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16. Abstract

This report presents a literature survey of some of the most pertinent concepts in the field of economic analysis of transportation expenditures and investments. Eight major topical categories are reviewed and summarized. These are: (1) Benefit-Cost Analysis; (2) Internal Rate of Return and Rate of Return Analysis; (3) Discount Rate and Opportunity Cost Analysis; (4) Macroeconomic Model Analysis; (5) Plant Location Decision Making; (6) Land Use Impact Analysis; (7) Input-Output Analysis; and (8) Regional Impact or Multiplier Analysis.

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ECONOMIC ANALYSIS OF TRANSPORTATION EXPENDITURES:

A LITERATURE REVIEW

William F. McFarland
Dock Burke
Jeffery Memmott
Jesse L. Buffington

Research Report 1106-2
Research Study Number 2-10-87-1106
"Impact of Highway Construction Expenditures on Economic Growth, Tourism, Planning Policies and Transportation"

Sponsored by

Texas State Department of Highways and Public Transportation

in cooperation with

U. S. Department of Transportation
Federal Highway Administration

METRIC (SI*) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

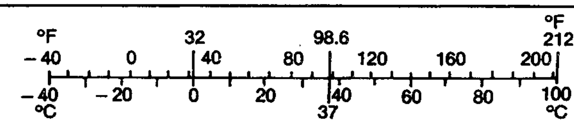
Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	2.54	millimetres	mm
ft	feet	0.3048	metres	m
yd	yards	0.914	metres	m
mi	miles	1.61	kilometres	km
		AREA		
in^2	square inches	645.2	millimetres squared	mm^2
ft^2	square feet	0.0929	metres squared	m^2
yd^2	square yards	0.836	metres squared	m^2
mi^2	square miles	2.59	kilometres squared	km^2
ac	acres	0.395	hectares	ha
		MASS (weight)		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
		VOLUME		
fl oz	fluid ounces	29.57	millilitres	mL
gal	gallons	3.785	litres	L
ft^3	cubic feet	0.0328	metres cubed	m^3
yd^3	cubic yards	0.0765	metres cubed	m^3

NOTE: Volumes greater than 1000 L shall be shown in m^3.

Symbol	When You Know	Multiply By	To Find	Symbol
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimetres	0.039	inches	in
m	metres	3.28	feet	ft
m	metres	1.09	yards	yd
km	kilometres	0.621	miles	mi
		AREA		
mm^2	millimetres squared	0.0016	square inches	in^2
m^2	metres squared	10.764	square feet	ft^2
km^2	kilometres squared	0.39	square miles	mi^2
ha	hectores (10 000 m^2)	2.53	acres	ac
		MASS (weight)		
g	grams	0.0353	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams (1 000 kg)	1.103	short tons	T
		VOLUME		
mL	millilitres	0.034	fluid ounces	fl oz
L	litres	0.264	gallons	gal
m^3	metres cubed	35.315	cubic feet	ft^3
m^3	metres cubed	1.308	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



These factors conform to the requirement of FHWA Order 5190.1A.

* SI is the symbol for the International System of Measurements

EXECUTIVE SUMMARY

This report contains a brief literature survey and example of some of the more pertinent concepts in the field on economic analysis of transportation expenditures. In topical categories, the eight major concepts presented here are:

1. benefit cost analysis
2. internal rate of return; and rate of return analysis
3. discount rate and opportunity cost analysis
4. macroeconomic model analysis
5. plant location decision-making
6. land use impact analysis
7. input-output analysis
8. regional impact or multiplier analysis.

IMPLEMENTATION STATEMENT

This report can be used to identify a basic set of reasons which describe several aspects of the relationships between economic activity and transportation. While not exhaustive, the list of references will guide the reader in pursuing productive lines of inquiry in eight topical areas.

CREDIT REFERENCE

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DISCLAIMER

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INTRODUCTION

Economic analysis is readily available to transportation agencies for use in analyzing vital interrelationships between transportation activities and the economy, such as: economic aspects of individual transportation projects; economic aspects of entire transportation systems or networks; and economic aspects of transportation policy elements. Success at each of these three levels is vitally important in preparing a modern transportation agency to successfully compete for its revenues and to wisely choose its expenditures.

For revenue support, transportation agency budgets must successfully compete with those of many other justifiably good programs. To do the most effective job in convincing citizens and elected representatives of the worthiness of transportation expenditures, transportation agency executives must be able to show the unambiguous, comprehensive significance of the transportation services they provide. Compelling evidence of success includes, of course, easily discernible examples such as miles of new roads built or reconstructed, tons of cargo handled, numbers of transit passengers carried, vehicle miles of travel, and a continuing very long list of other measures of transportation outputs.

Additionally, though, transportation agency expenditures are being evaluated in broader social and economic contexts. Legislators and voters increasingly want to apply transportation policy to support other complementary objectives, such as improved economic productivity and economic development. The importance of the relationship between transportation and economic variables has been underscored in several major policy reviews and initiatives. The AASHTO's 2020 Keeping America Moving: The Bottom Line, the National Council on Public Works Fragile Foundations: A Report on America's Public Works, FHWA's Future National Highway Program, and TRB's A Look Ahead: Year 2020 are four major national policy assessments that endorse the importance of transportation in promoting economic development, regional growth, and increased productivity. Similarly, some individual states--including Texas, Minnesota, Georgia, Tennessee, and North Carolina--have also implemented initiatives to incorporate promotion of economic activity into the goals/mission of their transportation agencies.

Several methods, or techniques, have been used to estimate the impacts of transportation projects, networks, and policies on the economy. This report describes some of the literature surveys that are available and cites representative studies. This is not meant to be a comprehensive review but is intended to indicate the nature of the available methods and to demonstrate some of the typical uses in transportation impact analysis.

BENEFIT-COST ANALYSIS

Benefit-cost analysis, rate of return analysis, and opportunity cost analysis are, in a general sense, simply variations of the same general structure of determining the expenditures, or group of expenditures, that are desirable (i.e. increases social welfare) and result in the highest return to the users of the facilities. Given the similarity, the general structure of benefit-cost analysis will be discussed first, with subsequent discussion on the variations of that basic technique.

Benefit-cost analysis has been used extensively to determine the desirability of public expenditures in transportation infrastructure, where they are treated as investment decisions. In recent years, the application of benefit-cost analysis to specific transportation expenditures has been rather narrow--for example, determining whether a proposed project is desirable (the benefits exceed the cost). To a lesser extent it has also been used as a rationing tool. If the cost of a group of desirable projects is more than the money available, the analysis is used to determine the projects that will give the greatest benefits for the available money. Those relatively narrow uses do not imply, however, that benefit-cost cannot be used in a broader context, relating public expenditures to economic development.

It should be recognized that benefit-cost analysis is a partial equilibrium technique. It does not take into account the secondary effects, if any, on prices and output in the economy. But it can be combined with more general techniques, such as input-output or macroeconomic models to provide that link. It can also be used in a broader opportunity cost framework that includes other factors such as economic development and environmental impacts.

The basic underlying assumption of benefit-cost analysis is that of efficiency, i.e. that the benefits to society should exceed the expenditures, and for any given level of expenditures, the benefits to society should be maximized. For a proposed transportation project, the direct benefits consist of reductions in the transportation costs for the users of that project. An important aspect of those benefits is that they continue to flow over the life of the project and may increase if the transportation demand is growing. Obviously those direct benefits can be substantial and are the ones typically included in a benefit-cost analysis. The benefits of a transportation project may include such things as delay savings, vehicle operating cost savings, and accident savings. There is also the possibility that there may be a reduction in routine maintenance costs or a salvage value at the end of the analysis period. The costs include right-of-way costs and construction costs. There are other costs which are sometimes considered, referred to as social costs or externalities. These include such things as air pollution and noise pollution. However, these costs are difficult to quantify and are generally considered in a qualitative sense and not included directly into the economic analysis [3]. However, there are indirect benefits that are generally ignored. Since the transportation costs are reduced (for both households and producers), it would be expected that those lower costs would be reflected in some combination of higher production, lower prices, higher investment, and higher consumption. Those indirect impacts become factors in stimulating economic growth and development. However, given the partial equilibrium nature of benefit-cost analysis, as discussed above, they are difficult to measure and include in the analysis. It may be more appropriate to analyze those indirect effects in a macroeconomic model with a transport sector, as discussed in a later section.

The traditional use of benefit-cost analysis for evaluating transportation projects has been increasing in recent years but has not yet received universal acceptance. Nor has it evolved to the stage that a standardized procedure and assumed parameters are accepted by all professionals in the field. There are, however, certain basic accepted concepts which are in widespread use--even if some of the details and assumptions may vary. For highway improvements, NCHRP Report 133, Procedures for Estimating Highway User Costs, Air Pollution, and Noise Effects [1], and the 1977 AASHTO Manual on User Benefit Analysis of Highway and Bus-Transit Improvements [2] have been widely used as reference guides, but the numerous manual calculations required make them tedious, time-consuming, and error prone. In addition, support data and techniques have become available that can improve the accuracy and credibility of the benefit-cost calculations presented in the manuals.

Measures of Project Desirability

Within the framework of benefit-cost analysis, if a public expenditure is treated as an investment, then the net benefits should be maximized. For an individual project, that means the benefits should exceed the cost. If a budget constraint does not allow all such projects to be funded, then the group of projects which collectively produce the greatest amount of benefits, within the budget constraint, should be selected. Since benefits and costs can accrue over time, they must be discounted to their present value. Three techniques or relationships are used to varying degrees in judging the desirability of a proposed project. These are, the benefit-cost ratio, the net present value, and the internal rate of return.

By far the most common measure of public project desirability is the benefit-cost ratio, sometimes called the measure of profitability. As the name implies, the benefit-cost ratio is the ratio of the benefits to the costs. The criterion for project selection is that the benefit-cost ratio must be greater than 1. However, when a budget constraint requires selection among desirable projects, the benefit-cost ratio can give incorrect results unless it is modified using an incremental approach.

A more reliable measure of project desirability is net present value. Net present value is defined as the benefits minus the costs. The criteria for project selection is that the net present value must be greater than zero.

If multiple alternatives are evaluated at the same site, then an incremental approach must be used. The increment of benefits must be compared to the increment of costs going from one project size to another, rather than the total benefits and costs. This is the approach described in the 1977 AASHTO Manual [2].

When there are multiple alternatives at individual sites, with a limited budget, and all desirable projects cannot be funded, then a procedure such as dynamic programming or integer programming can be used. McFarland developed a computer program, INCBEN [4], which selects projects with multiple alternatives for a limited budget using an incremental benefit-cost approach, with some switching rules, to optimize the funds available. This technique is much faster and easier to use than the programming methods, and closely approximates their results.

Use of Benefit-Cost in Transportation Assessments

The use of benefit-cost analysis in various applications and modes is extensive. Historically the use of benefit-cost analysis for public investment decisions first occurred in the United States for certain types of water projects with the Rivers and Harbors Act of 1902. Later the Rivers and Harbor Improvements Act of 1920 provided a means of charging local interests with part of the cost of improvements by requiring a statement of benefits which will accrue to local interests and recommendations for local cooperation on the cost of the project. As a result, the Corps of Engineers developed simple accounting techniques to evaluate the tangible costs and benefits.

Even though benefit-cost analysis was first applied to water resource projects, it eventually spread to other public investment decisions, such as health, transportation, urban renewal, recreation, land reclamation, education, research and development, and defense [3]. Similar trends have occurred in other countries. For example, England now uses COBA, a computer software package, to analyze highway investment decisions [10]. The World Bank has developed the HDM-III model for use in developing countries that makes economic evaluations of different construction alternatives and can be used to maximize the present value of an entire highway system [11]. There have also been benefit-cost applications of transportation modes other than highways. For example, Roess uses the technique for estimating the benefits of urban public transportation [12], and Taylor and Sandler use benefit-cost to analyze a proposed rail line relocation [13]. Several agencies have also adopted guidelines for conducting benefit-cost analysis for investment decisions. These included AASHTO for highways and bus transit [2], UMTA for bus rehabilitations [14], FAA for airport construction [15], and FRA for railroad relocation and extension [16]. The Tennessee Valley Authority gives a bibliography of techniques for water resource projects [17].

INTERNAL RATE OF RETURN AND RATE OF RETURN ANALYSIS

The internal rate of return is the discount rate such that the net present value is zero. The criterion for project desirability is that the internal rate of return be greater than or equal to the discount rate presumed to represent the required rate of return. The major weakness of the internal rate of return is the possibility of multiple rates of return. This can happen when the flow of net benefits changes sign more than once over the analysis period.

However, for most proposed projects, benefits will remain positive throughout the period, and multiple rates of return would not be a problem.

A simple example can be used to illustrate how multiple internal rates can occur. Assume in the current year there is an initial construction cost of $4 million for a contraflow lane on an urban freeway. The first year generates net benefits of $9 million. In the second year, the contraflow lane is converted back to a conventional freeway lane at a net cost of $2 million. As a result, two internal rates of return are generated: -75 percent and 100 percent. As a practical rule, the negative rate would be discarded. Internal rates of return should be used with some caution, it is possible to have multiple positive rates, though it is not likely to happen in analyzing proposed transportation projects.

The use of the internal rate of return for project desirability and selection is what is typically referred to as rate of return analysis. It is popular in development projects, where the discount rate is somewhat ambiguous, and a high rate of return, much higher than any reasonable discount rate, is used to show the project is desirable and should be undertaken. It is argued that the internal rate of return has an advantage as a result. Since the rate is calculated, it is not necessary to assume a discount rate, unlike the benefit-cost or the net present value. Since the assumption of a discount rate poses a problem for publicly funded projects, something is gained by not assuming a discount rate when using the internal rate of return.

However, the argument is not correct. There is no advantage in calculating a rate of return rather than assuming a discount rate. If the purpose is to determine the desirability of a project, then the internal rate of return must be compared to an assumed discount rate. If the purpose is to rank projects against each other, and if each project has a single internal rate of return solution, then any assumed discount rate will rank the projects the same using net present value. In either case, the internal rate of return offers no advantage over net present value.

DISCOUNT RATE AND OPPORTUNITY COST ANALYSIS

As mentioned previously, benefits and costs occurring over time must be discounted to present value, since benefits and costs occurring in the future are not as valuable as those in the present. The choice of that rate to discount future benefits and costs is important for several reasons. First, a discount rate which is too low will raise the present value of benefits and result in socially undesirable projects being selected. A discount rate which is too high will have just the opposite effect and will result in the rejection of socially desirable projects. Secondly, a rate which is too high will tend to favor projects which have a shorter payback period, projects with the flow of benefits occurring closer to the present, as opposed to projects with benefit flows over a longer period of time. Thirdly, an incorrect discount rate will affect the total amount of resources going to public investment projects and will, therefore, result in a misallocation of resources between public and private investment.

For private investment decisions, the discount rate should be the marginal cost of capital. But for publicly funded projects, both the marginal productivity of capital and rate of time preference between current and future consumption must be considered. Depending on what assumptions are made on what the discount rate represents, different rates are estimated. The actual number used typically ends up being a value judgement by the analyst or acceptance of some value used in another application.

For transportation projects, the 1977 AASHTO Manual [2], for example, recommends using the real cost of capital, which Hirshleifer and Shapiro [5] estimate at about 4 percent for low-risk investments. Based upon that, the AASHTO Manual recommends a discount rate of about 4 to 5 percent. NCHRP Report 133 [1] recommends a discount rate between 6 and 10 percent, based upon taxpayers' opportunity cost of capital for transportation projects of average risk. The actual discount rate used by different highway agencies and at different times varies widely, though most seem to be in the 5 to 7 percent range, according to a Texas Transportation Institute survey [6]. Florida, for example, uses 7 percent [7]; and the default discount rate in the HEEM-II computer program [8], used in Texas, is 8 percent.

The opportunity cost analysis is particularly concerned with the discount rate and the incremental benefit-cost technique, discussed earlier. Opportunity cost is defined as the loss of the best foregone alternative when another alternative is chosen. In the context of benefit-cost analysis, when an improvement alternative is chosen, the benefits are lost of other possible alternatives that the money could have been used for. That is the purpose of incremental benefit-cost analysis, namely, to calculate and select the combination of project alternatives that will give the greatest benefit, in other words so the opportunity cost is minimized. The discount rate also plays an important role, since the discount rate can be thought of as the rate at which society is willing to trade the opportunity cost of losing current consumption to gain higher future consumption resulting from the expenditure on the transportation facility.

Wisconsin has developed a more general opportunity cost analysis, incorporating a benefit-cost analysis within a broader framework [9]. This framework considers factors not incorporated into the benefit-cost ratio, such as economic development and environmental factors. This framework has the potential to reduce or minimize some of the criticism of traditional benefit-cost analysis.

MACROECONOMIC MODEL ANALYSIS

Macroeconomic models are models that describe the behavioral relationships in a simplified structure of the economy and can serve as valuable tools in evaluating impacts of changes in economic factors and/or other exogenous factors, such as government policies. A basic model of this kind usually contains variables such as income, consumption, investment, gross national product, trade balance, and so on. Changes in government policies affect those factors, and have ripple effects on some or all of the elements in the model. For example, the effects of fiscal policies (which include expenditure and taxation) on consumption, savings, investment, and the resulting effect on economic growth are often evaluated with macroeconomic models. The effects of changes in any of the policy or other exogenous variables are estimated through the behavioral relationships of the model. The dynamic or long-term effects on industrial production is sometimes then estimated by simulating effects on wages, profits, and taxes. They in turn determine disposable income, prices and wage rates, and business cash flow. There is then a feedback into the behavioral equations for estimation of the next period.

Surveys of Models

Comprehensive surveys of national and regional macroeconomic models have been made by Knapp et al. [18], Glickman [19], Shapiro and Fulton [20], and Bolton [21]. Other authors, including Glickman [19, 30], Treyz [31], Taylor [32], Charney and Taylor [33], and Shapiro and Fulton [34], discuss regional models' relative performance, evaluation, and analysis of sources of errors. Multiregional models are covered in several surveys of the literature, including Bolton [22, 23, 24], Issaev [25], Lakshmanan [26, 27] and Rietveld [28]. Economic base models, or shift-share techniques, are surveyed in Stevens and Moore [29].

Bolton [21] reviews the theoretical specifications of a large number of regional models, with emphasis on large, non-proprietary, operational macroeconomic models of single United States regions. Even with these limitations, however, there are many models to discuss. Bolton is especially helpful in giving an excellent introduction to single region and multiregional models as well as an overview of model structure, including differences between regional and national models.

National Macroeconomic Models

Large, national macroeconomic models are discussed in detail in Klein and Burmeister [43] and numerous other references. These models are "elaborate extensions of a Keynesian general equilibrium model of product markets, labor markets, government financial operations, and money and financial markets" [21, p.497].

Figure 1, from Bolton [21, p.497], shows the interrelationships in a national macroeconomic model. Bolton notes that there are one, several, or many mathematical equations for each box of the model, depending on industrial detail and other disaggregation. These can be behavioral equations, definitions, or identities [34, p.498].

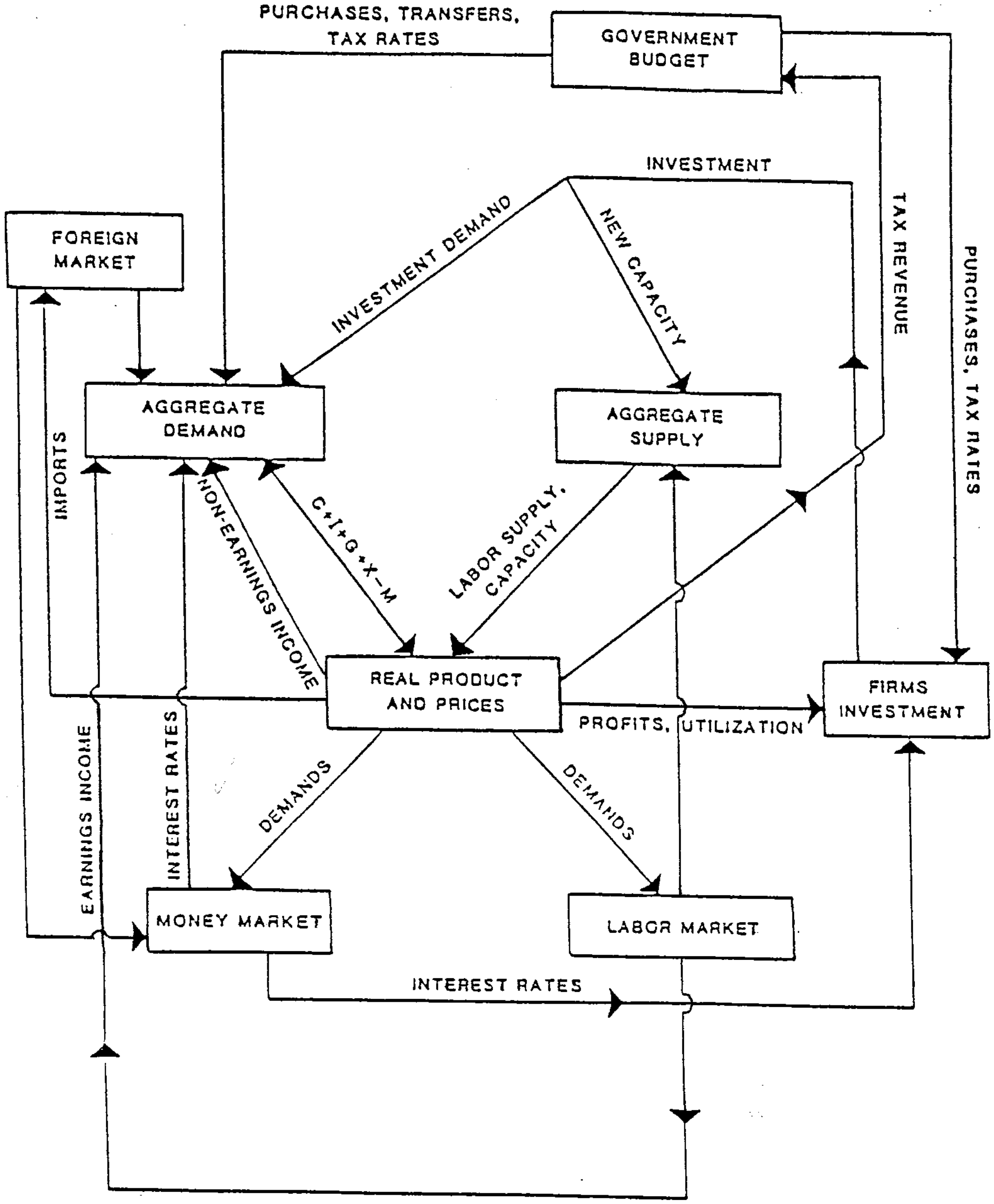

Figure 1. A National Macroeconomic Model [21, p. 437]

Multiregional and Regional Macroeconomic Models

For analyzing the regional effects of a national economic policy or event, a multiregional model is needed. Figure 2, based on Bolton [21, p.499; also 34], shows how three regions can be linked to a national model. Typically, in a "top-down" model national totals are obtained by solving the national model. These totals are allocated to the regions using equations in the regional models. In a "bottom-up" model, solutions could be derived in the regional models and then variables could be summed to obtain national totals. In "hybrid" models, there is feedback between the regional and national models. In practice, models are either top-down or hybrid, with national totals being allocated to the regions, sometimes with feedback. For discussion of different types of links to national models, see Klein [30], Bolton [21], and the surveys mentioned previously.

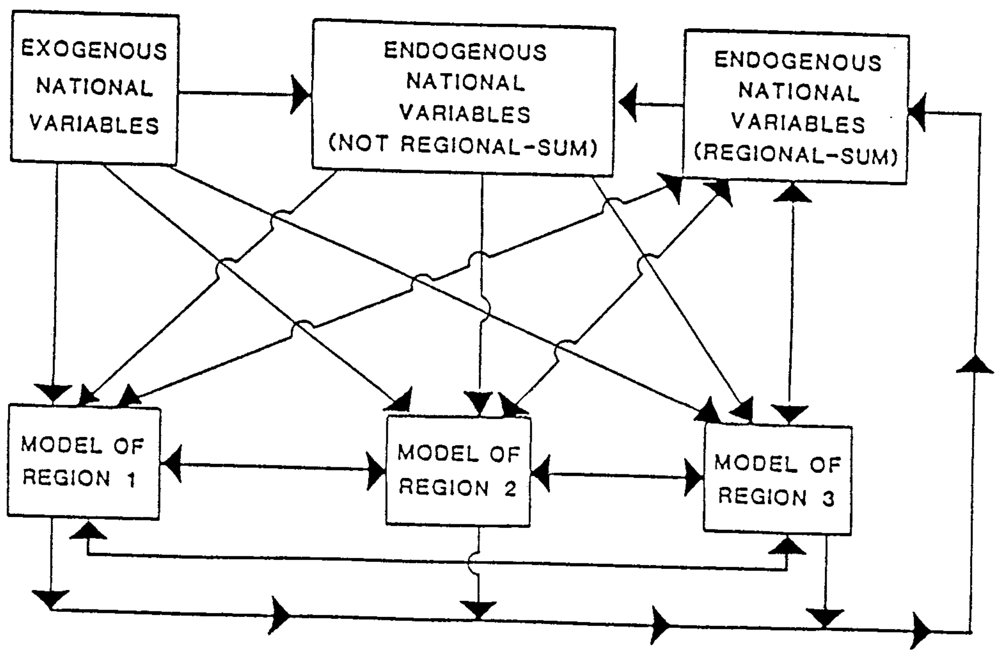

Figure 2. A Multiregional Macroeconomic Model [21, p. 499]

Bolton [21, p.501] illustrates some of the typical components of a regional model linked to a national model, shown in Figure 3. In many regional models, national outputs are used to determine output and employment in regional industries. Regional income is modeled as the sum of industry outputs or labor earnings. Often, income is estimated emphasizing personal income because of the high quality of the personal income data from the Bureau of Economic Analysis. Bolton and others discuss many of the data problems of regional models, and the following quotation gives the flavor of some of this type of discussion:

> The lack of investment, export, and import data (for the region) is almost always an insurmountable obstacle to estimating the same components as in national models. The overwhelming practice is to not use a Keynesian break-down of output by user, but one by geographical location of buyers: those located inside and those outside the region, or "export market" and "local market."...Regional output data are weak or missing outside manufacturing, so one must resort to controversial methods if one wants to predict total gross regional product (GRP). [21, p.502]

Many state and regional models have a structure that emphasizes special policy evaluation needs. For example, Texas models tend to emphasize energy industries, because of their prominence in the regional economy, supply-side relationships because of use of the sales tax for raising state revenue, and demographics because of the (until recently) rapidly-growing population. This is illustrated in the Texas Economic-Demographic Forecasting Model (TEDFM) developed by Plaut et al. [35], which is a state macroeconomic model composed of four interacting submodels: the demographic, the manufacturing, the production, and labor. Figure 4 shows the structure of TEDFM. Forecasts in these four areas provide forecasts for nine sectors in the economy for the state of Texas, with transportation and public utilities being one of them.

Regional Macroeconomic Models with Transport Sector

A regional macroeconomic model with a transport sector can be used to model commodity flows with an existing transport network with associated costs of transporting between regions, or nodes. It can also be used to analyze alternative transportation networks and, therefore, can be used to develop a more complete analysis of the effects of transportation investment. This more complete analysis is provided by predicting the change in commodity flows that are expected to result from changes in transport costs due to transport investment and also the effects of the investment, including multiplier effects within the region.

Because of the complexity of adding transport models to macroeconomic models, very few models include a transport system with transport between producing and consuming centers. Four models that do include a transport sector are especially noteworthy: the Polenske model, the Harris model, the Brookings model, and Butler's model; the latter three models are briefly discussed below.

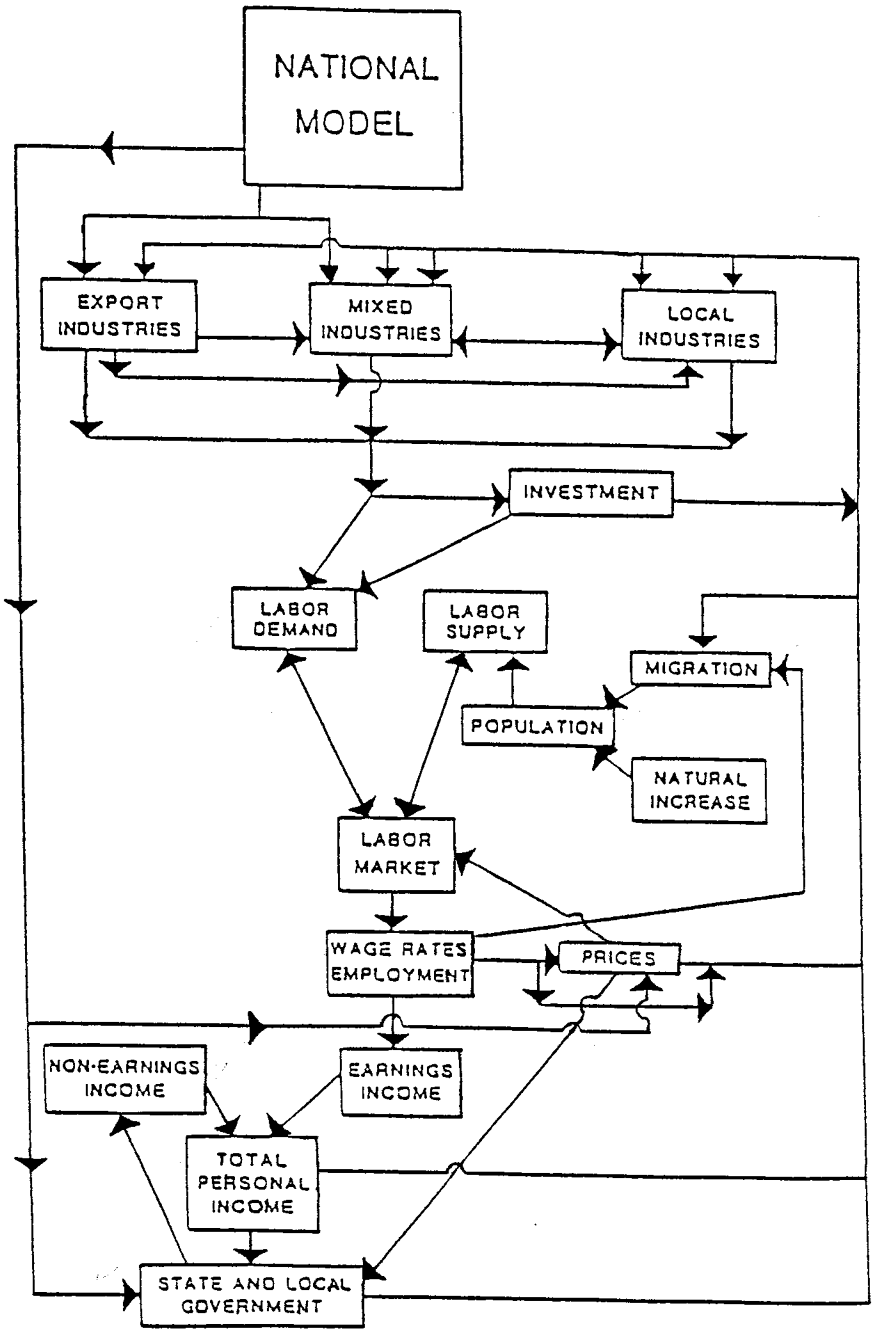

Figure 3. A Regional Macroeconomic Model Linked to a National Model [21, p. 501]

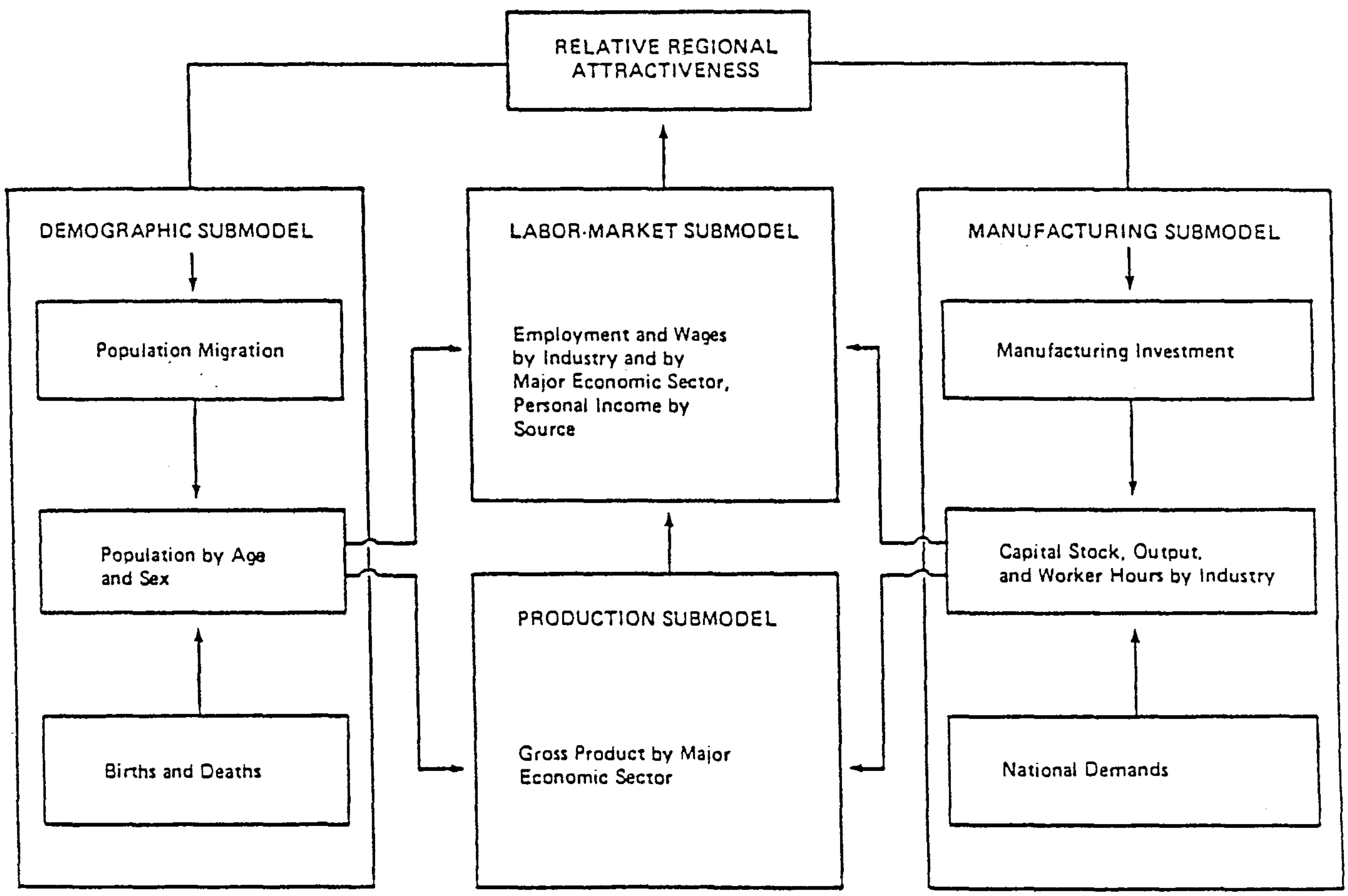

Figure 4. Overall Structure of the Texas Economic-Demographic Forecasting Model [35, p. 10]

The Harris model [36, 37] is a multiregional model of the United States, and at least four versions have been used in policy analyses. The Harris model can be used to forecast regional growth and is especially well adapted to evaluating alternative transport technologies and systems, even though there is considerable disagreement about some of the model's assumptions and structure. One of the four versions uses the 173 Bureau of Economic Analysis economic areas; another uses SMSA's and other regions; another version uses counties; and another uses DOT regions. Harris's model's characteristics have been summarized as follows [21, p.512]:

> There are output and employment variables for 99 industries (62 in manufacturing); equipment investment for 69. Many of the data are created by multiple assumptions about unobserved relationships, and parameters in regional share equations are estimated by cross-section regressions across regions, a procedure that is somewhat controversial. The model is annual and recursive, with no variables for a region entering directly into the equations for another region. However, explanatory variables include lagged transportation costs of inputs and outputs, estimated in a separate complicated demand- and supply-balancing linear programming transportation model. Transportation costs, along with relative labor and land prices, determine location rent, and location rent in an industry helps determine a region's share of that industry's national output. Investment is endogenous, responding to location rent. Lagged investment affects some regions' output shares and employment, acting as proxy for size and newness of the capital stock, which is not calculated. Harris also assumes that the ratio of capital to capacity output in all regions is equal to the national ratio.

One novel feature of the Harris model is that transportation costs are estimated by using data on commodity shipments such as weight, size, type of commodity, distance transported, and mode of transport. The highway cost model uses a regional highway congestion index that uses a measure of congestion on principal highways within a region. Among the types of policies that have been analyzed with the Harris model are regional economic effects of national highway systems; effects of the auto industry on the Detroit area; energy savings from increasing truck shipments by piggyback; regional impacts of changing individual highway segments; and several other energy and economic policies. The Harris model is by far the most widely used U.S. model with a detailed transport sector.

The Brookings Institute model, which was developed by Kresge and Roberts [38], is an especially interesting macroeconomic model with a well-developed transport sector. The model emphasizes transport of freight using rail and highway transport, and is illustrated in Figure 5. It is an annual, recursive model, designed to evaluate the impact on reductions in transport cost on any links between producing (or import) and consumption (or export) nodes. The transport sector is estimated by breaking down the final output into separate sectors, using an input-output model.

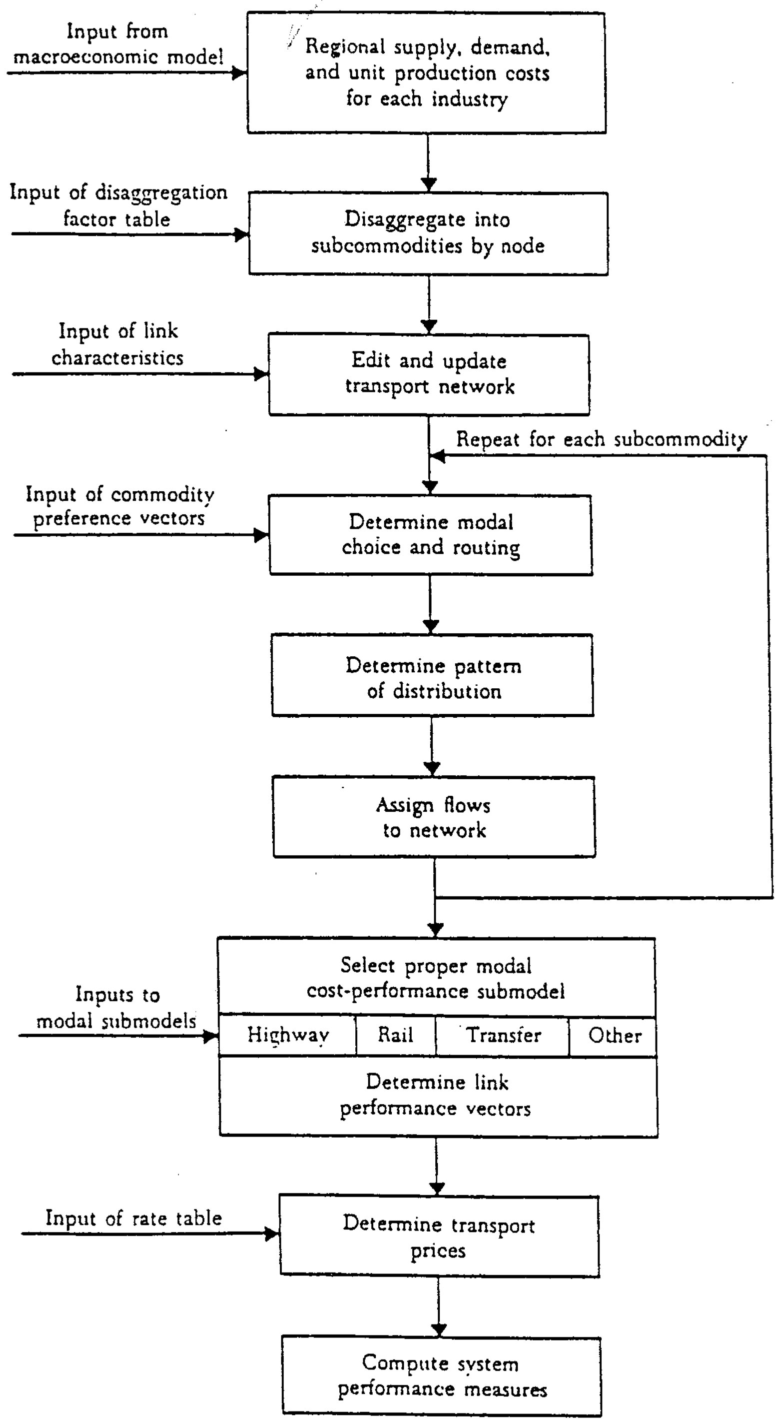

Figure 5. Structure of Bookings Transport Model [38, p. 40]

The Brookings model is structured in the following computational steps: (1) commodity disaggregation, whereby estimates of industrial supplies and demands for the commodity derived from macroeconomic models are first disaggregated before they can be used; (2) definition of a network consisting of links and nodes; (3) modal choice and routing by distributors; (4) commodity distribution from a few supply sources to a large number of demand points; (5) commodity assignment; (6) modal cost-performance calculation based on different modes, from highway to rail to other, on each link; (7) transport price determination; and (8) a summary of the system performance measures in terms of vehicles or links.

The Brookings model was used to model alternative transportation plans, especially railroads and highways in Colombia. From this case study, it was concluded that "... transport modifications alone are often not sufficient to have a major impact on the growth of gross domestic product" and that "... little difference will be discernible in overall consequences to the economy, at least in the short run." [38, p.155]

It also was concluded, however, that transport modifications have a major effect on interregional flows and the regional composition of output. Meyer noted that this result is similar to that found by Fogel [39] and by Fishlow [40], in their studies of the impact of railroads in the economic development of the United States in the nineteenth century. Both Fogel and Fishlow concluded that changes in transportation tend to change the composition of output more than they affect the aggregate economic growth. These two studies are recognized by economists as being path-breaking studies in the use of macroeconomics and econometrics to study hypotheses about the historical importance of technological change on output and location of economic activity. However, it should be emphasized that the results of these studies are quite controversial [41].

Another example of using a macroeconomic model, by Butler et al. [42], included a transport sector, although it was not a detailed sector like the Harris and Brookings models. The model can be used to estimate the total effects of simultaneous changes in highway spending, taxation, productivity, depreciation of motor vehicles, and vehicle miles traveled (VMT), for several economic variables. The model uses a variation of the Chase Long-Term Macroeconomic Model developed by Chase Econometrics Associates, Inc. The Chase Long-Term Macroeconomic Model consists of a set of simultaneous equations developed to predict approximately 700 economic relationships. Because VMT is not a variable in the Chase Econometrics model, Butler et al. modified variables related to VMT to reflect changes in highway use.

PLANT LOCATION DECISION MAKING

Location Theory

At any one time, various economic units have a specific location, although diverse influences have led to these locations. To even begin to understand why these entities have these specific locations, one must have a fairly complete understanding of not only economics but history as well. Because of the complexity of factors affecting location decisions, theoretical models of location have simplified the decision-making framework by assuming some factors are fixed and have studied other variable factors. Of course, this is the typical approach in all theoretical models. It is especially important to understand this approach and framework in reviewing the literature on location theory because the variables that are assumed fixed and variable are not always made clear. In other instances, it is not made clear how a specific type of study fits into the overall theoretical framework. Sampson and Farris [63] have provided a diagram, shown here as Figure 6, that is helpful in understanding this overall framework and how individual types of location studies fit. Figure 6 also indicates that each type of theory has implications for understanding economic development.

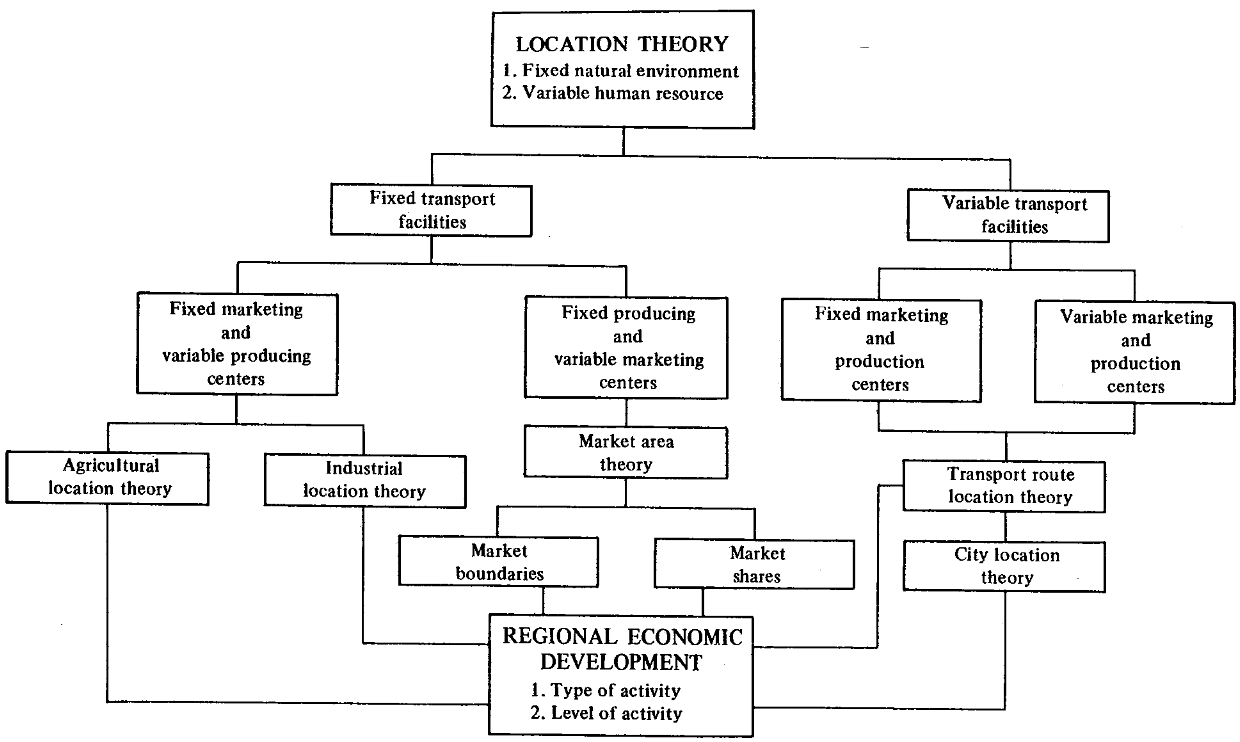

Figure 6. Types of Location Theory [63, p. 245]

Sampson and Farris discuss Figure 6 as follows:

> Transportation costs and location theory are inseparable. Traditional location analysis assumes either fixed markets and undetermined producing centers or fixed producing centers and undetermined marketing areas. Both industrial (or agricultural) location theory and market-area theory assume given transportation facilities, however. Analysis involving the determination of transport routes and facilities under varying production and marketing assumptions and the relationships between such routes and city location are not so well developed. Both the fixed (or given) transport and the variable (or undetermined) transport type of analysis, however, lead directly into the analysis of the types and levels of regional or spatial economic activit [63, p. 246].

The discussion in Sampson and Farris is limited almost totally to location theory with fixed transport facilities; that is, the left part of the diagram. This is not surprising since the majority of the discussion in the literature is concerned with this aspect of location theory. Much of the existing theory on location with variable transport facilities is concerned with city location theory, and indeed much of this could be classified as city location with the assumption of fixed transport facilities (not shown in the diagram, although somewhat related to other theories that are shown, since cities are places where industrial production takes place and cities also constitute markets. All of this is discussed in terms of agglomeration economics, the tendency of economic activity to be centralized in certain locations). That is, much of the location and growth of cities is discussed in terms of occurring on existing major transport facilities, such as oceans, rivers, railroads, and major highways. Most analysis of the location of transport facilities assumes fixed but growing marketing and production facilities. This is especially true of highways where forecasts of passenger and freight often are done by extrapolation of traffic on existing highways.

Among classical economists, Thunen, Weber, and Losch may be mentioned as pioneers in providing theories that aid in understanding location tendencies. Thunen noted that the location of agricultural production depended on transportation costs, and developed a theory showing that under certain assumptions, agricultural production of different commodities would take place in successive rings around a market area. Weber integrated cost of production for different inputs, transportation costs for inputs and products, and the location of the market to show how all factors enter into determining an equilibrium location. Both Thunen's and Weber's models were extended by Losch.

Hoover [56] has shown how the nature of transport costs, with fixed costs for a trip and variable costs that increase at a decreasing rate with distance, tend to favor a location either at the source of raw materials or at the market, as opposed to intermediate locations. This tendency is somewhat modified by use of locations at transfer points, such as at river or ocean ports, at major distribution centers, and at major rail junctions, where some types of activities tend to locate. This type of consideration must be taken into account in evaluating opinion surveys of location factors. That is, transportation costs may be important, but respondents may strongly favor either locations near raw materials, markets, or transfer points. Survey data can benefit from integration with theoretical models, but unless a theoretical framework is used, survey answers may be misleading.

Empirical Studies of Location and Transportation

Most empirical studies of plant location decision making are one of three types: (1) studies of decision making by firms from the viewpoint plant location factors for the firm (microeconomics); (2) state econometric studies that study the relative attractiveness of different states (or other regions) within the United States (or other nations); and (3) economic geography studies that include analysis of the general locations of industry and attempt to explain the reasons for different types of economic activities to be located at specific locations. In the following discussion emphasis is placed on the first two of these three types of studies.

Location Factors

Numerous studies have attempted to determine the relative importance of different factors in influencing the location decisions of business firms. Reviews of the literature on location factors have been made by several authors, including Stevens and Brackett [44], Townroe [45], Greenhut [58], Richards [54], and Carrier and Schriver [46, 47]. There also have been several summaries and critiques of these studies in recent years. Some studies are general, multi-industry studies, while others concentrate on specific industries, usually different manufacturing industries. The multi-industry studies show the different weights put on different factors by different industries and are useful for comparisons. Studies of specific industries also are of interest because they give in-depth evaluations of location decision making.

State Econometric Studies

The second type of empirical study attempts to use econometric models to determine the relative significance of different variables in determining new plant locations. These studies attempt to determine the relative attractiveness of different regions, especially states, influencing firms to choose specific locations. For surveys of the literature, see Due [57] and Bartik [62].

Most of the theoretical and empirical work in location economics is quite interesting in helping one to understand why economic activity tends to be located at specific sites. It is also interesting in terms of providing a general indication of the importance of transportation, since the dispersion of resources and the existence of transportation costs are what gives rise to location economics. The primary use of location analysis from the viewpoint of transportation agencies appears to be in helping to understand location decisions and possibly in providing information of a descriptive nature that can be used to show the importance of transportation. If leaders in a city, region, or state are interested in attracting a specific type of industry, they can better understand what factors are important by studying location decision making.

LAND USE IMPACT ANALYSIS

Background

Transportation facilities of all modes are located on land and abut land in various uses, ranging from vacant tracts to intensely used tracts. New facilities absorb land from other uses, and new and existing facilities impact the abutting land to some degree, ranging from extremely positive to extremely negative impacts. The degree or amount of impact also depends on the type (mode) transportation facility, the extent of access to the facility and the intensity of its use. Land use impacts are reflected in land values, i.e. the fair market value of the land and its improvements. Also, the levels of rent, business income, employment, etc. derived from the use of abutting land and its improvements are impacted by the transportation facility and are reflected in abutting land values. Therefore, a tract's use, market value, rental income, business income, and employment payrolls are all intertwined. To some extent, any one of them can represent the others in an impact analysis. Finally, transportation facilities and the level of their use not only impacts the uses of abutting land but also the uses of nonabutting land in the same transportation corridor, same community, or same region of the state.

Over the years, many studies have been conducted to determine the interrelationships between transportation facilities and land use, land value, income, etc. and to measure the effects of implementing different transportation policies or practices. Consequently, various methodologies or procedures have been developed to measure and assess these relationships and impacts. It should be understood that the methodologies or procedures discussed here are to measure the effects of a transportation improvement as are the benefit-cost, input-output, and rate-of-return procedures. For instance, the benefit-cost procedure measures changes in transportation costs to users which are also approximated in changes in land use, land value, and business activity. However, adding the results of the two types of analysis together would be double counting the effects of the transportation improvement in question. In other words, a reduction in user cost is capitalized into the value of the land which leads to higher land values and intensities of use [65].

The above described user cost impact is due to a change in accessibility [66] and is easily measured with the benefit-cost type of procedure. However, there are secondary negative impacts, such as changes in noise levels resulting from a transportation improvement [67, 68, 69], which are more difficult to measure with the benefit-cost procedure than with a procedure measuring changes in land values. Such secondary negative impacts offset some of the positive impacts derived from improved access provided by a transportation improvement.

The literature contains several sources that summarize techniques used for measuring the impacts of transportation improvements [70, 71, 72, 73]. Generally, these techniques can be classified into two groups: (1) land use-land value measurement techniques and (2) land use-traffic/urban development models.

Land Use - Land Value Measurement Techniques

Included in this group are the following techniques:

- study area - control area analysis
- study area - lateral/parallel band analysis
- regression analysis
- case study analysis
- opinion surveys
- mapping surveys

For the most part, this group of techniques uses the "before" versus "after" construction approach which compares land use and/or land value data for two points in time for each period. Also, these techniques measure ex post impacts [73].

The control area analysis is the technique most commonly used to measure land value impacts. When used in combination with the study area-parallel band analysis, it is probably the most accurate technique to measure impacts directly related to a transportation improvement. Researchers have used this technique extensively in estimating the land value-land use impacts of new radial freeways [74] and interstate highway bypasses [75].

The study area-parallel band analysis has also been used extensively to measure land use impacts of major thoroughfare improvements [76] and of railroads in an urban areas [77]. This technique is useful when a noncontiguous control area cannot be found. On the other hand, the study area-lateral band analysis involves a comparison of two transportation facilities similar in every respect but one. The difference could be adding main lanes or grade separations, different alignments or grade levels, different median or marginal accesses, or the like. Therefore, end to end segments of the same road can be studied, with one serving as the control. This technique also has been used to analyze stage construction impacts of freeways [78] and the development effects of freeway interchanges [79, 80].

Econometric techniques are used to estimate land value, land use, business income, payroll, and employment impacts of transportation improvements [71, 75, 78, 81, 82]. Texas researchers are currently studying the effects of major highway expenditures on employment and income in selected cities in Texas [83]. This study involves 67 highway improvements (bypasses, loops, and radial freeways) in 52 cities across the state. The "before" versus "after" approach is applied to this cross-sectional and limited time series data.

Case study analysis is used in most land use and value studies. Individual transportation improvements are studied in a detailed manner to collect enough relevant data before and after construction to sort out the effects of each improvement. Some of the data may be collected by personnel interview, by mapping, etc. Appropriate statistical analyses, including regression, are applied. The case study approach in studying highway improvements [69, 75, 76, 78], transit improvements [84], and railroad improvements [77]. A similar application of the case study technique is the study of Massachusetts' Route 128 involving two area cities. [85].

The opinion survey is a technique used to collect qualitative data to assess the depth of impacts of transportation improvements. This technique requires careful questionnaire construction and interview instructions to avoid collecting biased data. Again, appropriate statistical procedures should be applied in analyzing such data. TTI researchers have used this technique in many previous studies [69, 75, 76, 78] and are using it in a current study [86].

Map surveys are applied in collecting data and presenting results of land use impact studies. They are especially helpful in presenting a visual picture of before and after land uses. Map surveys are used extensively in two Texas studies [73, 76] and also in Dyett's beltway study [87].

Land Use - Traffic/Urban Development Models

The second group of land use impact models that have been developed are of two types as follows:

- land use-traffic volume forecasting models, and
- land use forecasting-urban development models.

These models are of the ex ante type that require forecasting traffic volumes or land use from more extensive data bases.

The first of this group attempts to forecast traffic volume and congestion data based on existing land uses along the transportation facility. One of the more complex models of this type, developed by Frey, et al., requires a great amount of data to establish coefficients for generated, attracted, and congestion traffic variables [88]. A simpler model of this type predicts traffic volume growth rates resulting from changes in highway capacity and land development along the road [82].

The second of this group of models, land use forecasting-urban development, attempts to predict land uses resulting from various transportation systems and land development policies. These models are designed to either describe or simulate the process of urban development and growth. Several of the models in this group are as follows [67,71]:

- empirical activity allocation model (EMPIRIC),
- projective land use model (PLUM),
- integrated transportation and land use model package, (ITLUP),
- access and land development model (ALD), and
- land use allocation model (LUAM).

At the time of their review, only two of these models had been tested enough to be put into operation. A new model called the projective optimization land use information system (POLIS) has recently been developed [89]. This model is structurally and behaviorally different from the traditional development model.

INPUT-OUTPUT ANALYSIS

Input-output models describe the interrelationships or flows of products and services between industries comprising the total economy. In tabular format, the columns of the model's table can be thought of as a list of the consuming industries; the rows contain the producing sectors [140, 141]. Each column in the table lists the purchases made by a particular consuming industry from each and every producing industry from which it acquires inputs. Similarly, each row in the table shows the sales of the various products/services (outputs) to the consuming industries.

Having captured the basic structure of an industry of an economy, the input-output model is frequently used to trace the effects of some change in economic activity as it works its way through the economy. For example, if the transportation sector desires to increase its output of services by $100 million, additional purchases of goods and services from those industries that supply inputs, such as metals, concrete, equipment, and fuel to the transport industry. These suppliers in turn, will increase their purchases of their inputs in order to fill the new orders coming from the transport sector. In the subsequent iterations, the producers of those inputs must supplement their outputs, and so it goes until the initial direct effect of $100 million has rippled its way through the rest of the economy. The resulting increases in total output will reflect both the direct, indirect, and induced effects [142].

The basic input-output models are of the Leontief structure and can be expressed as

$$X = (I-A)\ Y$$

where:

X = vector of each sector's total value of output

I = an identity matrix

A = a matrix of direct requirement coefficients

Y = a vector of final demand

The X vector contains the dollar value of total output for each sector of the economy. The A matrix contains the direct requirements coefficients and reflects the degree of interaction among the sectors within the model. Each column of this matrix shows the dollar value of purchases made from each sector of the economy per dollar of output by another sector. The Y vector contains values for each sector and measures that sector's total sales to final demand. From this model, analysts estimate final demand, employment, and income multipliers [142, 143]. These multipliers are discussed in more detail in the section entitled "Regional Impact or Multiplier Analysis."

A simple, hypothetical input-output (or transactions) table, such as that illustrated in Table 1, taken from Miernyk [94, p.9], shows how the output of each industry is distributed among other industries and sectors of the economy. The table is read as follows:

> Assume that the transactions in the table are in billions of dollars. Each row (reading from left to right) shows the output sold by each industry or sector along the left-hand side of the table to each industry or sector across the top of the table. Each column (reading from top to bottom) shows the purchases made by each industry or sector along the top of the table from industries and sectors along the left-hand side. To illustrate, ... industry E bought from industry C products worth 5 billion dollars [94, pp.10-11].

There are several references that discuss how to develop input-output tables and various data and survey problems involved in developing tables for a region. The Department of

Table 1. Hypothetical Input-Output Table [94, p. 9]

Industry Purchasing

Industry Producing	Outputs[1] → / Inputs[2] ↓	Processing Sector (1) A	(2) B	(3) C	(4) D	(5) E	(6) F	Final Demand (7) Gross inventory accumulation (+)	(8) Exports to foreign countries	(9) Government purchases	(10) Gross private capital formation	(11) Households	(12) Total Gross Output
Processing Sector	(1) Industry A	10	15	1	2	5	6	2	5	1	3	14	64
Processing Sector	(2) Industry B	5	4	7	1	3	8	1	6	3	4	17	59
Processing Sector	(3) Industry C	7	2	8	1	5	3	2	3	1	3	5	40
Processing Sector	(4) Industry D	11	1	2	8	6	4	0	0	1	2	4	39
Processing Sector	(5) Industry E	4	0	1	14	3	2	1	2	1	3	9	40
Processing Sector	(6) Industry F	2	6	7	6	2	6	2	4	2	1	8	46
Payments Sector	(7) Gross inventory depletion (−)	1	2	1	0	2	1	0	1	0	0	0	8
Payments Sector	(8) Imports	2	1	3	0	3	2	0	0	0	0	2	13
Payments Sector	(9) Payments to government	2	3	2	2	1	2	3	2	1	2	12	32
Payments Sector	(10) Depreciation allowances	1	2	1	0	1	0	0	0	0	0	0	5
Payments Sector	(11) Households	19	23	7	5	9	12	1	0	8	0	1	85
	(12) Total Gross Outlays	64	59	40	39	40	46	12	23	18	18	72	431

Commerce's RIMS-II analysis is based on work by Garnick [92] and Drake [93]. Three ways of developing a regional input-output table for a region are discussed by Miernyk as follows [94, pp.72-73]:

1. Apply national coefficients to control totals for the region.

2. Collect data on interindustry transactions by means of a detailed survey.

3. Use the intersectoral flows approach, developed by Tiebout and his associates, which represents a middle ground between the first two approaches listed above. The intersectoral flows model, or "rows only" approach, incorporates some of the features of an economic base-multiplier approach as well as some of the features of regional input-output analysis.

Transportation Applications of Input-Output Analysis

Input-output models are well-suited to address two types of analytical inquiries that bear upon transportation agency policies. First, the role and importance of the transportation sector needs to be described in relationship to the rest of the economy. Knowledge of relative magnitudes (such as that transportation-related expenditures represent 25 percent of the value of total GNP) are vitally important to define the macro-scope of transportation's role in the economy [51]. However, input-output techniques illuminate overall economic consequences, including those in individual sectors, resulting from some change in the level of activity recorded in the transportation sector. Secondly, and almost oppositely, detailed input-output models document the transportation sector's resource requirements and the interrelationships that produce impacts upon transportation in response to changes in general economic conditions [120].

Although national input-output models are available to describe and analyze the national economy and national impacts by industry, these models are especially useful at the regional level for showing industrial structure and performing impact analyses. This usefulness is demonstrated by the widespread use of input-output analysis at the regional level. In addition, a subset of input-output analysis - multiregional in scope - has been developed to analyze the interdependencies both of industries and geographical entities. These models show both the direct and indirect relationships among regions and among industries within the regions. Further, they allow analysts to trace changes in output/employment levels from one scenario to another, both by sector and by region. This is particularly important in analyzing transportation systems that cross several boundaries--inland waterways, railroads, and highway systems are primary examples [114, 111, 144].

Discussions of the limitations of input-output analysis often focus upon its assumptions and the significant data requirements. Importantly, input-output models usually assume unchanged technology, no economies of scale, and no substitution of inputs in the production process [120]. Industry data to develop the technical coefficients used in the model are usually obtained from extensive data survey efforts. Leontief [145] argues that technical, engineering descriptions of production processes (rather than dollar values of inputs) are the most ideal sources of information from which to derive the technical coefficients. Furthermore, such information gives an accurate description of the technology embodied in processes. Other analysts [143, 146, 147] see various nonsurvey approaches as the most cost-effective solutions to the acquisition of data for developing and updating coefficients for input-output models.

REGIONAL IMPACT OR MULTIPLIER ANALYSIS

When there is new spending in a region or nation, there is an initial increase in output and employment. As this money is spent, it becomes income to other people, who in turn spend it creating additional income and employment. This cycle creates what is known as the multiplier effect. Using assumptions about the structure of aggregate spending functions, it is possible to estimate aggregate multipliers that can be easily used to estimate these types of effects.

Aggregate Multiplier Analysis

Aggregate multiplier analysis was developed by John M. Keynes [115], building on earlier work on aggregate employment multiplier analysis work by Richard F. Kahn [116]. Aggregate multipliers show how much total output or employment will increase due to an initial, autonomous increase in spending by government, investment, consumption, or net exports. These are discussed in standard macroeconomic textbooks.

In the short run, aggregate demand is a key determinant of the level of income and employment in the economy. The reason is that aggregate demand determines the extent to which the economy's productive capacity will be utilized. The aggregate demand schedule is a summation of the uses of the economy's output. Since the output of the economy consists of several categories of goods and services, the demand for the output of the whole economy is a demand for the various categories of goods and services that enter into the national output or income.

The fundamental idea behind the multiplier concept is that any change in the expenditure rate for any of the component parts of the aggregate demand schedule will have magnified effects upon the overall national income or output level. There are two major effects associated with an autonomous increase in expenditures that lead to an increase in output. The initial, or primary effect, is associated with the initial change in output. The induced, or secondary effect, arises out of the fact that the original recipients of the increased income will in turn spend some portion of this increase for goods and services. It is in this secondary effect that is the key to the multiplier process. In the absence of any induced changes in spending, the impact of the increase in autonomous expenditure on the output level could be no greater than the initial change in expenditure. The multiplier effect results from the sum of the initial and induced changes in expenditures that ensue from a change in the rate of expenditure for any of the components of aggregate demand.

The amount of induced consumption in the multiplier process is determined by the marginal propensity to spend, that is, the increase in total spending per unit increase in national income. Once it is known what proportion of an increment of income will be spent for goods and services, the magnitude of the secondary or induced effects resulting from an autonomous increase in expenditure can be determined. The marginal propensity to spend thus provides the analytical key to the increases in secondary spending, and consequently, to the numerical value of the multiplier.

Multiplier analysis can be utilized in evaluating transportation expenditures, by applying an estimated multiplier to autonomous changes in expenditures for transportation. This would produce estimates of resulting changes in output through the direct and induced effect on spending.

Regional Impact Analysis

Aggregate multipliers do not show the details of how multiplier effects are worked out throughout the economy. However, using input-output tables and other data, it is possible to develop output and employment multipliers for specific regions and industries. The use of multiplier analysis has been facilitated by the many excellent interindustry studies. Perhaps the best known and most-widely used of these studies in the United States are those prepared by the Bureau of Economic Analysis, U.S. Department of Commerce, the latest of which are called the "RIMS-II" analysis and tables. Especially useful in this proposed NCHRP Project is the User Handbook [91], which gives not only detailed procedures but also several helpful examples of the use of multipliers. Case studies included in the User Handbook are evaluations of the impacts of (1) building a new factory and manufacturing its output, (2) expenditures by tourists, and (3) shutting down a military base.

Output and Employment Multipliers

Miernyk [94] explains that local and regional impact studies measure the direct, indirect, and induced income and employment effects of changes in final demand in one or more sectors of the local or regional economy. Most multiplier studies have been regional in nature. Indeed the only difference between an impact analysis and a general multiplier analysis is that in the former, attention is focused on the total changes in an economy (national or regional) that are expected to result from exogenous changes--changes in final demand in some of the major sectors of an input-output system. Most regional impact studies have been concerned with measuring the effects of changes in final demand for existing industries in the region. Some, however, have been concerned with measurement of the total impact of the location of a new industry in an area.

Miernyk also describes the procedures for developing sectoral output (or income) multipliers from an input-output table [94, pp. 32-50, especially pp. 43-45]. The first step in the development of sectoral multipliers from an input-output table is to "close" the basic transactions table with respect to households by moving the household row and column into the processing sector, and reconciling the household row and column totals. Second, a table of technical coefficients is computed using this revised transactions table. The third step is to compute the direct and indirect requirements per dollar of final demand for the new system which includes households in the processing sector finding a general solution to the new transactions table by computing a transposed inverse matrix of the difference between the revised transactions table and an identity matrix.

The results of this operation are given in Table 2. Various types of multipliers can be developed and two of the more common are illustrated in Table 2, denoted as Type I and Type II multipliers. Type I and Type II multipliers are described as follows by Miernyk [94, pp.48]:

The Type I multiplier is sometimes referred to as a "simple" income multiplier since it takes into account only direct and indirect changes resulting from an increase of one dollar in the output of all the industries in the processing sectors. The Type II multiplier is a more realistic measure which takes into account the direct and indirect effects indicated by the input-output model plus the induced changes resulting from increased consumer spending. Thus for each sector the Type II multiplier will always be larger than its Type I counterpart. ....
The Type I multipliers are limited to the direct and indirect effects on income of a given change in output, but the Type II multipliers also show "the chain reaction of interindustry reactions in income, output, and once more on consumer expenditures."

Table 2. Hypothetical Income Interactions and Multipliers [94, p. 47]

Sector	*Direct income change* (1)	*Direct and indirect income change* (2)	*Indirect income change* (3)	*Type I multiplier* (4)	*Direct, indirect and induced income change* (5)	*Induced income change* (6)	*Indirect and induced income change* (7)	*Type II multiplier* (8)
A	.25	.63	.38	2.52	1.23	.60	.98	4.92
B	.32	.62	.30	1.94	1.21	.59	.89	3.78
C	.18	.58	.40	3.22	1.13	.55	.95	6.28
D	.13	.61	.48	4.69	1.20	.59	1.07	9.23
E	.18	.56	.38	3.11	1.11	.55	.93	6.17
F	.20	.59	.39	2.95	1.16	.57	.96	5.80

The Type II multiplier from Table 2 is multiplied by the initial increase in spending to obtain the "total" change in income. Employment multipliers can be used to show the change in employment for an initial change in spending. Employment multipliers can be developed using techniques described in detail by Miernyk [94, pp.50-55]. Many input-output studies develop employment multipliers for each industry, and these can be used to estimate the direct, indirect, and induced change in employment for a given initial change in spending.

Use of Input-Output Analysis and Multipliers

Income and employment multipliers are widely used for showing the direct, indirect, and induced impacts of government spending. Many multipliers are available from national, regional, and local input-output studies. Numerous national organizations work up tables or other data that can be easily used to show impacts. Multiplier analysis has numerous limitations, but its ease of use and understanding make it one of the most used techniques for showing regional economic impacts.

The development of readily available input-output based multipliers and economic analysis packages, such as RIMS-II, has stimulated the use of economic multipliers (earnings and employment) to analyze the effects of transportation improvements and expenditures. The RIMS-II effort has produced a set of regional (groups of counties) multipliers that are widely used to estimate the impacts of project and program expenditures by a variety of private and governmental entities.

Direct impacts are calculated to show the initial effects of the transportation improvement. Reduced costs, new facilities, enhanced service--a variety of transportation improvements can be described and estimated. Of course, the process of estimating and the items to be included in the estimate of initial direct impacts depend upon the mode being analyzed [130, 111, 144].

Multipliers have been widely used to show the impact of highway expenditures, transit expenditures of different types, waterway improvement expenditures, and airport expenditures. For many years, state good roads associations have used impact analysis to show the economic impact of highway expenditures. These multiplier effects typically only show the income and employment impacts of the initial highway expenditure.

More recently, however, there has been an important extension in the highway field to apply input-output analysis and multiplier analysis to estimate the indirect and induced impacts of changes in user costs related to highway expenditure programs. Politano [111] shows the effects of highway project improvements described initially in terms of efficiency savings, mobility savings, and safety savings. The REIMHS process is shown on the following page with proposed modifications to allow for regionalization of the analysis. The initial savings are multiplied by input-output derived multipliers to estimate the individual impacts and the total system-wide earnings and employment effects attributable to the highway improvements.

The U.S. Corps of Engineers has been a major user of multiplier analysis and input-output analysis in estimating the impact of waterway expenditures and improvements. The Corps of Engineers uses input-output analysis and multiplier analysis not only for estimating the impact of the initial expenditure but also for obtaining the multiplier effect on income of reductions in transportation costs. The analysis is very detailed and recent developments have been well described [e.g., 114, 115, 116]. Impact analysis also has been used numerous times, and for several decades, by some coastal and inland river ports to estimate income and employment impacts of expenditures by ports and port-related industries. Procedures have been developed and are published as a Port Economic Impact Kit [121]. (The first edition of this kit was published in September 1979 as a joint effort of MARAD, the Canadian Ministry of Transport, and the Pacific Coast Associatioin of Port Authorities.) The second version identifies three types of direct impacts, as related to: port industries, local port users, and port capital spending. This "how-to" approach describes the data collection needed to define initial direct impacts and the use of multipliers to complete the estimate of the total impacts of spending in the three categories. The Impact Kit gives results of selected previous impact studies, as summarized in Table 3.

The American Public Transit Association [112] has developed published employment multipliers by type of transit expenditures to show impacts as shown in Table 4.

Several good general references are available on methods of doing an economic impact study of airports [126, 127, 128, 129, 130]. Butler's report [130] is especially good at categorizing benefits and ways of estimating impacts. There are also numerous case studies that need to be studied for specific techniques [Examples are References 131 through 139].

Table 3. Examples of Multipliers from Port Impact Studies

	Type of Multiplier		
	Output (Sales)	Employment	Payroll
California	2.11	2.24	2.06
Oregon	1.69	1.94	1.71
Washington	1.68	1.90	1.71
Alaska	1.78	1.89	1.93
Los Angeles/Long Beach	2.10	2.36	2.13
San Francisco/Oakland	1.94	2.21	2.06
Portland/Columbia River	1.86	2.15	1.90
Puget Sound	1.72	2.08	1.80
Georgia	1.71	2.17	2.03
Port Longview	1.35	1.62	1.38
Philadelphia	1.8	-----	-----

Source: Port Economic Impact Kit [121], from various studies.

Table 4. Employment Impacts of Transit Expenditures

	Number of Jobs Created by $100 Million Investment		
Type of Expenditure	Direct	Indirect	Total
New Rail Starts	3,380	4,610	7,990
Rail Modernization	3,213	4,387	7,600
Buses and Garages	3,149	4,301	7,450
Operations	4,060	5,550	9,610

Source: American Public Transit Association [112].

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