

# Highway Location and Economic Development

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•THE THESIS PRESENTED in this paper is that highway location can affect the economic development of an area. The theory of how combinations of factors, including highways, affect the level of economic development is explained. It is then shown how operations research techniques may be employed to develop mathematical models that will measure the impact of the factors that affect economic development. The manner in which the model can be used to test the impact of past and proposed highway locations on the economic development of areas is developed. This is done in the hope that interest can be aroused in employing an objective means of allocating highway construction funds so that the economic development of areas of the nation may be further advanced. It is a proposal and not the results of research, because resources and cooperation are required to carrying the proposal to fruition.

Economic development is of prime importance to areas and the individuals residing in the areas because it is the basis for obtaining the better things of life. In areas where economic development is retarded, the people are poor, standards of living are low, and the area is unattractive when examined from almost any position. The reverse is true in areas of extensive economic development. Wide expanses of the United States are examples of high levels of economic development. India and China are illustrations of economies in an embryonic stage of development.

To establish the impact of highway location on economic development in an objective manner, the component parts of the research must be reduced to quantitative measurements. Due to the nature of the components and a lack of agreement as to their structures this is difficult to accomplish in some areas of research. Economic development itself is a nebulous concept and any efforts to measure it quantitatively are liable to criticism. This is not unique, of course, as doubts can be raised about the applicability of any general purpose measurement by citing instances wherein it does not completely satisfy particular criteria in special circumstances. Nevertheless, quantitative measurements are needed when quantitative methods are to be employed; therefore, economic development is measured here by per capita income. This only partially measures comparative wealth because imputed income, for example, does not enter the computation. It is not implied here that imputed income will vary proportionally with measurable income, and per capita income is recognized as having deficiencies as a measure of economic development. It is used principally because population and income received are available on a fairly accurate basis and in suitable geographic breakdowns for the purposes of the proposed analysis.

The level of income and economic development of an area depends on its basic industries. These are the industrial activities whose outputs are shipped beyond the limits of the area for sale, and income is brought back in return. Manufacturing, mining, and agriculture are basic industries. That part of transportation which brings in income from tourism is also a basic industry. Governmental units such as military installation, universities, and similar activities whose payrolls are provided from outside the area are basic industries. The entire complex of trade and service activities exists only to support the needs of the workers engaged in the basic industries and its level of social attainment depends on the income levels generated by the basic industries.

A transportation system, be it rail, river, or road, also performs a basic function as it is the means of moving the output of the basic industries to market to be exchanged for the money that flows back into the area. The development of railroads during the past century caused the economies of many areas to grow, as did river and sea traffic before that period. Today, with the development of trucking and passenger transportation, the location of a highway can have an impact on the development of a community

comparable to that of the earlier location of railroad, and vice versa, because it joins the community to markets where its output can be sold. Without a swift and economical means of getting output to market, the income and general economy of an area can little grow, regardless of the amount of basic wealth and productive facilities it may possess.

Today, economic development is no longer the change or chaotic proposition that it was in the relatively recent past. With the knowledge of how it can be brought about, the United States has embarked on programs to accelerate the economic development of friendly nations and raise their levels of income and wealth. Some of these efforts are proving successful though others are encountering difficulties in achieving their goals. The success or failure of an economic development program depends on the ability of the program managers to select the particular combination of factors appropriate for developing an economy and combine them in the right amounts to achieve a goal. This is true in domestic development programs, also, but it is not as well-publicized inasmuch as domestic programs are carried on in a less organized manner than are foreign aid programs.

Putting together a proper set of factors for the purpose of raising the level of economic development is an extremely complicated task, particularly when resources are limited and are to be allocated on a subjective basis. But operations research has been employed successfully in dealing with problems having similar characteristics and it offers the means of objectively ascertaining the identity and degree to which factors affect economic development. Furthermore, it provides a means of experimenting with this information in such a way that decisions can be reached objectively as to the optimal courses of action for achieving the goals of economic development.

Operations research, of course, is simply the application of the scientific method to problem solving. It is used in connection with problems of either a qualitative or quantitative nature. When a problem can be quantified, a mathematical model is built that contains all the factors affecting the solution of the problem. This model is then used for experimental purposes, among which is the testing of alternative courses of action. To achieve higher levels of economic development, this approach can be employed to reduce the uncertainty that exists when a choice must be made from among factors to employ for achieving optimal economic development.

The type of highway location to be studied here is one that connects a community to a major trading center. By delimiting the problem to this extent, the effect of highway development between major trade centers on the economies of small intervening communities is omitted for subsequent analysis. In planning the mathematical model for determining the impact of highway location, the problem is defined as one of locating and determining the impact of all the important factors that affect the level of economic development. A list of these factors would be made up initially. It would include manufacturing output, mineral production, agricultural production, tourist activities, the transportation system, investment capital, and others. As has been explained, per capita income is employed as the measure of the level of economic development. Then a number of test areas would be selected on a geographic basis so as to make up a representative cross-section of communities or larger economic areas. Among themselves the communities or areas would show a wide range of income. Then statistics would be compiled for each area relative to its per capita income, volume of output, total government payrolls, and whatever more is deemed appropriate in the theoretical development of the model.

For the transportation system, the presence of a railroad, river, road, etc., connecting a community to a major market would be denoted by a number. Then a scatter diagram would be prepared with the per capita incomes of the communities as the dependent variable and the volume of business in the trade centers to which they are joined by the transportation system as the independent variable. The numbers would serve as a basis for developing the diagram and a study of their distributions would suggest the manner and extent to which a correlation exists between trade area volume and per capita income of the communities of areas. The correlation would not necessarily be very high because other factors also affect the size of the per capita income. The analysis could be further refined by breaking it down into a correlation in which highways

are the connection between communities and trading centers. It can also be done for railroads and waterways. Functional relationships of some degree would exist for each mode of transportation which would be made suitable for further analysis by reducing them to mathematical expressions. With these mathematical expressions it would be possible to predict the impact of locating a highway that would lead from a community by substituting into the mathematical expression the volume of business in the trade center to be connected with the community and noting the effect on the per capita income of the community.

Of course, the solution to the problem is not that simple. Some of the other factors that affect economic development in addition to highway location have been noted. It is apparent that if there is no production in an area, a highway connecting it to a major trade area would have little impact on its economic development, aside from social and cultural aspects. There are too many highway projects of this type already. This is important to states that have limited funds for highway construction. Because many factors affect economic development, each of the factors would be processed in a manner similar to that employed for evaluating the components of the transportation system. This would result in a series of mathematical expressions, each relating per capita income to a factor on a functional basis. The mathematical expressions would then be organized into a single-equation mathematical model that would establish their combined effect on per capita income. The general form of this model would be

$$I = f(A, F, M, R, H, W, G, \dots,)$$

in which  $I$  (per capita income), is shown as a function of  $A$  (agricultural output),  $F$  (factory output),  $M$  (mining output),  $R$  (trading volume in centers connected by rail),  $H$  (trade volume in centers connected by highways),  $W$  (trade volume in centers connected by water),  $G$  (government payrolls), and other factors found to be significant.

The solution would then be quantified by obtaining estimates of the values of structural parameters. In developing these estimates it is not proposed to use least square multiple regression analysis. Estimates so obtained frequently have the wrong sign of relationship. They also have a tendency to change in value whenever a factor is either added or removed in the analysis. When parameters which should be relatively stable can be fluctuated so easily their validity for the purpose of a model that will have repeated and varied usage is doubtful. The operations research approach to this type of model building is less mechanical, requires more knowledge of the structural relationship between the variables, and involves more labor and experimentation.

In the operations research approach, the types of functional relationship between the per capita income and each of the factors are theorized from the economics of the problem. These may be linear in nature but more likely they will be nonlinear to varying degrees of complexity. Each of the functional relationships is usually graphed to ease the subsequent analysis. Then the general form of the equation which describes each functional relationship is selected. Equations already exist that describe some of the expected relationships but it is not unusual to derive the equation of a particular and peculiar relationship. The structural parameters of the general equation are next quantified by selecting values that appear to relate per capita income to each of the factors in the manner described by the graphs and the theory of the relationships. When factors jointly affect the dependent variable, they can be so specified and the relationships expressed in a closed form. The results are mathematical expressions describing functional relationships that are as realistic as the capability of the operations researcher will permit.

The factors will exert varying degrees of impact on per capita income, so they must be weighted. This is started by assigning hypothetical weights on the basis of some rating scale. The scale values are then cumulated, expressed as relative to 100, and used as denominators for the mathematical expressions. This completes the initial effort toward developing the mathematical model for testing the impact of the factors, including highway location, on economic development.

The validity of the model would be tested by substituting historic data on each of the factors affecting economic development and deriving estimates of per capita incomes. These estimates would be compared with actual values for those periods. In

the initial model it should be expected that some, or possibly all of these estimates, will differ from the actuals by more than is desirable. The conceptual aspects of the model will then be reworked by re-examining the theory, the form of the functional relationships, the weighting system of denominators, and the need for additional or fewer factors. Then a new mathematical model will be devised and tested. This reworking may continue through several stages but eventually a model will be derived that is theoretically sound, mathematically consistent, and produces satisfactory estimates of per capita income. When this stage is attained, the model can be used for experimental purposes.

To use the mathematical model to test the impact of highway location on economic development, an area that will be affected by a proposed highway will be defined. Area information will be compiled on each of the factors of the model. This information will be substituted in the model with conditions as they are at present, with zero trade volume for any nonconnected trade center. Then the existence of the highway will be introduced by substituting the trade volume for the center that it will connect to the area and noting the effect on the per capita income of the area. If the per capita income increases sufficiently then it is known that the proposed highway will appreciably affect economic development, and vice versa. This procedure will be employed each time the impact of a proposed highway on economic development is sought.

The uses of a model of this type will be extensive. For one, it will place a state highway commission in a position to allocate its limited highway construction funds to projects that will result in the greatest amount of economic development. In a somewhat parallel circumstance a highway commission faced with the decision of selecting one road project from among several desirable ones can use the model to sort out the project that will produce the greatest amount of economic development. A highway commission that is under pressure to build a road that is politically expedient, but little else, can use the model to demonstrate the small return from the investment and, if desirable, make contrasts with the economic gains to be made by using the funds on other projects. The model can also be used to plan a long-range highway development program by ordering all possible highway construction on the basis of the amount of economic development that the potential construction jobs will engender. This program can be reviewed and revised periodically after substituting the most recent statistics on the development factors in the model and ascertaining desirable modifications which will contribute further to the economic development of a state. And, of course, past highway construction programs can be studied for the extent to which they held back economic development.

If it were an objective of the study, the model could be designed to ascertain the impact of different types of highway construction on economic development. In the breakdown of types of transportation connecting trade centers and communities, the highways could be divided into two, four, and six lanes, or black top, cement, and gravel, and functional relationships established between communities and connecting trade centers by type of highway.

To develop a model such as is proposed here would be neither costly nor technically difficult. Much of the economic data are already available. Collecting and classifying information on communities and connecting trade centers would be the laborious task. Techniques for developing the operations research model are already available and can be made readily applicable in the hands of competent statisticians.