Appendix E

A Source of Theory for Highway Impact Studies
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It has long been known that transportation plays a vital role in the well-being of communities. As long ago as 1813, A. Young, the then British Secretary of Agriculture, reported:

> The roadway was no sooner completed than rents rose from
> 7 shillings to 11 shillings per acre; nor is there a
> gentleman in the country who does not acknowledge and
> date the prosperity of the country to this road.
> (A General View of the Agriculture of Sussex, 1813)

This common knowledge has long posed problems to those who would predict or explain the impact of improved transportation routes. It has not always been clear, however, that a large body of theory is available that should serve to relate seemingly diverse impact problems, point up priorities for research, and allow generalization from limited empirical experience.

Perhaps part of the reason highway impact studies have not been oriented more closely to theory is that the nature of impact is not entirely obvious. The impact of a transportation route, say a road, is a functional impact. Routes function by connecting places. Good routes bring places close together, poor routes keep places separated. A route improvement occasions an improved functioning of the route and places served by the route are brought closer together. The impact problem, then, is a problem that treats relationships between locations and we must look to theory that treats locations explicitly for a theoretical basis for impact studies.

Other likely reasons why impact studies have not been more closely theory oriented might be mentioned. The researcher has been tempted by issues of public policy (for example, is the impact of a one-way street system more or less desirable than the impact of a two-way grid?) and rightly so, for many of these issues have been extremely important. Also, there has been much need for the traditional simple and expressive cost-benefit approach to impact problems and the researcher's attention has been rightly attracted to these problems. It will be pointed out shortly that cost-benefit analysis may have a basis in theory that treats of locations.

It must be understood that in the current statement we are not depreciating studies of the class referred to in the above paragraph, these studies have been and will continue to be important. The present statement is concerned with another subject. We wish to emphasize the availability for impact problems of theory that treats locations.

This theory, here termed location theory, may be thought of as serving in several situations. Not all of the theory that treats locations is usually termed location theory. For simplicity, however, this term is used in a broad sense in the present study. These situations are used as divisions of ensuing portions of this statement. It must, of course, be recognized that the succeeding discussion makes no pretense at providing a complete discussion of all theoretical statements available.

EXPLANATIONS OF LAND USE

Land use tends to be the outcome of competitive bidding for loactions. Relative location may change when highways are improved and, thus, land use may change. Theory that explains land use as the outcome of location is clearly pertinent to the highway impact problem.

There is a long history, dating from Thünen (1826), of theory explaining the arrangement of agricultural land uses. In this theory agricultural land uses compete for the supply of land, and ability to compete is determined by location and transportation qualities. The theory has recently been restated by Heady (1952), Dunn (1954) and Isard (1956) and treated in axiomatic form by Marble (1956). There is no doubt that the theory is a powerful conceptual tool, especially as it may be applied to broad areas. Kellogg (1935) found the notions of the theory useful in one study, but Garrison (1956) did not find the Thunen notions useful on a local level. The findings of Church (1950) are interesting in this general context.

Land use in urban areas has been approached in a manner quite similar to the Thünen scheme for agricultural land uses. Ely and Wehrwein (1940), for example, have provided an account of the process of displacement of urban land uses due to competitive bidding for locations. Park (1925), Hoyt (1939), Mitchell and Rapkin (1954), and others have also suggested schemes which serve to explain land uses, but these schemes are based on broad "ecological" notions and are less explicit than those concerned strictly with the competitive bidding for sites. Firey (1947), Durden (1955) and others have provided summary statements of these latter schemes and have reported that the theory gives mixed results when applied to actual situations.

ARRANGEMENTS OF TRANSPORTATION ROUTES, URBAN FUNCTIONS, AND URBAN CENTERS

Another body of theory seeks to explain the arrangements of cities and transportation routes. Transportation is basic to the system, which is defined on an ability to trade goods from urban centers to surrounding tributary areas. The approach is aggregative and geometric. Urban functions group together, giving rise to urban centers while the spacing of these centers is geometrically determined by the competition of groups of functions for market areas.

There are several sources of theory for this problem. Christaller (1933) some years ago provided a general discussion of a theory (the hierarchical class-system) and elaborated a special case of the theory. The character of this special case has been elaborated in the American literature by Ullman (1941). This theory and the associated concepts of Fetter (1924) have since been further developed by Lösch (1944) and Isard (1956) and in both cases interesting results are available, especially with reference to the arrangement of transportation routes. The theory has since been subjected to empirical testing by Green (1948), Brush (1953), Bracey (1953), and many others. Vining (1955), however, has pointed out some empirical problems of verification of the theory. On the other hand, Berry (1956) has shown that the theory is viable, at least when one is concerned with the smaller urban centers.

Alternate approaches are available for the same problem. Bogue (1950) has recently treated the notion of metropolitan dominance over tributary areas. Reilly (1931) has popularized gravitational models that seek to explain the competitive positions of cities. Models essentially of the same type have been applied to alternate location processes by other, e. g., Carroll (1955) and Stouffer (1940). It has been pointed out by Converse (1946), Ikle (1954), and others that these models produce good results when applied to data. On the other hand their conceptual bases are not clear. Thus, it is not clear how these concepts might be applied with value to highway impact problems.

LOCATION OF PARTICULAR ENTREPRENEURS

There are also tools available for dealing with particular entrepreneurs or particular industries, in contrast to the levels of aggregation implied in the discussion above. Weber (1909), Dean (1938) and Engländer (1926) have provided simple schemes applicable to the small producer, Kelley (1956) has discussed the problem for the retail establishment, while Chamberlin (1933) and Orr (1957) have dealt with the large producer. Samuelson (1952), Enke (1951), Fox (1953), and Orr (1957) have dealt with the equilibrium of industries as a whole. These spatial equilibrium models are important, especially if one wishes to work from cost-benefit or optimizing standpoints. For example, Fox (1953) has shown how explicit recognition may be made of changes in transport costs. Orr (1957) further demonstrated how net social returns resulting from trade could be maximized by making optimum use of the available transport system. This latter has direct implications for cost-benefit notions; here is a measure of returns from transportation.

THE ECONOMY AS A WHOLE

Weigmann (1931), Predohl (1925), Palander (1935), Lösch (1944) and Isard (1956) have shown how the impact of transportation is viable within the broad context of economic theory. Isard (1956) in particular has noted that if transport is considered as an input of the same nature as the classical factors of production—land, labor, and capital—then location notions can enrich the theory of economics. Economic theory has been of use in important transportation problems for many years, of course, and valuable theoretical ventures in this frame of reference are provided by the works of Beckmann (1952) and Koopmans (1949). It is noted here only that current merging of concepts may make economic theory even more valuable for the problems before us.

SUMMARY

A tentative attempt has been made to state the highway impact problem as one of relationships among locations. To the extent that this is proper, references to location theory serve to provide an orientation for highway impact studies.

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Statistical Analysis of a Road Improvement Impact Problem
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Several "standard" research designs are available for the solution of problems. The present discussion illustrates how one of these standard designs, a regression design, was applied to a highway impact study. 1/ In the case in point each observation in the data set consisted of a property value matched with measures of the road service of the subject property and other qualities of the property bearing on its value (for example, land utilization). The measurements of road service were in miles of road for a cross classification of road surface type by road use type (e. g., we could speak of 10 miles of dirt road used for the journey to work).

The first problem was to estimate the association of property value with road service.

THE ESTIMATES

The problem was handled by multiple regression methods using inverted matrices. This method is not new, but the large amount of computational labor involved has discouraged its use on as an extensive a scale as that in these studies. However, the use of electronic high-speed computers made the inverted matrix solutions practicable here. The use of inverted matrices simplified the calculation of errors of the regression coefficients, the tests for significant differences among the coefficients, and the deletion of independent variables from the regressions in order to simplify the presentation and use of the findings of the studies.

In general, the postulated relationships took the form:

$$Y = \alpha + \sum_{i=L}^{n} \beta_i X_i + \epsilon$$

in which Y is property value, α is a constant, and the X_i's are the variables of road use, etc.

For each study, the data were arrayed on punch cards and matrix transposition, multiplication, and inversion steps yielded the net regression coefficients (the b_i's as estimates of the β_i's), the variance-covariance matrix, and the error variance.

Decision Criteria

These materials were then used to resolve each regression into its principal components. Terms were deleted using t criteria for the hypotheses $\beta_i = 0$ and $\beta_i = \beta_j$ and on the basis of the contribution of each

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1/See William L. Garrison, "The Benefits of Rural Roads to Rural Property", Seattle: Washington State Council for Highway Research, Part IV of the Allocation of Road and Street Costs, 1956.