Overview of Methodology

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Major emphasis of this conference was the identification of models and methodologies for organizing and using existing data for designing future data collection efforts and for applying systematic analysis and scientific procedures to the understanding of policy problems and the making of public decisions regarding transportation system improvements and economic development.

Transportation benefits accruing to road users in terms of time savings, cost savings, and savings from accident reduction are the primary effects of transportation improvements. These transportation user benefits, the main components of benefit-cost analysis, provide a quantitative assessment of the relative benefits of different alternatives in a common monetary measure.

Economic impacts measure the secondary effects of capital expenditures on the regional economy. The impacts affect income, employment, production, resource consumption, pollution generation, and tax revenues. These impacts may be classified broadly into three types: direct, indirect, and induced impacts. Direct impacts are consequences of economic activities carried out on the site during construction and operation. Indirect impacts derive primarily from off-site economic activities associated with the production of intermediate goods and services required for the construction and operation of the improvement. Induced impacts are the multiplier effects of the direct and indirect impacts.

USER BENEFIT ANALYSIS

Improvements to the transport system can change travel characteristics in terms of the amount of tripmaking, trip distribution, time patterns, users, and cost or level of service of the trip. In addition, changes can occur in the capital, labor, and service requirements for designing, building, and operating the physical transport facilities and vehicles.

A basic premise of economics is the intimate relationship between price and demand on the one hand, and price and supply on the other. Demand functions or demand curves are statements of the number of trips that will be made or purchased at different levels of overall trip price, for which the perceived price of travel is the total payment in expense, time, and effort that the traveler perceives or thinks about in making a trip.

On the one hand, it is necessary to know how the unit price of travel will change as more and more tripmaking is made and as system design and operation are changed. On the other hand, it is necessary to know what price different volumes of tripmakers would be willing to pay for the trip in question. The interplay between these two relationships will permit determination of the actual use that a facility will experience and of the benefit or value accruing to its users.

Once the equilibrium point or intersection between the supply and demand curves has been determined, the total system costs can be computed. This information is equally applicable to an improvement in an existing system, to the construction of an entirely new system, or to the comparison of consequences of different levels of improvement (*1*).

CURRENT APPROACHES TO IMPACT EVALUATION

By far the largest number of transportation impact studies have been evaluations of highway projects. The most important distinction is between impacts on users and impacts on nonusers. With respect to the latter, considerations that have been emphasized in the literature are location and land use, land values, and levels of economic activity. Changes in the uses of land served by a highway improvement are extensively documented in impact studies. The implicit theory behind most of these studies seems to be that the new economic activity in the vicinity of a highway improvement represents a net benefit for the region and that it is caused only by the highway improvement.

No subject has received more attention in impact studies than land value changes induced by a new highway. From the way land value data are interpreted, the implicit theory seems to be that changes in the market price of land represent the capitalized value of the entire future stream of user benefits. But there is another important way in which benefits to users are transferred to nonusers that has been largely ignored in highway impact evaluation. A firm whose transportation costs decline will find that this user benefit is transferred internally in terms of increased profits if the benefit is not also received by the firm's competitors. In this case, the benefit is capitalized into land value. However, if the firm's competitors also receive the benefits, the firm may be forced by competitive pressure to decrease its prices, passing on some or all of the benefits to the consumers of its production (*2*).

Some studies attempt to measure the impact of a transportation change on such variables as retail sales, industrial investment and employment, and postal receipts, a more direct approach than analyzing land use data. However, at no place in impact studies does there appear to have been a rigorous examination of relationships between these variables and changes in community welfare.

The research design that dominates impact studies is the before-and-after method. In its simplest form, this design may be regarded as two snapshots, one before a transportation

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change and one after. Observations are made of the impact variables at the two times, and the difference that is detected between the values of each variable is considered the impact of the transportation change.

Firms and households often take a long time to locate or relocate their establishments because of the time required for planning, administrative procedure, and construction. Hence, variables representing the impact on land use and location may not stabilize for some considerable time after the opening of the highway. However, it is clear that over a long period of time there will be many exogenous influences upon the variables being observed. In the simple before-and-after approach, the assumption is made that the change in a variable under observation is caused only by the transportation change. This assumption is violated when the observations are contaminated by influences other than those attributable to the transportation improvement under study (*3*).

THEORIES OF URBAN AND REGIONAL GROWTH

Development is much more than simple growth because it involves changes in quality as well as quantity. However, in an economic context they can be assumed to be synonymous for many purposes, such as in studying transportation impacts. Consistent explanations of patterns of urban and regional growth are provided by economic theory.

Techniques currently available for forecasting urban or regional growth make direct use of one or more facets of trade, location, or staple theories. Each available method assumes that the regions for which forecasts are required have already been defined, that good historical data are available, and that historical relationships will continue to hold in the future. Most forecasting methods link regional fortunes to those of the nation and are predicated on the hypothesis that a solution to the basic economic problem of optimal area development is public and private investment at levels high enough to at least maintain the competitive position of the area's export industries and to provide for the growth of both export and local markets at a rate equal to or greater than the rate of increase in regional labor productivity (*4*).

Long-run effects of transportation changes derive from their influence on locational decisions of firms, households, and other establishments. Variables that are held constant in the short run—job location, place of residence, retail, and industrial locations, for example—are allowed to vary in the long run. However, the state of understanding of these effects is poorly developed. No model represents the market for urban land capable of any but the most primitive types of application, and no model, good or bad, seems to represent the dynamics of the market—the rates at which relocation occurs and the factors influencing the rates.

MEASUREMENT OF THE EFFECTS OF TRANSPORTATION CHANGES

The treatment of the subject of impact measurement is divided into two parts: (a) sources of secondary data, and (b) survey procedures for gathering primary data.

Much useful secondary data exists in various forms such as administrative data used by government agencies at all levels and common data as gathered, compiled, and published by the Bureau of Census and other government agencies. Secondary data of interest include transportation variables, socioeconomic variables, land use variables, housing sector variables, and business sector variables.

In addition to making use of existing data, obtaining primary data involving the impacts of urban transportation changes by means of sample surveys is often necessary. Because the principal application of the data will be to study changes in travel demand and locational decisions of the population, the major emphasis will be on surveys that obtain information from individuals in households or businesses with questionnaires or similar instruments that can be self-administered or administered by an interviewer. Generally, such surveys provide the only hope of obtaining economic and behavioral data in a sufficiently disaggregated form to relate changes in these activities to possible specific causal changes in the environment. Survey methods include household interviews, telephone interviews, mail questionnaires, rider surveys, and office interviews.

MODELING IMPACTS OF TRANSPORTATION INVESTMENTS

In order to evaluate appropriate methodologies for relating transportation and development, visualizing the process by which methodologies are used to develop models that can, in turn, be used for policy evaluation is helpful. A formal model is a synthetic representation of the modeler's mental conception, whereas a methodology is the means by which that conception is transformed into the model. Methodologies provide the modeler with ready-made tools and constructs with which to create a model to allow the modeler to use the work of others instead of creating tools from scratch. Use of an accepted methodology makes it easier to perceive the structure and rationale of a new model, but may lead to restrictive assumptions about the reference system. A methodology developed from repeated model-building efforts in a given field for a particular type of problem may not be applicable to other situations.

A few of these methodologies and their innovators are as follows: linear programming—Dantzig, input-ouput (I–O) analysis—Leontief, econometric modeling—Tinbergen, land use analysis—Lowry, and system dynamics—Forrester (*5*).

Linear economics is the basis of two regional development methodologies: (a) I–O analysis, and (b) linear programming. I–O analysis pictures the economy as a set of interdependent industries and activities each of which requires the productive output of the others as input to its productive process. In the United States, the Bureau of Labor Statistics began publishing official I–O tables in 1952. Many governments have used I–O budgeting in preparing their 5-year plans (*6*).

Whereas I–O analysis postulates a single set of industry outputs (i.e., one feasible solution) as being uniquely determined by a specified set of final demands, linear programming generally allows for any of a number of feasible solutions or combinations of activity levels to produce enough commodities to meet or surpass an indicated set of final demands (i.e., satisfy a set of constraints). To help choose among the possible alternatives, an objective function, typically a cost or benefit criterion, is provided that is expressed in terms of the decision variables. Linear programming models have been developed to predict interregional commodity flows in many countries.

A second field within economics, which fostered two approaches to regional development modeling, might be referred to as statistical economics or quantitative economics. Two methodologies that fall into this class are econometric modeling and microanalysis. An econometric model is, in practice, a set of simultaneous difference equations relating exogenous and endogenous variables. Econometric models of a national economy take major sectors of the economy, such as the business and household sectors, as their components and are highly aggregative.

Microanalysis is a methodology for modeling a national economy that operates at a microunit level. Its primary components are the decision units of which the economy is composed: households, firms, labor unions, etc. These decision units interact through probability statements. A microanalytical model is moved forward in time by the process of Monte Carlo simulation. The probability of an action is calculated and the computer is made to draw a random sample that is compared with the derived probability to determine whether or not the action is to take place and to what degree.

A methodology specifically developed by Forrester of the Massachusetts Institute of Technology to analyze feedback systems is system dynamics. System dynamics is a way of analyzing the behavior of complex socioeconomic systems to show how organization and policy influence behavior.

ECONOMIC BASE ANALYSIS

Present theoretical and empirical findings all stress the importance of export activity as a determining factor in economic growth. Any region within a specialized economy must import to survive—and, to pay for its imports, the region must in turn export to other regions. Thus, a basic sector of urban activity will be the production of goods and services for export. Another sector consists of output activity that, because of convenience and comparative cost, will always be local (e.g., retailing and repair services). If the city is in equilibrium with imports equaling exports and with local (residentiary) output just equaling demand, the question is, on which sector will the equilibrium most depend? Export activity will be the most important, especially in the short run, according to staple or export theory. Urban export activities essentially limit residentiary activities unless these too become a part of the city's exporting base. Fluctuations in the levels of urban exports are a prime cause of changes in urban economic activity. Consequently, forecasts of urban economic activity may be based on multipliers that relate residentiary activities to exports.

In economic base analysis, certain activities are classified as exogenous. These activities comprise the export industries whose fortunes are determined by forces outside the city or region. All other industries are classified as endogenous or residentiary. The fortunes of these industries are determined by internal forces that can be represented by a multiplier linking the export sector to total regional activity. This multiplier is estimated by observing historical relationships between export activity and total regional activity. Then, given estimates of the future magnitude of export activity, application of the multiplier will yield a forecast of the total regional activity.

The inability of simple economic base, two-sector models to adequately depict the urban economic structure has been amply demonstrated. Therefore, in recent years most students of the urban economic base model have favored the multisector approach known as I–O analysis. This method reveals the internal and external relationships of an urban economy in great detail. In this respect, I–O analysis overcomes many of the defects of the simpler methods, especially for purposes of short-run analysis.

I–O ANALYSIS

First developed by Leontief in 1936, I–O analysis is now one of the most typical approaches to the assessment of secondary impacts of public sector development projects and programs. The I–O approach distinguishes itself from other methodologies in that it is more disaggregated and expresses more interdependence between economic activities. Therefore, it more readily shows the behavior of an economic system explicitly and in detail at the national, regional, and local level in response to various economic development policies (*7*).

However, because of their inability to express explicitly the feedback relationships between producers and the transportation system resulting from an oversimplification of input coefficients and interregional trade flow coefficients, conventional I–O models can hardly be used for projection purposes concerning the impacts of various transportation investments.

In the mid-1970s, the Bureau of Economic Analysis (BEA) completed development of a nonsurvey method for estimating regional I–O multipliers known as the Regional Industrial Multiplier System (RIMS). More recently, BEA completed an enhancement of RIMS known as the Regional Input-Output Modeling System (RIMS–II). In RIMS–II, direct requirements coefficients are derived mainly from two data sources: (a) BEA's national I–O table, which shows the input and output structure of more than 500 U.S. industries, and (b) BEA's four-digit Standard Industrial Classification (SIC) of county wage-and-salary data, which can be used to adjust the national direct requirements coefficients to show a region's industrial structure and trading patterns. Regional multipliers for industrial output, earnings, and employment are then estimated on the basis of the adjusted coefficients.

REGIONAL ECONOMIC MODELS

In addition to the I–O approach, economic models that include some transportation variables are spatial equilibrium analysis, production function models, regional econometric models, and regional projection models.

Transportation investments influence the location of industries, firms, and people, which in turn influence the cost of transportation of inputs of production. Thus, unlike most other economic models, transportation tools need to be unusually sensitive to spatial issues. Indeed, the following discussion largely concerns ways in which long-standing approaches can be adapted to problems with significant spatial variation.

Spatial general equilibrium analysis divides an economy into several geographic regions. Market demand and supply equations are used to represent each region's behavior with a typical assumption that supply and demand functions are linear. A major drawback of this type of model is the difficulty in estimating a demand and supply equation for each type of good because of the need for detailed data and the multiplication of the number of demand and supply equations as the number of regions multiplies. Although most of these models date from the 1950s and 1960s, they have received some renewed interest.

Production function is not the ideal form to investigate in detail an economic impact of an infrastructure investment because it is best used for global analysis of the United States, of a state, or of an industry (specifically manufacturing).

For any commodity, the production function is the relationship between the quantities of various inputs used per period of time and the maximum quantity of commodity that can be produced with it. More specifically, the production function is a schedule (table, graph, or an equation) showing the maximum output rate that can be achieved from any specified set of usage rates of input given existing technology.

Limiting the components of the production function to highway investments and nonhighway investments could be useful for investigating the efficiency of highway investments at the state level. An index could be developed and standardized to the average U.S. highway investment efficiency to detect under- or overinvesting in highways at the state level. Presumably, disaggregation of the capital stock for highways is feasible and a measure of efficiency could be derived providing that the price of the disaggregated inputs and output are known (*7*).

SYSTEM DYNAMICS MODELING

Difficulties in solving the problem of the interrelationships between regional development and transportation investments arise because the problem is the object of two different disciplines—development planning and transportation economics—using different languages. System dynamics methodology is used to bridge the gap between the two disciplines by establishing chains of causality from variables within decision makers' control (levels of investment, resource allocations, regulatory actions, and taxing and pricing policies) to socioeconomic development indicators (industrial growth, job creation, unemployment, in- and out-migration rates, population, population density, land use intensity, and per capita income).

A model of this process can be complex and can consist of hundreds of variables. Because of the necessary feedbacks, the determination of the optimal transportation system to maintain a desired level of development can be, to say the least, elusive.

SUMMARY OF MODELING ECONOMIC IMPACTS

All economic models are limited in their ability to duplicate the complex reality of a dynamic economy. Selection of an economic model depends on the type of uses for the results and on the details of information sought. The strength of economic models lies in their theoretical soundness, whereas their pitfalls result from a lack of empirical data needed to support every theoretical intricacy. As a result, applied economic models often are relatively unreliable in practice.

The effects of transportation investments can be divided into three parts: (a) a multiplier process generated by the initial spending on implementing the project, (b) a series of changes in economic structure and then in sectoral outputs or indirect effects attributable to the performance changes in the transportation system, and (c) changes in final demands or induced effects from income effects and population shifts. Direct effects are more or less defined by the economy and can be calculated by using conventional I–O models. Although transportation is a prerequisite of economic growth, its significance as a catalyst may largely depend on the socioeconomic condition of the region concerned.

Changes in the transportation system may take different forms ranging from changing transport costs (money and time) to transport amenities (convenience, comfort, fewer accidents, etc.). The changes may set in motion the whole economy or have only minor influence on it, depending on (a) production sensitivity of the economy to transportation costs, (b) availability of markets and input factors and the possibility of using substitutes, (c) existence of economies of scale and economies of agglomeration, and (d) local attitudes toward production expansion. Relationships between those aspects of the economy and transportation savings should be predicted and quantified and the possible changes in input coefficients and trade flow coefficients caused by the investment should be estimated before using I–O analysis to project the indirect effects of the investment. At present, the computational burden seems to be formidable.

In general, a transportation improvement reduces the spatial resistance between regions. Therefore, improvements help to open up the economy in the sense of more choices of substitution among factor inputs and product outputs. Transportation savings may be put to two uses. First, savings can be used to expand production capacity and market area and to reduce commodity prices. Under a competitive economy, this will create a new system of input combinations, market shares, and equilibrium prices. Furthermore, the final demands in all regions will also be changed (income effects). Second, savings may be used to increase primary inputs that will not only shift the inputs from the transportation sector to primary sectors, but also induce more final demands (income effects). Income effects of the transportation savings from nonbusiness travel should also be considered.

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