Economics of Highway Location: A Critique of Collateral Effect Analysis

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•CONSIDERABLE controversy exists over the type of analysis which best evaluates the economic changes due to realignment of spatial relationships caused by highway location improvements. A general classification of the analyses for measuring the actual impact or for estimating the potential effect of highway improvement shows that highway location methodology is trichotomous. First, the traditionally applied analysis is the engineering economy method based on total primary user benefits and costs. Second, welfare economists contend that maximum social efficiency in resource allocation requires measurement of the total secondary or tertiary collateral benefits and costs. The relationship between these two methods of analysis has been examined in detail in an earlier study in which the conclusion was reached that the collateral effect method does have certain advantages over the traditional engineering economy analysis (1).

The final category in this trichotomy is marginal analysis based on the equality of marginal user benefits and costs as the measure of efficiency in the use of resources in highway investment. Economists who advocate this last method have expressed considerable doubt as to the conceptual and operational relevance of the use of total values in this decision process (2, 3). The principal objective of this paper is to review highway location methodology in general, and discuss collateral effect analysis in view of the criticisms of the marginal theorists in particular.

The engineering economist accepts the proposition that the highway user effect is the proper category of variable to use. This is so only because of the practicability of measurement and the possibility of avoiding double counting if collateral variables were used. This implies that double counting is inherent in collateral effect analysis. Quite the contrary, it is the avoidance of double counting which gives collateral analysis an advantage. The idea of measuring effects of a higher order than the primary user effects is also a major criticism of the marginal analysts, but for a different reason.

The welfare approach relies on income accounting techniques adapted to the local problem and other methods derived from research connected directly and indirectly with the Highway Cost Allocation Study (4). Criticism by the marginal theorist aimed at the income analysts who must account for the value of public goods and services may be applied also to the problem of accounting for the geographical distribution of the effects of a highway improvement in a given corridor. It is feared if collateral variables become relevant criteria for location analyses, it would just be a matter of time before such criteria would be used for other highway investment decisions. The reason for such concern is the possible misallocation of resources due to overvaluing the benefits of the highway investment. Therefore, marginal cost pricing or the public utility pricing approach even for location decisions is strongly advocated (5).

The procedures of the engineering economy approach and collateral effect method are sketched briefly. The marginalist viewpoint is also presented, followed by its critique of the collateral effects approach. It is also shown that collateral effect analysis can predict the effects of several alternative highway locations on a given corridor and thereby serves as an adequate criterion for public services decisions. This is

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accomplished by comparing a series of models illustrating the characteristics of each approach in highway location analysis.

ENGINEERING ECONOMY METHOD

Once a corridor is designated for a new highway, there are usually several alternative locations which are technically acceptable. The benefit-cost ratio of the engineering economy method evaluates the most profitable alternative among several possibilities by comparing annual user benefits of each alternative with the added annual highway costs. Annual costs consist of the amortization of capital investment, interest on capital, maintenance and operation. Annual highway user benefits, on the other hand, consist specifically of savings in the cost of highway service between two common points.

According to the AASHO Committee on Planning and Design Policy, there are seven principal factors which should be considered: (a) solvency of a system or groups of systems of highways; (b) land, improvements to land, and community benefits; (c) cost of construction or improvement of the highway; (d) cost of maintenance and operation of highways and their appurtenances; (e) direct benefits to road users in the form of reduced vehicle operating costs and savings in time; (f) increased comfort and convenience to road users; and (g) benefits to road users in the form of accident reduction. Regarding quantification of solvency, land and community benefits, and accident reduction, the report adds that due to the character and the general absence of measurable values with acceptable accuracy, it is not possible to specify measurement techniques despite the importance of the factors (6).

It is frequently asserted by proponents of the engineering economy method that secondary effects of highways are only user benefits transferred; therefore, to add user and secondary benefits would be double counting. Likewise, there would not be any differential between user and secondary effects if calculated properly. The fact that only those benefits which accrue to the highway user are considered is further justified by the assumption that revenue supporting the highways is obtained from the users themselves. If this were true, it would be desirable to maximize the benefit-cost ratio based on user benefits.

Using the traditional procedure, an estimate of implied collateral effects is obtained from a sample origin-and-destination survey which provides data indicating the quality and quantity of current traffic flows among various land uses. From these data, used alone or in conjunction with land-use surveys, the projected traffic for a given year is determined, and the total highway user benefits are calculated. From this it can be seen that the problem does not lie in recognizing the importance of collateral effects but in the fact that they are not used operationally.

COLLATERAL EFFECT METHOD

Collateral effect analysis, a welfare approach, unlike engineering economy and marginal analysis, is founded on the precepts of mutually exclusive categories of effects occurring at the primary, secondary and tertiary levels of economic activity resulting from the highway improvement.

Three levels of collateral effect analysis are possible. Secondary collateral effect analysis deals with the nontransferential primary effects and the transferred primary effects, including the externalities measured at the primary and secondary levels. Tangible secondary collateral effects include retained earnings of motor carriers, changes in tax ratables, redistribution of increased earnings by motor carrier industry and highway transport-oriented firms, decreases in gross earnings of industries that are substitutes for the motor carrier industry, increases in gross receipts of firms complementary to highway service facilities, and changes in agricultural production adjacent to the highway.

A higher order analysis—extended-secondary collateral effect analysis-uses transferred secondary effects and nontransferential primary and secondary effects. A third method-tertiary effect analysis-measures the ultimate changes in the economy resulting from a highway improvement, e.g., land values and price level changes. A larger degree of externalities is measurable at a higher order of analysis than at a lower level, but at the same time, the higher the level of analysis, the greater is the difficulty of obtaining meaningful data. Consequently, collateral effect analysis is discussed in terms of the secondary level.

The analysis (1) is essentially a five-step procedure. The first step is to determine the level, composition and normal growth trend of the economic structure in each alternative highway impact zone within the corridor. The relevant trend can be obtained by observing three major economic flow variables: industrial production, agricultural activity, and commercial activities.

The second step is to determine the ratio of the value of collateral effect variables to the value of selected economic structure activities. There is an interdependent relationship between the extent of highway improvement effect and the absolute level and composition of the preconstruction economic structure. This relationship can be determined precisely only after the elements of the economic structure have been broken down into highway-influenced and non-highway-influenced categories. The five specific activities considered as highway influenced are motor carrier industry transactions, agricultural production on land in the area adjacent to highway improvement, receipts of industries complementary to highway services, receipts of industries which are substitutes for highway services, and changes in tax ratables from highway existence.

The third step requires computation of a value for the total change in each collateral effect variable during the life of the highway improvement. The degree of change of the collateral effect variables is a function of the level and composition of the economic structure and the ratio of collateral effects to the economic structure.

In the fourth step, the predicted normal growth curve is modified to allow for the net benefit of the highway improvement. The result is a trend line which reflects the effects of a highway improvement in the zone. This method provides data concerning the net benefits from the improvement. The difference between this predicted growth curve and the normal growth curve computed in the first step provides a benefit value for the secondary collateral effect analysis benefit-cost ratio.

The final step consists of placing the differential obtained in the previous step–the net benefit of the highway improvement–in a benefit-cost ratio employing the traditional concept of costs. This ratio is a measure of the highway effect in a given zone. A similar ratio is computed for each alternative study zone, providing a basis for evaluating the alternative routes. The choice of the best alternative becomes the matter of selecting the route with the highest collateral benefit-cost ratio.

At the theoretical level, certain impacts of the highway improvement will be overlooked unless collateral effect analysis is used singularly or as a complement to traditional analysis. The advantage of collateral effect analysis is its ability to account for the larger degree of effects associated with highway improvements. This analysis is designed to measure the impacts of the highway improvement which originate with the highway, arise through use of the highway externally to the user, and are transferred effects from lower levels of occurrence.

MARGINALISM

Marginalism is an economic principle which explains a form of maximizing (or minimizing) behavior. When producers equate marginal cost with marginal revenue, they are maximizing profits (or minimizing losses). In equilibrium in a purely competitive economy, the allocation of resources according to this principle would be the most efficient, both privately and socially. The value of the product would equal the cost of production at the margin. In other words, the cost of producing an additional unit of output (marginal cost) just equals the amount the consumer is willing to pay for an additional unit (marginal revenue). This analysis would have to be modified appropriately as market conditions varied from the purely competitive assumptions.

The marginal approach as it is applied to highway investment follows the same logic. The efficiency of the allocation of resources into highway use is maximized when the marginal benefit of the highway, which is the addition to value to the highway user from employing another unit of highway service, is equal to the marginal cost of the highway investment. The marginalist accuses the welfare economist of forgetting this principle when collateral effects such as externalities or net non-user benefits are included as a measure of social benefit. The marginal approach would argue that the cost of obtaining an extra externality is zero as far as the additional cost of the highway facility is concerned. Therefore, this value in the investment or location decision should also be considered as zero for efficient allocation of resources into highway use (7). The value problem is reflected in Adam Smith's famous diamond-water paradox:

> The things which have the greatest value in use have frequently little or no value in exchange; and on the contrary, those which have the greatest value in exchange have frequently little or no value in use. Nothing is more useful than water, but it will purchase scarce anything; scarce anything can be had in exchange for it. A diamond, on the contrary, has scarce any value in use; but a very great quantity of other goods may frequently be had in exchange for it. (8)

The answer to the paradox is evident today in the concept of the marginal cost. Diamonds are relatively scarce so the cost of getting an additional one is very high, whereas water is quite abundant and its cost is usually very low. This distinction in value as argued by the marginal theorists is relevant to highway location analysis in the following manner: the value or benefit of a highway improvement can be measured by the price users of the highway are willing to pay for additional highway services. This amount reflects the marginal benefit of the highway service. Assuming that the highway cost is to be borne by the highway user, this benefit received from the highway at the margin when equated with marginal cost would offer an appropriate criterion for comparing alternative locations. This approach to the evaluation problem implies that if the value of collateral effects cannot be obtained at the margin in the market through the price system, then it is inappropriate to use these as variables in the benefit accounting procedure. This is the primary marginalists' criticism of collateral effect analysis.

COMPARISON OF METHODS

This review of the three approaches to highway location analysis permits a closer look at some of the fundamental differences. The method of doing this is to review several representative models from the literature and to construct a composite model through which the nature of the assumptions, variables and results can be compared. These models demonstrate three specific issues among the engineering economy, marginal and collateral effect analyses: (a) the importance of externalities in measuring private and social welfare, (b) the inflexibility of supply of highway services due to indirect pricing of highway services, and (c) the nature of the multiplier or coefficient of expansion of transferred effects.

Pure Competition-Neutral Collateral Effects

The first model represents marginal analysis in an environment of pure competition and a heterogeneous distribution of resources (3). Buchanan assumes that highways are privately produced and marketed; all roads are toll roads. There are many owners of the roads and each owner is free to set his own toll. There are sufficient alternative roads to insure perfect competition in the marketing of highway services. Under these assumptions, the price of highway services will equal the marginal cost of construction and maintenance of highway facilities. The factors considered in the model include highway service, vehicle service and driving time. This model implies that a highway improvement which would increase the supply of highway services to the new level would occur in response to a previous increase in demand for highway services. The price of highway services at the existing level of supply would rise, thereby providing a sufficient incentive for the construction of additional highways. Eventually an equilibrium would be reached. The benefits to the users would be reflected in the prices of highway services which are equated to the marginal costs of the increase in the supply of highway

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and the restructuring effects are neutralized through the equalization of changes in demand and supply of all goods and services within the economy. The indivisibility of highways and their services and the condition that highways are not ubiquitous are abstracted from the analysis.

Garrison arrives at a neutral effect of a highway improvement under somewhat different assumptions (10). The effects of a highway improvement accrue only to the highway user and the full amount of these benefits are taxed through a system of tolls. The tolls serve as revenue for providing subsidies to those made worse off by the highway improvement. Therefore, there is no net effect on the non-highway users and highway improvement effects on users have been neutralized. This example approaches the welfare concept. In all three models, collateral effects or externalities are ignored because secondary effects are neutral when the condition of the competitive model is assumed, as in the case of Buchanan and Zettel, or when the cost of the highway service is directly priced and compensation given, as in the Garrison model. The supply of additional highways is based on user demand, but the location of the new highway will be influenced not only by user demand but also by the degree and distribution of collateral effects. This latter consideration is necessary if maximum social benefit is to be obtained.

Monopoly-Non-Neutral Collateral Effects

The highway system in reality is publicly owned and the cost of highway services is priced directly so that there may be a divergence between maximum social benefit and maximum private benefit. Buchanan derives collateral or non-neutral effect by postulating a monopolistic highway model (3). The simplifying assumptions follow his competitive model very closely at first. There is a heterogeneous distribution of resources. Highways are privately produced and privately marketed. All roads are toll roads. Owners of the roads are free to set their own tolls. The monopolistic feature of the model is a result of the lack of enough alternative routes to insure competition. Under these conditions, the prices of highway services are greater than marginal costs. The result is the existence of collateral benefits. These will accrue to the monopolist initially and then will affect the economy. Because the highway facilities are privately owned, there is no question for society concerning the locations of routes. Monopolists desiring to maximize profits would locate highways without the consideration of collateral effects. They are concerned mainly with maintaining the barriers to perfect competition in this situation.

Greater realism in the conditions of alternative highway location decisions is found in Zettel's non-neutral effect model (9, pp. 32-33). The objective of this abstraction is to show the problem which exists when only a limited number of highways can be built or improvements made. This model represents the engineering economy philosophy and assumes the following conditions:

1. There are two zones, x and y, respectively.
2. There is a heterogeneous spatial distribution of land uses and economic activities in each zone which produces traffic and creates a need for highways.
3. The economy is dynamic in that there is economic growth and an increase in population.
4. Economic growth requires additional highway improvements to maintain the economy of each zone in equilibrium.
5. Highways can only be built in discrete segments over time and at selected locations.

Priority of one highway improvement may be due to certain advantages for residential or industrial development which will suggest greater prospective economic growth even in the absence of the highway improvement. The priority will be determined by evaluating user benefits relative to the cost of the highway. Regardless in which zone the highway is built, the effect of the highway improvements will be distributed unevenly throughout the area.

The benefits accrue to the highway users as a class, but the degree of effect, both positive and negative, is a function of the users' locations relative to the highway improvement. The increases in revenues of highway users in the areas adjacent to the highway improvement will be greater than the costs assessed these users. The distribution of these net gains throughout the economy in higher levels of economic activity are considered by Zettel to be secondary effects which are shifted to the non-users of the highway through the capitalization process. He contends the total benefits at the secondary level can be no greater than the original amount of gain received directly by the user.

A more recent model representing the marginal approach, under noncompetitive conditions, was constructed by Forte and Buchanan (7, p. 113). A public good and service, which may be assumed to be a highway, is provided in a limited quantity within an implied heterogeneous distribution of resources. The services are available without direct charge. It is further assumed that a "fully competitive adjustment" does not take place. The result is that returns to the factors of production may be greater than their cost. For purposes of this analysis, this would be returns to highway users or to other highway-oriented activity. These differential returns to the factors, which may be called rent, replace the cost of production and at the margin in the marketplace become included in the market value of private output. The implication here is that user effects may be transferred to final consumers in cases where highway services are intermediate. The conclusion is reached in this case that value at the margin has no relation to the cost of production because the price of the service is indirect (7, p. 113). If this is interpreted correctly, the basic principles of marginalism seen in the two earlier Buchanan models would suggest that direct pricing of highway services is required if marginal value is to equal marginal cost. Cost would determine the supply of highway services, which is not now the case with indirect pricing. The divergence between marginal value and marginal cost created by the pricing method postulated in this model creates a difficulty for using marginalism as a criterion of highway investment.

The conditions in which collateral effect become important have been abstracted so far. These effects can be made explicit by constructing a composite model. As in all previous models, the distribution of resources is assumed to be heterogeneous. A limited supply of highway service resulting from a highway improvement causes an unequal distribution of effects throughout the location corridor. The economy is dynamic and responsive to highway investment changes. Some degree of unemployment exists and is distributed unequally throughout the corridor. The highway network is supplied as a public good by the government. Indirect charges are made on highway users, but not in response to the supply and demand for highway services. Therefore, fully competitive adjustments cannot take place in the price of highway services. In addition, certain externalities occur from highway construction and highway use. It is further assumed that transferred highway user effects create secondary and tertiary economic activity which results in an increase in the level of the economic structure at rates which can be expressed as "multipliers" or coefficients of expansion. When these data become incorporated into the procedure of the collateral effect analysis, the total effect of the highway location includes the nontransferred user effects, secondary transferred effects and externalities of highway construction and use; this total value is a more complete measure of welfare than would be obtained by other methods.

These models have demonstrated how the wedge of externalities and indirect pricing of highway services forces the effects of the highway improvement to differ in value as the assumptions differ from those of the purely competitive market. The forces of spatial monopoly and imperfect knowledge create an ever-widening differential between private benefit and social benefit.

The Zettel and Garrison models reflected the engineering economy concept that transferred benefits must equal highway user benefits. In the Buchanan models, the marginal principle of maximizing private benefit in terms of user benefits and highway cost is explicit. The Forte-Buchanan model incorporates the institutional difficulty in public service indirect pricing which in following their criterion is applicable to public highways as well. Finally, the composite model emphasizes the importance of externalities, transferred effects and the differential in the measure of economic benefit.

CONCLUSIONS

It is now possible to summarize the implications and conclusions of the methodological difficulties which have been demonstrated in this series of models. These difficulties are the importance of externalities, the inflexibility of supply of highway services, and the nature of the coefficient of transferred effects.

The importance of externalities or external economies results from the public nature of the highway facility. Certain benefits of the highway are rendered collectively, rather than privately. Inasmuch as these are external to the highway user, collective decision-making is required. It is impossible to have the benefits of a highway for some without providing them for all in some degree because the by-product effects impinge inseparably on many people (11). On the other hand, private decisions, under the direct pricing assumption, might still fail to evaluate the worth of externalities in terms of highway use because of the lack of private ownership of the collective effects. Collateral effect analysis would account for the effect of externalities through the change in value of the gross corridor product.

If, under the extreme assumption, marginal user costs on all alternative routes were equal for private maximization, collateral analysis could evaluate the degree of secondary transferred effects and externalities. In a sense this is moving toward the Pareto Optimum, which if the welfare concept of achieving a position whereby somebody is made better off without anyone else being made worse off.

When the equality assumption is relaxed and a differential is measured by the marginal approach, the situation exists as to whether the same direction and degree of difference would be measured by the welfare concept. If the differential is in the same direction, there is no problem. However, if it is not, an additional question may be raised. Is the benefit measured by the collateral effect approach greater than the loss in highway user benefits reflected by the marginal approach? This situation involves a value judgment of interpersonal comparisons of the value of the loss to that of the gain. The additional problem of compensation enters at this point. Are those experithrough externalities and transferred effects willing to compensate :o take the loss? In the decision-making process, this would be nec- a consensus as to the location of the highway.

g models show that under private ownership of the highway, externali- ɘ priced and would not enter the decision process. The cost of obtaining nalities is zero in terms of the cost of producing extra services. There- of the externalities should not enter the highway decision. These values ·iately accounted for in the price and quantity changes of private produc- ve value for these externalities in highway investment analysis would vestment. This marginal principle maximizes private investment and ount for a divergence in the level of private and social welfare. The en- nomy method implies the existence of externalities, but only in the degree ɘrate additional user effects.

analytical difficulty and point of contention of the marginal approach is that ity inherent in indirect pricing of highway services leads to erroneous al- esources because the supply of highway services is not a function of price. fect analysis accounts for this by valuing the additional supply of highway rms of the total effect of the highway in the absence of direct pricing. If ıg were the rule, the need for collateral analysis would be reduced unless ıve locations resulted in precisely the same marginal values. In this case, ry collateral analysis would maximize not only the private allocation of ut also the social allocations. Engineering economy imputes the cost and ghway services to the user, thereby avoiding the problems resulting from ct pricing.

l area of difficulty is the concept that secondary effects may be greater than high. user effects. Marginal analysis concludes that the value of externalities be accounted for in relative price changes or price level changes in the economy. This we have already observed is a part of the tertiary collateral effect analysis. However, these values could not be attributed to the highway investment in the marginal approach. Engineering economy analysts proposed for practical purposes that secondary effects cannot be greater than user effects because they are only capitalized user effects. Collateral effect analysis, through adding up mutually exclusive effects, does determine a coefficient of expansion representative of the degree that the total effect of the highway location is greater than the sum of use effects.

In view of these conceptual problems, there is a place for collateral effect analysis in alternative highway location decisions. Nevertheless, the applicability of collateral effect analysis varies with the conditions of this problem. Collateral effect analysis would be most effective if the goal is to maximize the economic welfare of a society within a corridor in which a highway is to be located, because it offers the most sensitive comparison of economic variables even in light of the difficulties arising out of externalities, indirect pricing and multiplier effects.

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