arrangement of the whole complex of residences following an anticipated highway improvement. Other approaches to the problem were taken, however, in order to experiment with other aspects of impact problems.

Research Questions

During the discussion of retail businesses it was mentioned that a highway improvement occasions a freer flow of traffic as well as a rearrangement of land uses served by that traffic. It is widely known that the purposes and characteristics of travel change, when improved facilities are available. One study of households was concerned with such changes: How does travel from residential sites vary when highways are improved (Fig. 2)? Corollaries to this question are the ways the availability of highway transportation enter into residential site selection and, thus, changes in the structure of residential areas follow highway improvements. In the view of the researchers, these are more penetrating questions than questions that could be answered by observing highway improvements and changes in the structure of residential areas, asking: How does the structure of residential land use change when highways change? That is, the latter identifies how patterns change; the previous question bears more closely on why changes occur.

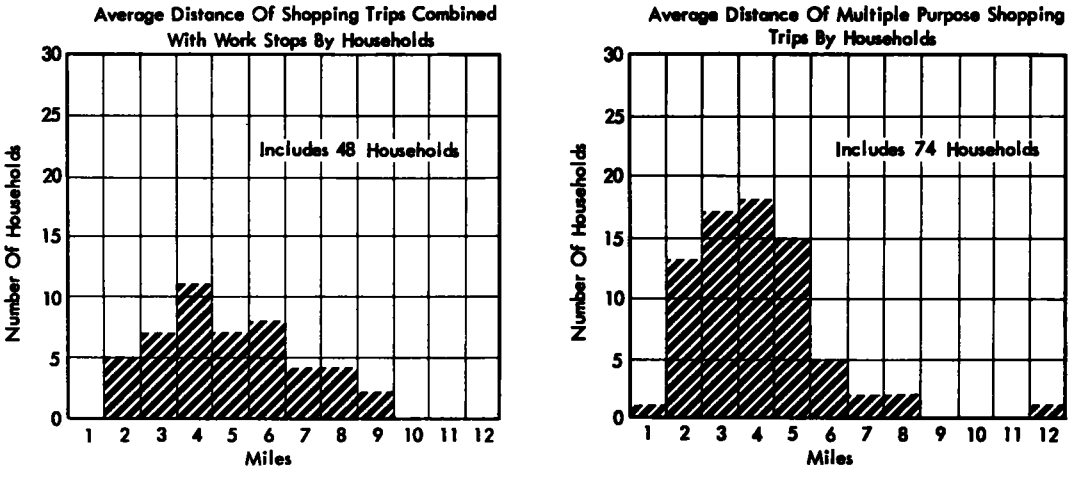

Figure 2. Frequency distributions of average distance traveled by households, Cedar Rapids, 1949.

The problem of the structure of residential areas relates closely to the problem of the structure of retail businesses. In the discussion of retail businesses it was asked how a single system of land uses changes when highways are improved. This simplifies the problem because how retail business land uses change will depend on how other land uses change. Land uses compete with each other for space, and travel is between various types of activities. Stated another way, changes in the structure of residences would occasion changes in the structure of retail businesses. Another aspect of the study of households focused on this question: What are the mutual relations between the structure of residential areas, travel from households, and retail business land uses?

Data Utilized

Data on trips from households in Cedar Rapids, Iowa, were the basic travel information used in the studies. The data were from 30-day travel diaries which were supervised by interviewer contacts every other day through the period of the study. (These basic data were collected by the Traffic Audit Bureau, Inc., and were made available for purposes of the study by that organization and the Outdoor Advertising Corporation of America.) A sub-sample of 100 households was used for expediency in the analysis.

Other data used in the studies were on property values in Spokane, Washington, and Cedar Rapids, Iowa, and the location of retail businesses in each city. Census block statistics were used for property value data, and data on retail business were obtained by field work in Cedar Rapids and from the study of Spokane mentioned in the earlier portion of this paper.

Selection of a Residential Site

A general notion giving direction to the study was that the occupant of a residential site balances cost of his transportation against the cost he must pay for the site at which he resides. The individual who travels a great distance to his residence occupies an inexpensive suburban or rural site. The individual who selects a site convenient to the termini of his trips, and thus keeps travel cost to the minimum, must reside in high rent districts close to the center of town. It is postulated that decreased cost of transportation due to continued highway development will occasion a much greater substitution of transportation cost for site cost. As a consequence, the locations of residences will be widely dispersed in locations where modern transportation facilities are available.

The notion of substitution of transportation cost for site cost was used as a guide to the study of a broader question—a study of how an improved transportation system and easier travel result from transportation improvements, and play their part in changes in structures of activities. One way this broader question was recognized in a study of travel from residential sites was by recognizing the many purposes of travel since travel characteristics may differ by purpose. Travel for department store shopping may not change with improvements of highway facilities, for example, while travel for recreation might change tremendously. These changes would certainly have implications for changes in the structures of these activities.

The research problem stemming from this general notion was to identify the relationships between site cost and travel cost in order to have specific information on the willingness of persons to substitute one for the other.

Several sets of data were examined in two study areas. Each set of data was examined using multiple regression techniques to associate the location of residential sites (within the network of travel connections) with site values.

A study was made in Spokane, Washington, which used simple airline distances from shopping centers as the measure of household location. Information on density of population, racial character, and direction from the central business district were also related to the value of residential sites. The Cedar Rapids study area treated essentially the same problem but variables were weighted by performing a logarithmic transformation upon the regression model. Too, distances were measured in road distance, and the place of work of the head of the household was introduced as a travel parameter.

In each case, census data were used for the value of single family dwelling units, and in Cedar Rapids census data on rents were also processed.

Results varied from model to model, but there was no evidence of strong relationships between the variables studied.

Motivated by the rather weak results achieved by computing the models, supplemental studies were undertaken of the manner in which households utilized transportation. The Cedar Rapids travel data were used for this analysis of characteristics of travel which associated (a) lapsed time away from home, (b) trip frequencies, and (c) total distance traveled with location of the residence (measured in a variety of ways) and a group of socio-economic factors. In all, fourteen independent variates were associated with the three dependent variates (listed above) in three separate studies. Results varied from case to case but, in general, the performance of the models was fair, the models explained roughly half of the observed variations. In the elapsed time and trip frequency studies the socio-economic variables tended to exhibit the greatest associations. In the total distance study the location variables were the most significant. One exception was the variable road distance to the nearest low-order retail center which was significant in the trip frequency study.

Shopping Trips

The Cedar Rapids data on trip characteristics of household were also analyzed from the point of view of the arrangement of retail businesses. The notion here is that individuals travel different distances and at different frequencies for various types of goods and services. The amount of transportation consumed by individual retail business establishments was measured in terms of customer travel to the individual establishments. The shopping center reference points were developed by methods used in the Spokane study of the spatial arrangements of business centers.

The extent of combining purposes of trips was marked—59 percent of the trips studied were for combined purposes. Of the single stop trips, groceries, supermarkets, and theatres accounted for more than half (55 percent). It was found that single-purpose trips were generally shorter than trips for multiple shopping.

It proved extremely difficult to analyze the multi-purpose trips and relate these multi-purpose trips to the complex structure of business centers. An attempt was made to determine groupings of trip purposes but no isolated groups could be developed from the data. Thus it was not possible to construct an ordered grouping of trips which could be compared directly with the ordered groupings of the location of business establishments. As with the other studies of travel from households, it was not possible to establish simple sets of strong relationships.

ANALYSIS OF A SPECIFIC INDUSTRY

One study just discussed embraced the whole complex of retail business and the other the whole complex of travel patterns. The third research approach was through the examination of a particular activity in terms of its spatial layout and travel requirements. This approach merges the approaches of structure and movement. Physician care was studied because of the availability of some reasonably good data. In addition to incorporating concepts from the two studies discussed previously, the physician care study used methods of analysis and points of view which were unique. In particular, the study used a specific measure of the benefits or pay-offs from highway improvements.

It was remarked earlier that highway improvements represent a change in the network of communications over which organizations compete for customers. The act of improving facilities sets off a rearrangement of competing centers and, provided the improvement is warranted, the activity is positioned more favorably after the highway improvement than before. That is to say, improved transportation facilities introduced efficiencies in the activity. Recent history of the physician care activity dramatically illustrates this idea. Prior to the turn of the century most persons were served by physicians nearby or not at all; long distance travel was within the means of a relatively few persons and individuals were restricted in physician care to local non-

specialized physicians. With the introduction of the automobile and the widespread development of paved highways, it became possible for almost anyone to travel a great distance to seek the exact medical care desired. Thus, more transportation was consumed in the process of obtaining medical care, more choices of physicians were available, and physicians could specialize. This resulted in higher quality physician care. To continue to generalize from the example, there were benefits or payoffs to consumers (better medical care), to the transportation industry (more transportation consumed), and to the medical activity (more specialization and more output because the physician could see more patients).

The notion of pay-offs to producers, consumers, and transportation was a guiding notion in the study but, as mentioned earlier, the study complements the studies centering on arrangements of activities and use of transportation by households.

Measuring Pay-Off

A scheme known as the spatial equilibrium model was the organizing device of the study. The spatial equilibrium model answers the following question: Given a set of producers and consumers with each producer and consumer having known supply and demand characteristics and given that consumers are supplied efficiently over a transportation network with known transportation costs, what will be the pattern of production, consumption, and flows if the transportation system is changed? A change in the transportation system may be thought of as the introduction of new routes or a change in transportation cost on existing routes. The spatial equilibrium model also answers the question: What is the value of the change in the transportation network (Fig. 3)? The spatial equilibrium model was applied in three ways in the present study.

In an earlier portion of this study it was emphasized that business activities are set within a complex system of sets and subsets of supply centers and trading areas. It is known that this is the case for medical services. Certain well-known clinics in large urban areas attract patients from great distances, even internationally; within individual regions there are movements at a regional scale; and particular patterns of movements are associated with individual urban centers. No attempt was made to specifically codify the character of the system of physician care centers and trading areas but the existence of such a system was recognized by operating studies of various scales. A national study was undertaken dealing with trade among nine regions. A study on a regional level was undertaken using data for western Pennsylvania, and a study on an urban level was made using data for Seattle, Washington.

Data Utilized

In stating the problems solved by the spatial equilibrium model it was mentioned that supply and demand characteristics as well as transportation costs are given. It was necessary to have information of this sort for each application of the model and, in addition, it was necessary to know the structure within which changes occur and the changes in the transportation network which change structure. Fulfilling these data requirements presented major problems in the analysis.

It is well known that the demand for physician care in a large measure reflects numbers of persons and their disposable income. The ready availability of information on these variables from well-known sources meant that this data could be worked up in a straightforward manner. Physician supply characteristics were approximated by investigating data on physicians' incomes under various conditions and such data are also readily available.

It was necessary to have information bearing on the utilization of the transportation system including cost and patterns of flow between centers of care and tributary areas. Information of this type was available from a study of western Pennsylvania and from the travel data for Cedar Rapids, Iowa, mentioned earlier in this paper. Also, new data were obtained by a study of movements for physician care in Seattle, Washington.

Information requirements on highway facilities prior to highway improvements and changes in cost and arrangements of routes after highway improvements were rather specific. The highway improvements were those of the Interstate Highway System, so

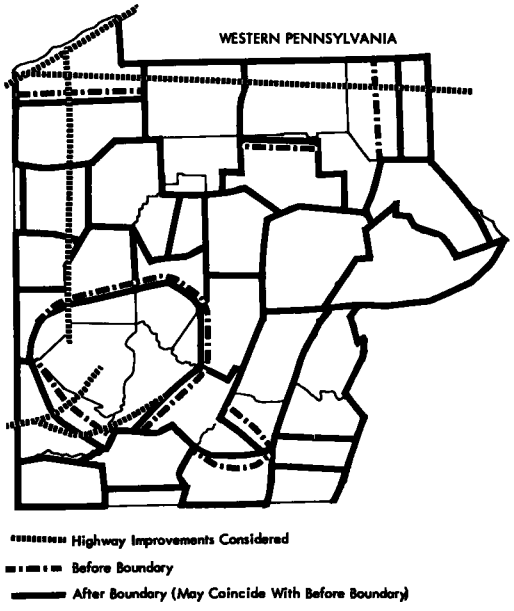

Figure 3. Estimated shifts in boundaries of medical service areas following highway improvements.

anticipated changes in routes were available from planning literature. Materials bearing on cost differentials between facilities of the class of the Interstate Highway System and previous facilities were adapted from prior studies.

The Studies

There were three separate applications of the model—a national nine-region study, a study on a regional level of western Pennsylvania, and a study on an urban level of Seattle, Washington. The national study examined the equilibrium solution for 1950 and made a gross evaluation of the value of having interregional trade. Because there had been no actual observations of movements of persons for care interregionally, and thus little was known about the validity of the operation, no attempt was made to carry the national study through to an evaluation of rearrangements of regional alignments given changes in highway facilities.

A previous study in western Pennsylvania served as the data resource for the intraregional study. A basic solution for 1950 was examined in this case and this solution was compared with projected major changes in highway facilities. Data were restricted to observations on a county level and consequently the analysis was carried through only in a general way for this study area. Too, a rather limited amount of Interstate Highway construction is anticipated for western Pennsylvania, and this limited the magnitude of anticipated effects.

Data in the Seattle study were relatively fine scale in comparison to the two previous studies. Equilibrium models were computed and benefits and losses as the result of planned freeway construction were evaluated.

IMPLICATIONS

Results of the studies have pertinence in a variety of directions. There are, for example, implications for urban and regional planning policies and procedures, policies of highway design and rates of development, and theories of urban growth and development. Although remarks on these points might be interesting, it seems most important to continue to stress implications for further studies of transportation impact problems. The studies reviewed exhibit what can be done now with available ideas and techniques, and also exhibit directions where the exact character of efficient research is obscure. Briefly, successful studies were made of the impact of highway developments on individual activities and on groups of activities. On the other hand, problems of the analysis of transportation from residential sites seem intractable. The ensuing study of research implications will elaborate these brief statements.

Single Industry Studies

In the study of physician care, it was possible to carry the study to a final determination of the impact of highway improvements in terms of producers, consumers, and transportation consumed. The final determinations lacked generality, however, because they were made for one specific urban area and one of many types of highway improvements. Since only one-fifth of one percent of consumer expenditures are for physician care, the analysis lacked generality that might have been achieved if an activity more significant in terms of expenditures had been selected for study.

These problems of lack of generality are by no means insurmountable. More studies are needed for more activities and in more cases. However, analysis difficulties would appear in studies of other activities which would be more formidable than in the study of physician care. It was mentioned earlier that the case of physician care was selected because of data availability. It would be difficult to find other activities where fine scale data are available comparable to those for physician care. Too, the study was facilitated by a number of previous studies on physician care, and it would be difficult to find other industries where comparable levels of information were available. Even in the physician care case, it was necessary to adopt a number of approximate measures in order to operate the study empirically.

The ensemble of data used in the single study included information on highway changes and cost of transportation changes associated therewith. Information from known plans was sufficient to establish changes in highway facilities, but notions of cost associated with new facilities were only fragmentary. Here is another source of error associated with single activity studies.

The use of measurements which are only approximate is especially dangerous. It will never be practicable to study each and every situation, generalizations must be made from specific studies to many cases. Errors which may be relatively minor in a specific instance may become quite significant when projections are made to many cases.

Groups of Activities

The single activity approach fails to single out the interplay of the variety of location forces guiding response to highway changes. That is to say, the study of a single activity neglects the possibility that what is occurring in another activity may affect the studied activity. This problem of the whole complex of activities may be subjected to analysis and this is an important implication of the study of the complex of retail business activities. It has been shown that through a combination of cross-section and temporal classification devices it is possible to make explicit statements of the sensitivity of business structure to highway improvement.

What is needed is a replication of the study of structure in many places and with observations based over a long period of time. Observations of structure at many places would more clearly codify the exact character of the spatial structure subject to analysis. The use of longer periods of analysis would extend experience to cases where actual relocation can be observed.

This is not to say that all that is required is a series of directly repetitive studies. Transfer of interest from retail business structure to some other structure, say the structure of wholesaling, might raise unforeseen problems of analysis. Too, it would be desirable to generalize from the level of a complex of activities of a particular type, say retail business, to more complex situations: that is, the whole structure of activities, recognizing retail businesses, wholesaling, residences, etc., as individual components of structure. Certainly problems will arise at this level of aggregation that have not been experienced before.

Location of Residencies

It was not possible to produce incisive results from manipulations of data relating to travel from residential sites. Thus, the nature of empirical work which will give detailed information on the general problem of the rearrangement of households following highway improvement remains obscure. Useful results are urgently needed. The problems of estimating demand for transportation and thus estimating traffic volumes in light of the relocation of households is central to the whole problem of highway impact and information on how households consume transportation under various conditions is essential to its solution. It should also be mentioned that solution of the problem would enrich the results of researches of the types discussed previously. Problems of the rearrangements of business location, for example, could be solved more precisely if problems of the relocations of households could be solved.

The remarks above should not be taken to mean that no useful work has been done on

the use of transportation from households, for instance, Hall's (4) study of travel in San Diego. A great deal of work has been done with aggregations of households and empirical results on topics such as trip frequency. The problem under discussion here is at a disaggregated level. This point is made clearer in the discussion of the utility matrix to follow.

Lack of results from the research implies that the problem of household travel is an exceedingly complicated one and that fruitful empirical work is not practicable until a better understanding is available of processes that condition travel consumption. This problem is complicated in several ways. One is the analysis of the multi-purpose trip. A large proportion of all trips are multi-purpose and these proved extremely difficult to analyze. Specifically, it was not possible to relate patterns of multi-purpose trips to either spatial patterns of business land uses or the makeup of households generating the traffic.

A Suggestion

Inability to make incisive statements regarding travel from residential sites indicates that travel decisions are much more complex than relatively naive models will reveal. From discussions with others and the review of research (Marble (5)) it may be suggested that two elements should be introduced into the models. The first is measure of the utility of travel as such to the traveler. Previous models have treated travel as a phenomenon to be minimized while achieving gains at destinations. Perhaps one should think of maximizing joint gains from travel as such and gains at destinations, subject to limitations on the amount of travel that is regarded as desirable, and the like. The second is that the traveler has imperfect information regarding the outcomes resulting from travel.

These two notions may be explained rather crudely in a table (Table 1). There are n households and m destinations. Associated with each household and each destination is a utility of the trip, u_{ij}. Household 1 assigns the utility u_{11} to destination 1, for example.

It is easy to see why statements about individual households are extremely difficult. Associated with the household is a vector of trip utilities, $u_{i1}, u_{i2}, \ldots, u_{im}$, from the utility matrix and knowledge of the elements in this vector is needed. But these elements are not fixed numbers. Take the case of shopping destinations, for example. Prices, goods available, and services at individual destinations change from time to time and the traveler lacks perfect information on these. Thus, the household is choosing in light of probabilities of the utility of trips, and utility assignments would change from time to time as well as from member to member of the household. Too, in associating characteristics such as trips made by households with a destination (examining a column) it must be recalled that households are at varying locations and, consequently, are reacting to their vector of utilities in varying ways. In this sense, the average of a characteristic, such as average trip length, is by no means necessarily related to some summary measure of the utilities, such as average utility.

The discussion in the paragraph just completed emphasizes the value to the traveler of reaching the destination. There is also value attached to the act of making the trip. Thus, the elements u_{ij} in the utility matrix may be separated into a u^*_{ij}, which is the value of being at the destination, and a u'_{ij}, which is the value of making the trip ($u^*_{ij} + u'_{ij} = u_{ij}$). As was true of the value of achieving the destination, the value of making the trip, u'_{ij}, would vary from time to time since congestion, weather, etc., vary from time to time. The traveler would have imperfect knowledge of the state of these factors, so the u'_{ij} are not fixed and known numbers.

Predictions of Trips from Residential Sites

A significant body of information has been obtained by measuring amounts of travel, for example, trip frequencies. But this information is of questionable value in projecting characteristics of travel following highway improvements since it only indicates to what extent the desire to travel results in travel, given present travel facilities. A change in travel facilities will result in a changed amount of travel. But knowledge of

TABLE 1

MATRIX OF TRAVEL UTILITIES

Households \ Destinations	1	2	3			m
1	u_{11}	u_{12}	.	.	.	
2	u_{21}	.	.			
3	.					
4	.					
.					u_{ij}	
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this change is limited since there is no direct information on relationships between travel characteristics and travel desires.

Estimation of travel characteristics in terms of the utility matrix poses a major problem to the researcher. But estimation can only follow exact statement about the matrix to be estimated, and discovery of empirical devices powerful enough for that estimation. This is a major problem and a major challenge to the highway transportation analyst.

SUMMARY

Experience indicates that useful studies may be made of the impact of highway improvements on single industries and on groups of industries. Studies of household travel in relation to highway improvements which centered in travel to retail business location and changes in travel characteristics, were of limited success. Lack of success suggests that household travel characteristics are much more complex than the simple models used to approximate travel characteristics indicate.

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