Models to Predict the Economic Development Impact of Transportation Projects: Historical Experience and New Applications

Glen Weisbrod
Economic Development Research Group, Inc.
617-338-6775, x202
gweisbrod@edrgroup.com

This EDR Group working paper was subsequently published in
Annals of Regional Science, ***December 2007***

Abstract

Methods used for assessing economic impacts of proposed transportation projects have continually evolved over time. Whereas they once focused largely on the economic benefit of time and cost savings for travelers, they may now encompass broader factors such as accessibility roles in supply chains, labor market expansion, global trade growth, and their economic development implications. This broader view can be particularly important when considering transportation projects affecting network connectivity and activities of logistics centers, inter-modal terminals, and international gateway facilities.

Using examples throughout history, a generalized description is developed of the range of access, reliability, quality and cost factors that can affect the nature of economic growth impacts of transportation projects. While the set of factors is consistent with both theory and research findings, there has been a significant shortfall in their coverage by applied computer analysis models used for transportation decision-making. This article critically examines the coverage of access impacts by various classes of predictive economic impact models, and then describes new directions in applied models to assess regional impacts of transportation projects on business productivity, growth and attraction. Finally, it outlines a new analysis framework that is designed to facilitate use of improved modeling methods for assessing regional-level economic impacts of multi-modal transportation investment.

1. Objective

This article examines the range of computer analysis methods and tools used by government agencies and their consultants to estimate the regional economic impacts of proposed transportation projects. At the outset, it is important to note that there have always been gaps between reality, our theories to explain it, empirical research and tools used for policy decisions. A variety of computational, data observation and resource limitations also come into play to require simplifications in empirical research and analysis tools. Yet while the presence of such gaps may be understandable, it is still important to identify their nature and the potential for error that they may introduce when predictive models are used for policy decision-making.

There are differences in the objectives of scholarly research and applied models that are important to recognize as part of any evaluation of predictive models. For instance, there are lines of research that demonstrate a general relationship between transportation investment levels and economic growth rates (e.g., Nadiri and Mamuneas, 1998), and a relationship between highway presence and localized growth (e.g., Isserman and Rephan, 1995). While such studies can be of great value in demonstrating that transportation investment can make a difference in economic growth, they are not useful for transportation planning agencies that are considering alternative project proposals regarding how to spend a given transportation improvement budget. For transportation planning agencies, there is a need to evaluate the economic development impacts (as well as the efficiency and environmental impacts) of individual highway, rail, airport and marine port project proposals. As discussed in this article, it has long been recognized that regional economic impacts can vary greatly depending on the form and locations of the proposed facilities, and the types of changes they can have on travel times, costs, accessibility, reliability and connectivity of travel routes and services. For the last twenty-five years, transportation planning agencies have, in fact, already been using various computer models and tools to predict the likely economic impacts of proposed projects.

The fundamental assumption underlying this article is that predictive economic impact models used for decision-making should be sensitive to causal factors and elements of access impact known to make a difference in the effect of transportation projects on regional economic growth and development. While current empirical research may have not yet determined the optimal structure of equations for all such causal relationships, it is nonetheless clear to transportation planning agencies that total omission of important factors is even more likely to yield error in their assessment of project proposals. Thus, this article focuses on three very fundamental questions: (1) What are the causal factors and elements of accessibility that are known from historical experience and from empirical research to affect the economic impact of transportation projects? (2) To what extent are they covered by various classes and types of predictive economic impact models? (3) How is this information used in assessing project benefits and costs?

This article shows that there have been significant omissions in the coverage of important transportation-related access impacts among predictive economic impact tools, though newer models are closing that gap. It also finds that there is often confusion in the interpretation of economic impact model results, particularly in the use of economic growth impacts for benefit/cost analysis. Together, these findings point to the need for a general framework to help organize data and present results in a consistent manner.

There are other remaining issues concerning predictive economic impact models, including the validity of their structure and underlying empirical econometric equations, as well as the consequences of mixing static transportation assignment models with dynamic economic simulations -- that can lead to predictive error even if the component models are correctly specified. There are also issues concerning the accuracy of economic impact forecasts. All of those issues remain for another article. At this point, the first step should be to assess how well causal factors and access changes are covered at all in regional economic impact models. After all, if existing models omit important factors, then their usefulness is limited even if they end up being accurate in some cases. By highlighting the basic problem of coverage, this article can help provide a basis for subsequent investigation of the appropriateness and validity of both empirical research and predictive impact modeling methods.

Finally, it should be noted that while this article traces the evolution of *computational methods* used to estimate or predict the economic development impacts of transportation, it complements the evolution of *policy thinking* about the nature of these relationships, which has been discussed in a separate paper by Weiss (2002).

2. Historical Models of the Transportation - Economic Development Connection

The effect of transportation investment on economic development comes from the role of transportation facilities in enabling movement and interchange of activities between locations. The earliest works in regional science recognized that both growth and concentration of economic activity at any given location depends (at least in part) on access to markets and the location economies enabled by that access. This is reflected in works on central place development (Christaller, 1933), scale economies (Marshall, 1919) and agglomeration economies (Weber, 1929). Yet to more fully understand the economic development role of transportation improvements, it is also useful to take a business decision-making perspective and identify the mechanisms whereby transportation can affect supplier and buyer markets and costs, affecting the pattern and magnitude of economic growth among various industries and locations.

From a business development viewpoint, transportation improvements can affect economic growth and development in at least four ways: (1) by enabling new forms of trade among industries and locations, (2) by reducing cargo loss and enhancing reliability of existing trade movements, (3) by expanding the size of markets and enabling "economies of scale" in production and distribution, and (4) by increasing productivity through access to more diverse and specialized labor, supply and buyer markets. Each of these elements can be illustrated by historical examples which significantly pre-date the formalization of modern theories supporting them. Each is summarized below:

2.1 Development of Inter-Industry Trade. Economic development refers to the growth and development of the economy of a nation or region, as most commonly measured by the increase in its income and job creation over time. In ancient times, the relationship between transportation and economic development was already clear as economic growth depended on producer and customer market access through transportation routes. Roughly two thousand years ago, ancient caravan routes such as the Silk Road, the Spice Route and the Gold and Salt Route were firmly established as the distribution backbone for bringing distant products to European markets.

As these trade routes became firmly established, they became formalized as distribution networks that effectively expanded jobs and income for various producers, traders and merchants. They also supported the economy of intermediate industries and locations that provided traveler services. For example, inter-industry trade led to development of a value-added supply chain along the Silk Road, with a set of silk, carpet, apparel ceramic and gem products being manufactured and traded between a string of trade centers in Europe, Persia, India and China. In Africa, intermediate trade and traveler service economies developed in places such as Timbuktu, which started as a camel stop along the Gold and Salt Route trade route between Africa and Europe. A millennium later, inter-industry trade accounting was formalized in input-output analysis (Leontief, 1951) and later supply chain management (e.g., Bowersox and Closs, 1996).

2.2 Transport Infrastructure to Reduce Costs and Enhance Reliability. Over time, continued infrastructure investments improved travel times, reliability and capacity. The Romans built over 50,000 miles of paved roads to support a trade network of national defense and interstate commerce routes. Gaza and later Caesarea were developed as intermodal freight center connecting ship routes in the Mediterranean with land routes for goods coming from Arabia and Asia. This intermodal transfer improved schedule reliability and reduced losses by allowing use of a land route from Arabia that avoided the dangers of uncharted rocks and piracy originally plaguing Red Sea travel, combined with a Mediterranean Sea route to Europe that avoided the difficult terrain and weight limitations associated with land travel across Europe. A millennium later, transportation loss rates were predicted using mathematical formulations of uncertainty risk analysis (e.g., see Bedford and Cooke, 2001).

2.3 Increasing Markets and Productivity. Fast forward to only two centuries ago, and we find that the US started to invest in trade and freight routes for essentially the same reasons as the Romans. Early federal programs supported development of highways (e.g., Cumberland Pike in 1818) and waterways (e.g., Erie Canal in 1825) as means to expand market access for wheat and other agricultural products to be shipped from distant inland farms to New York and other major cities nearby along the coast. The result was a substantial drop in wheat prices, as consumers gained access to a greater supply of agricultural products from lower cost producers. It also led to a substantial rise in income generated by farmers, who gained access to a wider market for their products. A century later, the concept of market scale economies became formalized by Marshall (1919).

2.4 Reducing Isolation and Enhancing Access to More Diverse Markets. The theme of market access enhancement continued into the 1960's, as highway investment was still seen by US government officials as a means for facilitating income growth through enhancement of access for labor, materials and customer markets. An early federal report focused on the benefit of the interstate highway system as increasing access by appearing to reduce effective distances between areas (FHWA, 1970). In 1964, a Presidential Commission reported that "economic growth in Appalachia would not be possible until the Region's isolation had been overcome" and Congress reacted the next year by funding the Appalachian Development Highway System "to generate economic development in previously isolated areas." (ARC, 1964). Three decades later, the economic efficiency benefits of greater access to diverse inputs was formalized in work by Krugman (1991) and Fujita et al (2001).

A final aspect of the relationship between transportation and economic development is the "reverse impact" of congestion. By imposing an effective limit on throughput, raising travel times and costs, reducing reliability and diminishing access, congestion can potentially undercut or even reverse all four of the preceding types of economic development impacts enabled by transportation investments.

Congestion delay has long been a concern in urban areas. Over two thousand years ago, Julius Caesar banned chariot traffic from the center of Rome during daytime to reduce traffic congestion. Toll points and gates were also put in to help control traffic flow. Today, as in the past, high levels of congestion during peak times can also lead to both recurring delay and higher likelihood of non-recurring incidents, which together can significantly reduce reliability and raise travel costs, thus reducing some of the advantages of location associated with the affected areas and routes (Weisbrod et al, 2003).

These historical examples illustrate the wide range of ways in which transportation changes can affect economic development. They provide the basis for Table 1, which lists key transportation impact mechanisms, along with characteristics of transportation services that affect those impact mechanisms. This list can be used as a set of criteria foe assessing both the breadth of relevant research studies and the limitations of predictive models.

Table 1. List of Historically Important Mechanisms for Transportation Impacts on Economic Development

(A) Mechanisms Enabling Economic Development
- Development of routes enabling new trade between industries and between locations
- Improvement in travel cost and travel time for existing passenger and freight movements
- Reduced uncertainty and risk, diminishing loss and improving reliability
- Expansion of markets, allowing for "economies of scale" in production and distribution
- Increasing productivity from access to more diverse inputs & broader markets for outputs.

(B) Mechanisms Reducing Economic Development
- Congestion-induced negative impacts on trade flow volume, travel time, cost, reliability and market access

(C) Aspects of Transportation Performance
- Travel time and expense
- Logistics processing time and expense
- Reliability of schedule
- Spoilage or loss rate
- Accessible markets (suppliers, labor, customers)
- Access to intermodal facilities, interconnections
- Cargo capacity, weight and volume limitations
- Time, day and seasonal variations in above factors
- Induced impact on demand and traffic growth

The most important finding from these historical examples and the list of factors in Table 1 is that many facets of travel time, cost, reliability, market access, intermodal transfer connections and travel route connectivity can all come into play as relevant factors affecting the economic growth of industries and locations. In fact, from ancient days to the middle of the last century, no one would have thought to assess the economic benefit of transportation investment as merely the value of savings in passenger time and vehicle costs, as is still frequently done in benefit/cost calculations by transportation agencies. It would be unthinkable to assess the business growth, job and income benefits of new transportation facilities and services without also considering factors such as accessibility to markets, scale economies from market expansion, reliability, intermodal logistics and connectivity. But then again, they had neither mathematical models nor computer software to oversimplify that assessment.

3. Towards a Generalized View of the Transportation - Economic Development Connection

Empirical research has been evolving to address more of the complex factors at play in the preceding historical examples. It is useful to summarize some of the types of transportation economic impact factors that have been shown to be important in empirical research studies, as that provides a basis for later evaluating their coverage in applied computer models. While the functional forms that relate transportation factors to economic outcomes also remain important issues that remain to be addressed, the focus here is just on assessing models from the most basic viewpoint of their completeness in covering relevant factors affecting the economic impacts of transportation. Research to date suggests that the following types of factors can be important to consider when evaluating transportation project proposals:

3.1 Mode and Industry Cost Differences. The earliest theories and historical examples showed that transportation improvements can reduce transport costs differently among various industries. Specifically, labor market size (and its associated travel times and costs) can vary by industry since commuting distances and commuting mode choices have been shown to differ by occupation (Weisbrod et al, 2003). Similarly, distances for material and product deliveries (and their associated travel times and costs) can vary by industry because various materials and products are transported and delivered via different combination of modes. As a result, bias arises in the estimation of market access and transport costs when the "the heterogeneous nature of the traded products, and the distance they cover" is missing from analysis (Lopes, 2003).

3.2 Quality Differences. Besides affecting the size attributes of markets, expanded access can also affect the price and quality attributes of available labor and material supplier markets. These factors also affect economic growth insofar as they can affect the extent of a "match" in relevance between attributes of the available market and a given industry's specialized labor or material input requirements. The importance of considering quality as well as price attributes is also expressed in economic development literature on workforce skill training (e.g., Blakely and Bradshaw, 2002), supply chain product specialization (e.g., Bowersox and Closs, 1996), and the productivity effect of improved access to differentiated inputs (e.g., Krugman, 1995; Weisbrod and Treyz, 1998). The quality of highway has also been shown to affect economic development over time, with greater economic diversity occurring in areas served by higher speed highways (Horst and Moore, 2003).

3.3 Transport Network and Access Conditions. Impacts of transportation improvements on travel time and distance can diverge substantially, because variation in network density, route connectivity and congestion factors can together make the pattern of travel time changes among locations quite different from the patterns of straight air distance (Combes et al, 2005). To capture the variation in "ease of travel" between zones, transportation and economic analysts have sought to develop inter-regional "impedance" factors that are both mode and direction-specific (Lindall et al, 2005). The direction-specific nature of impedance factors is due to the uni-directionality of many product flows, resulting from supply chains and distribution channels in buyer-supplier relationships (Enright 1996). In addition, access and connectivity to intermodal terminals are shown to be important factors in the concentration of some industry sectors (Targa et al, 2005). Finally, some industries have threshold factors for maximum acceptable travel times and schedule variability, which effectively limit their market areas. For instance, just-in-time scheduling processes can limit suppliers to those that can reliably provide same day delivery.

The historical cases and research findings together lead to a generalized view of key factors determining how a specific transportation improvement can lead to economic growth in a given area. There are two parts to this view. First, equation 1 expresses a relationship between regional economic growth and changes in accessible market size, market access cost and market quality (diversity or specialization) factors. These factors can vary by industry, due to differing input requirements and transport needs, as well as by location. Equation 2(a,b,c) relates the changes in accessible market size to shifts in passenger and freight mode mix and associated travel times, travel costs and reliability factors that vary by industry and by location.

(1) ΔECON (i, j) = *fn* { ΔLMKT(i,j), ΔLQUAL(i,j), ΔLCOST (i,j), ΔSMKT(i,j), ΔSQUAL(i,j), ΔSCOST (i,j), ΔCMKT(i,j), CQUAL, ΔCCOST (i,j) }

where:
Δ = change, i = each given industry, j = each given location, *fn* = a function of:
ECON = level of economic output (products and services produced in the area)
xMKT = size or scale of the market that can be accessed
xQUAL = qualities (diversity or specialization) of the market
xCOST = cost of labor, material or delivered products in that market
x = "L" for labor, "S" for supply materials or "C" for customers

(2a)
ΔLMKT(i,j) = *fn1* {ΔLMM(i,j), ΔLTIME(i,j,m), ΔLCOST(i,j,m), ΔLREL(i,j,m)}
(2b)
ΔSMKT(i,j) = *fn2* {ΔSMM(i,j), ΔSTIME(i,j,m), ΔSCOST(i,j,m), ΔSREL(i,j,m)}
(2c)
ΔCMKT(i,j) = *fn3* {ΔCMM(i,j), ΔCTIME(i,j,m), ΔCCOST(i,j,m), ΔCREL(i,j,m)}

where:
fn 1,2,3 = functions of:
xMKT = size or scale of the market that can be accessed
xMM(i,j) = mode mix for travel in industry i in location j
xTIME(j,m) = travel times to outside areas from location j (given mode mix m)
xCOST(i,j,m) = travel cost to outside areas from location j (for industry i with mode mix m)
xREL(i,j,m) = reliability of travel time from location j (for mode mix m, including effects of network and intermodal connections as well as line congestion
x = "L" for labor, "S" for supply materials or "C" for customers

Together, the explanatory variables included in these equations indicate that transportation impacts on the economy can depend on three types of markets (labor, supply materials and customers), three types of market features (size, cost and quality) and variation by mode and industry/commodity. Together, they represent the very wide range of factors that can be relevant when evaluating economic impacts of transportation changes.

4. Classifying Computer Models of the Transportation - Economic Development Connection

In the 1960's, computers inspired a bright future of hope. That was reflected in an article entitled: "Will Model Building and the Computer Solve Our Economic Forecasting Problems" (Highway Research Board, 1966). The next four decades showed that computer models in fact can have intrinsic limitations requiring a continuing effort by analysts to address new and emerging impact issues.

In the field of transportation, computers enabled urban transportation network models to emerge in the 1960s and 1970s as tools to forecast and allocate future trips among alternative routes on an urban road network (CATS, 1962). In the field of economic development, computers enabled input-output models to emerge in the 1960s and 1970s as tools that allocated flows of dollars among product supplier and buyer industries (Shen, 1960; Schaffer, 1972). Both models were effectively allocation techniques for tracking and forecasting future flows (for traffic in one case, and for dollars in the other case). Together, the two provided a structure for calculating the effect of road improvements on traveler costs and the impacts of those cost changes for a regional economy. This foundation has led to a several different classes of models for assessing the economic consequences of transportation improvements. They include regional impact models, land use-development models, macroeconomic models, regional economic simulation models, and local access models. It is useful to review each class of models and their relative strengths and limitations to highlight differences in their coverage of the Table 1 impact mechanisms.

4.1 Early I-O Based Impact Models. The 1980's marked the emergence of the computer simulation models that attempted to forecast the regional economic growth consequences of transportation projects. The earliest models, as well as other models that followed, drew on regionalized input-output (I-O) models to calculate how growth in any single industry would affect broader growth among other industries in a region. Multi-regional I-O models then enabled analysis of impacts across regions. While that approach allowed analysis of transportation spending effects, it required an exogenous first step to estimate how a change in travel times and costs (for workers, material inputs and/or delivery to customers) would lead to direct growth of affected industries.

The Regional Economic Impact Model for Highway Systems (REIMHS) applied was initially developed in the mid 1980's and applied for North Central Texas (Politano and Roadifer, 1989). It included of set of factors to translate spending on new highways and highway travel cost savings into expected increases in the flow of household and business income. The model then applied regional I-O multipliers to calculate the total additional business growth. REIMS was later also applied for highways in five other states (Stokes et al, 1991).

A similar set of analysis steps was employed with a multi-state version of the Regional Science Research Institute's PC-IO Input-Output model system to calculate short- and long-term economic impacts of introducing high speed train along the US northeast corridor. That study covered spending impacts and extended the valuation of cost savings to air to rail mode shifts for both business and non-business travel (Parsons Brinckerhoff et al, 1989).

Together, these early I-O models were notable for incorporating differences in transport mode use and travel cost savings among industries and among regions, yielding economic impact results that also varied among industries and regions. However, they assumed fixed trip origins and destinations for travel patterns, and did not allow for any additional market access impacts.

4.2 Land Use and Development Models. While the regional economic impact models focused on the economy at a regional level, a related line of research has focused on forecasting land density and development patterns and their sensitivity to transportation conditions. The transportation-land use models were built on the same basic I-O core concepts, but operated at a finer spatial level. For instance, the widely used MEPLAN model used aggregate level I-O tables to forecast total economic impacts of population and basic industry growth, and then spatially disaggregated the economic forecast across a highly detailed zone system using information on inter-zonal highway network travel times and costs, with discrete choice models of business and household location choices (e.g., Echenique 1994).

The more recent PECAS (Production, Exchange and Consumption Allocation System) model in Oregon and Ohio incorporates endogenous calculations of local land demand and prices, based on accessibility measures derived from a highway network to represent distances and costs for commuting and commodity movements among zones (Hunt and Abraham, 2005).

The TELUM (Transportation Environment and Land Use) analysis model, also sometimes referred to as TELUS, extends the land use modeling approach to also calculate total economic impacts of transportation spending and travel time benefits. Originally developed and applied in New Jersey, the design of TELUM includes calculation of highway travel time impacts by forecasting effects of access change on land development growth, which can then be put through the input-output model to forecast total impacts on the regional economy (Pignataro, 1998).

There are many other transportation and land use models that also utilize economic impact factors, besides those cited here. However, these examples illustrate an important the aspect of this entire class of models, which is their integration of economic growth and I-O forecasts with transportation networks to derive multi-faceted measures of access to markets and demand for locations. That makes it possible to assess the impacts on transportation projects on business market expansion and dispersion of residential and business locations. Since these model systems are oriented toward land use forecasting, however, the access measures naturally focus on road system times and costs between population and business activities. They generally do not address rail, air or marine modes or specialized freight transportation requirements..

4.3 Macroeconomic Models. Another class of economic models focuses more on large scale macroeconomic principals of investment and cost of labor, capital and transportation as industry inputs. Commonly known as Computable General Equilibrium (CGE) models, they employ a series of simultaneous equations representing supply and demand for labor, capital and transportation inputs, and then derive equilibrium costs for these production inputs. Those results are used to forecast changes in industry output, based on production functions that relate industry output to changes in those input factors. CGE models were originally designed for use a national, international or large region scale. Early works showed how interregional trade between regions can be modeled on the basis of industry-based costs derived from average shipping distances, without distinguishing any further modal or spatial differences (Buckley, 1992).

Ivanova (2004) used the Spatial CGE Model for Norway (PINGO), with 20 regions and 10 commodities. This was used together with a multimodal freight network data (covering road, rail and sea travel), to establish transport costs for commodity trade among the regions. This information was then used to calculate economic impacts of proposed new inter-regional transportation routes that would shift those transport costs.

ASTRA, a systems dynamic model of the European economy, was designed for estimating economic impacts of changes in taxes, transport costs and public investment in transportation. The model was originally developed in 1997 and updated within the TIPMAC (Transport Infrastructure and Policy Macroeconomic) process (Cambridge Econometrics, 2003). It includes regional I-O matrices, along with a macroeconomic module to estimate demand-supply interactions using production functions. That provides a basis for assessing impacts of transport changes on effective labor supply, capital stock and total factor cost and productivity. ASTRA was applied to estimate economic growth effects of investing in the proposed multimodal system of Trans European Network (TEN). At that level of analysis, spatial detail was limited to major regional zones within each of the European nations. Travel demand was forecast for distance bands, with generalized transport costs that represent composite effects of changes in transport times, congestion levels, accidents and operating costs. (Martino et al, 2005)

These spatial CGE model systems are notable for integrating economic simulation models with transportation models to forecast impacts of proposed projects on business growth and inter-regional trade (freight shipment) patterns by industry and by region. In doing so, they draw on multi-modal transportation models and data sources to calculate industry-specific changes in inter-regional freight shipment costs. However, they are designed to operate at a coarse regional level of spatial detail, which is appropriate for simulating supply, demand and intensity of use of labor and capital stocks. Accordingly, the measures of transportation cost also tend to be coarse, and other local factors such as highway and intermodal connectivity and access changes are usually not fully covered.

4.4 Regional Simulation Models. There are also economic simulation models that focus on a specific region, which may be as small as a county or metropolitan area, or as large as an entire state. These models are typically oriented towards estimating the consequences of an individual transportation project (or a set of projects) for the economic development of a specific region, which makes them of particular interest for this article. As region-oriented models, they measure economic development impacts in terms of the change in jobs and income generated within a specified study area. This regional perspective recognizes both expansion of existing business and attraction (relocation) of business from elsewhere as local economic development gains.

The REMI Policy Insight (REMI-PI) is a commercial package that is widely used in the US, and available at a national, state, regional, metropolitan or local county level. It was not designed specifically for transportation, but rather, as a general policy analysis system that can estimate the regional economic consequences of a wide range of tax, investment and regulatory policies. As a simulation model, it combines all of the major elements of large-sale macroeconomic CGE models (covering impacts on economic growth from changes in labor supply, capital stock, factor cost and productivity) together with local level modeling (covering impacts on population migration, cost of living and local industry operating costs). The model can be used in a single region form or multi-regional form; either way it distinguishes internal trade from trade with the rest of the US and world. Recently, an economic geography element was added that adjusts regional purchasing patterns on the basis of changes in generalized commodity access and labor access indices reflecting “effective distance” between regions. The use of this model is of particular interest because it had been a basis for many past economic impact studies in the US and it had spawned a variety of other related tools for evaluating transportation economic impacts.

The first applications of the REMI-PI model for transportation projects occurred was a 1988-1990 study for a proposed highway in Wisconsin (Weisbrod and Beckwith, 1992). It was followed by similar applications of proposed highway corridors in Indiana, Iowa, Louisiana, Kentucky and over a dozen other states during the 1990s. All of these studies used the REMI-PI model to calculate the economic growth impacts of business cost changes which would result from highway improvements. To accomplish this, they relied on a standard highway network model which has fixed origin-destination and trip generation assumptions, which was used to calculate effects of the proposed project on savings in vehicle-hours of travel and vehicle-miles of travel time (by mode and trip purpose). Those results were then monetized into travel cost savings and allocated among industries.

All of these studies recognized that the economic impact of a new highway can go beyond effect of travel cost savings derived from a standard highway network model with fixed trip tables. They recognized that additional traffic and business activity could be also attracted to a region when a project expands markets, provides access to particular types of intermodal facilities and services, enhances logistics and warehousing efficiencies due to new highway interconnections, enables new delivery patterns supporting supply chains or opens up new tourism venues. Thus all of these studies exogenously estimated additional market access and connectivity impacts beyond the effects of cost savings for existing industries and travel patterns.

The early studies relied on surveys and interviews to gauge the economic development implications of improving access and connectivity for various industries. For instance, the Wisconsin study used a business survey to profile local commodity flow patterns by industry. It found that local industries had widely varying shipping requirements that would make the proposed highway project much more important for the food products industry than for the paper industry. A panel of regional economic development experts was then assembled and used to estimate the likely magnitude of highway project impacts on new industry attraction to the state and affected corridor.

Later reviews of the Wisconsin study approach concluded that while there were indeed limitations with modeling just travel cost savings for existing travel patterns using the REMI-PI model, the use of expert panels may not be the ideal solution for estimating additional business attraction since personal expectations can over-estimate actual results (Luskin, 1999). In response to such concerns, the Southwest Indiana highway study used the REMI-PI model and a highway network model together with a new Transportation Business Attraction Model that estimated potential business attraction effects of improving highway market access and connectivity beyond effects of travel cost changes. This approach was subsequently applied to other proposed Indiana highway projects (Kaliski et al, 1999). It later formed the foundation of Montana's Highway Economic Analysis Tool (HEAT), a GIS-based system that added detailed commodity flow data and an improved version of the Business Attraction Module to account for economic consequences of highway projects changing access to airports, intermodal rail freight facilities and international border crossings, as well as labor and truck delivery markets (Wornum et al, 2005).

The value of combining a regional economic model with detailed commodity flow and access patterns was further demonstrated in a broader multi-modal framework by the RUBMRIO (Random Utility Based Multi-Regional Input-Output) Model for Texas (Juri and Kockelman, 2006). It incorporated county-based input-output tables, and added CGE-type market equilibration features to calculate shifts in demand and prices for land and labor among counties. It also introduced a random utility approach to calculate the "disutility" (a composite measure of effective cost) for inter-zonal commodity purchases, calculated from models of mode and origin choices by industry. This model is notable for its consideration of inter-zonal rail and highway commodity flows, travel times and costs, and its detailed estimation of how proposed rail and highway projects can lead to both economic growth and economic redistribution implications.

A different approach to modeling the regional economic consequences is illustrated by the CRIO (Cost-Response Input-Output) model. Following the concept of "Occam's Razor," CRIO is a reduced form regional model that adds a strong set of features for estimating the incremental effects of transportation improvements at the local and regional levels, but shaves off broader macroeconomic factors that do not normally come into play for these types of situations. This tool, designed for assessing proposals that simultaneously affect multiple transportation modes, combines an I-O model and economic growth baseline forecasts with a series of econometrically-derived functions relating transportation access and travel cost changes to shifts in local industry output and employment growth. It has been used as part of the broader TREDIS system (discussed later) to estimate the regional economic impacts of road and rail improvements intended to improve freight flow in congested regions (including Vancouver, BC, Portland, OR and Chicago, IL). A strength of this model, which makes it particularly useful for such situations, is its industry-specific sensitivity to changes in delivery schedule reliability, market scale and intermodal terminal access, all of which utilize non-linear functions with thresholds before productivity benefits appear. However, the model assumes no shifts in labor/capital substitution or labor costs within industries, based on the fact that those broader factors seldom change in any perceptible way in response to incremental transportation improvements made at a local scale in North America.

In general, the regional studies tend to utilize more detailed information on travel time and access changes affecting different modes and industries than the broad-brush cost measures generally used in national and sub-national macroeconomic models. The regional studies often also consider commodity flows, regional system reliability and interconnectivity factors among modes to a much greater degree than the land use models. Some economists and proponents of various models tend to blur these spatial distinctions and attempt to apply the same macroeconomic principals to all levels of geography. However, these examples of model applications show the complexity of cost and access considerations that can arise at a local or regional level, and the value of specialized tools that can address them.

4.5 Market Access Measures and Impact Models. There are also models that focus specifically on how transportation access changes can affect local business attraction and location decisions. Those findings can be used on their own, to help develop complementary economic development strategies. They can also be used together with other transportation and economic models in a broader analysis system.

The Transportation Business Attraction Model was originally developed for Indiana's Major Corridor Investment Benefit Analysis System. It used a two step process to estimate the business attraction opportunities associated with a new or substantially upgraded highway link between rural and urban areas. First, it measured the gap in business mix and growth (by detailed industry) in the rural areas whose access would be improved, compared to patterns and trends in the major urban areas to which they would be connected by the highway. Second, it identified the extent to which those gaps could be explained by deficiencies in transportation connections, which would be reduced or eliminated by the proposed new highway (Kaliski et al, 1999).

Shortly thereafter, the ARC-Opps (Highway Opportunities) and later LEAP (Local Economic Assessment Package) spreadsheet tools were developed for use by the Appalachian Regional Commission. These stand-alone tools enabled regional economic development agencies within Appalachia to identify targets for economic development and business attraction in areas where served by newly-completed portions of the Appalachian Development Highway System. While they used the same two-step logic as discussed above, they also covered an expanded list of accessibility effects. That included effects of transportation improvements on expanding labor markets, truck delivery markets and shopping markets, as well as tourism markets and highway connections to air, rail and marine terminals. Those models were accompanied by guidebooks on their use for economic development strategy (Economic Development Research Group, 2001 and 2004).

An additional feature of LEAP was its recognition that business attraction opportunities associated with transportation improvements would also be affected by the other factors, including quality of workforce education, quality of broadband and industrial park facilities, and factor costs. Table 2 presents an example of how that model combined the rating of transportation sufficiency with ratings of other factors to show the roles of both types of factors as barriers to local economic development.

Table 2. Example of a rating system to show the relative roles of transportation and non-transportation factors as barriers to local business attraction (for a sample area)

(1 = CRITICAL DISADVANTAGE; 2 = IMPORTANT DISADVANTAGE)

		Factor Costs					Labor Market		Transportation			
Sector	DEFICIENCY (# OF JOBS)	TOTAL PRODUCTIO N COSTS	LABOR COSTS	LAND COSTS	ENERGY COSTS	TAXES	WORKER BASE	SKILLED WORKER S	WATER TRANS	AIR TRANS	RAIL TRANS	HIGHWAY TRANS
Agricultural services	91	1	1				1			1		
Fishing	0	2										
General contractors	2,612											
Heavy construction	35											
Food products	507	2			2							
Textile mill products	90	2			2							2
Apparel and other textile	1,277	2								2		2
Furniture and fixtures	192	1								2		
Rubber and plastics	957	1										
Leather products	56									1		
Industrial machinery	357	1						2		2		
Electronic/electric equipme	4,724	2						2		1		1
Trucking & warehousing	610	1		1						1		1
Transportation by air	236	1	2		2		2	2		1		
Transportation services	184	1	2		2		2					
Communications	1,798							2				
Electric, gas services	321							1				
Wholesale - durables	110	1	2				2	2		1		
Wholesale - nondurables	627	1	2				2					

Source: Economic Development Research Group 2004)

The CDSS (Congestion Decision Support System) model represents an alternative approach that focuses on effects of urban congestion for labor markets and for truck delivery markets. Originally applied for the Baltimore and Chicago regions, it incorporated research findings to show how changes in worker commuting access can have economic impacts that vary among occupations, while changes in truck delivery access can have economic impacts that vary among industries. The model was designed to use this information to forecast the effects of alternative congestion scenarios on business costs by industry (Weisbrod et al, 2003).

An econometric model developed at the University of Maryland extended many of these same facets of access to a much finer "zip code" zonal level of spatial disaggregation. The model, developed for a region of Maryland, showed how the level of economic activity in a given zone (measured by the number of establishments in each of seven industries) can be forecast on the basis of transportation supply (density of highways), an index of adjacent zone business agglomeration accessibility and peak period access times to airports, intermodal freight terminals and rail transit stations as well as to labor, consumer and supplier markets (Targa et al, 2005). This model was then used to estimate impacts of a planned "Intercounty Connector" highway.

Of course, there are still situations where no individual access model can substitute for a basic market study. Market studies are needed and have been applied in situations where a new highway can open up market access to enable specific new industries. They can range from a new gold mine area in Canada (Conference Board, 1994) to a proposed tourism destination at the birthplace of a famous country music legend.

There are also specialized tools for tracking impacts of transportation changes on spatial connections and economic flows between regions. REMI-TranSight is a pre-processor to the REMI-PI model that represents transportation project impacts as modifying the effective "distance" between multi-county regions and thus increasing reliance on supplier-buyer relationships between those areas. That approach relies on generalized distance measures between regions, a concept that does not necessarily recognize variation in speeds and travel times among modes or among parts of the transportation network, nor the effect of shifting reliance on highway, rail, air and marine modes by various industries.

More detailed and realistic approaches have come with the integration of geographic information systems (GIS) with transportation network data and multi-modal terminal/port data. That approach makes it possible to utilize a greater level of spatial detail to improve the measurement of accessibility changes within a region, and then still apply a regional-level economic model to asses the broader economic development implications. Viewing a proposed project in that way, it is possible to show how a given improvements in road or rail transport connections can affect the size of labor markets and shopping markets within the region. It can also show how highway transportation improvements can affect access to intermodal connections such as airports, marine ports, intermodal rail/truck loading facilities and international gateways. The addition of GIS has facilitated development of new analysis systems to measure access and connectivity changes and their impacts on regional economic development.

The web-based EDR-LEAP system is an extension of the earlier LEAP model which integrates GIS tracking of access patterns with USDOT highway network and intermodal terminal and port datasets, to calculate the travel time from any community in the US to rail, air and marine terminal/port facilities having regularly scheduled services. That information is used to calculate the impacts of travel time changes on the size of population markets reachable within various travel time conditions. It enables the system to then assess impacts of alternative transportation scenarios for specific industries that are dependent on intermodal connections and delivery market access. EDR-LEAP has been used on its own for identifying local economic development opportunities associated with new highway corridors in Pennsylvania, Tennessee and other states. In addition, it is an integral part of the TREDIS (Transportation Economic Development Impact System) framework that also incorporates regional economic models to assess economic development impacts of regional transportation proposals. Applications of this approach include congestion impact studies in British Columbia, Oregon and Illinois (e.g., Economic Development Research Group, 2005).

An even broader example of a GIS-based analysis framework is the Highway Economic Analysis Tool (HEAT), that was developed for Montana DOT system to integrate detailed state transportation models, commodity flow data and customized GIS software. That system provides further detail on changes in access to international trade gateways as well as intermodal facilities and delivery markets for specific industries and commodities. Both accessibility approaches were designed to work with economic impact models to evaluate the full implications of access changes as well as travel time/cost changes (Wornum et al, 2005).

5. Use of Economic Impact Model Results in Benefit/Cost Analysis

All of the preceding classes of models generate some measures of the estimated impact of transportation projects on the growth of economic activity in a region, and any such study is conducted because some decision-makers feel that economic impacts are a relevant consideration for evaluating proposed projects. However, the issue of how economic impact results are used for decision-making is not a simple matter. In the transportation research literature, it has long been clear that *economic development impacts* of transportation are not the same as the *economic value of project benefits.* Yet it can be argued that one of the most dangerous elements of applied economic impact modeling has been the blurring of these differences in the use of economic impact studies. Key similarities and differences between these two concepts are as follows:

- *Similarities* -- Business-related travel time savings and travel-related money savings (including operating costs) affect the economy through changes in expenditures by households and businesses, and through productivity enhancement for businesses. These are elements of impact on economic growth and they are also elements of project benefit.

- *Factors Where Economic Development Measures are Broader* -- Impacts on a regional economy can <u>include</u> some factors that may not be counted in the net value of project benefits. For instance, economic growth impacts on a region or country can include short-term effects of construction spending, as well as longer-term effects of attracting business investment from another region or country. However, in benefit-cost accounting, construction spending by itself does not necessarily bring any net income benefit over the alternative of spending the same money on other investments. (That is the opportunity cost.) In addition, while business relocation decisions are typically motivated by the opportunity to increase profitability and return on investment, the net productivity benefit for the broader nation or world is usually less than the impact on a local area's economic growth.

- *Factors Where Economic Development Measures are Narrower* -- Impacts on the economy can exclude some factors that may be counted in the net value of project benefits. For instance, the dollar value of personal travel time improvements (an element of traveler impact) and the dollar valuation of air quality improvements (an element of social impact) are both real project benefits that can be assigned an economic value. However, that value does not automatically turn into an equivalent change in the flow of money and income in the economy. In addition, improvements in transportation safety are a clear social benefit, but they do not necessarily create any more net jobs and income in a local economy; in fact, they could lead to a loss of jobs and income in medical and car repair occupations.

These similarities and differences lead to a series of alternative ways to view the economic impacts and benefits of transportation projects, which are illustrated in Table 3. They highlight the fact that there are economic values of traveler benefits (which include travel time and travel cost savings), broader user benefits (which include productivity benefits for shippers and receivers) and even broader social benefits affecting non-users (which include environmental benefits). The table also distinguishes regional economic development from other benefit classes, since business growth may be considered a beneficial outcome for the affected region, but its inclusion of business relocations from outside regions means that it is counting some impacts that would not necessarily be a benefit from a larger national view.

On the other hand, business relocations due to transportation access improvements would normally occur only if there were also some resulting profitability or productivity gains (exceeding the transaction costs of relocation), which would be counted as a user benefit. Other elements of business relocation or shifts in economic growth patterns may reflect desirable distributional gains (e.g., better use of underutilized human capital and infrastructure capital, especially in economically distressed areas) that can also be counted as a national benefit. Regional economic impact models can provide information needed to assess those effects.

Table 3. Difference between Economic Value of Benefits and Impacts on the Economy

	Travel Efficiency Benefit	Full User Benefit[a]	Social Benefit	Econ Development Benefit
$ Passenger Time Savings for personal travel	Yes	Yes	Yes	-- [7]
$ Passenger Time Savings for business travel	Yes	Yes	Yes	Yes
$ Travel Vehicle Operating Expense Savings	Yes	Yes	Yes	Yes
$ Shipper/Recipient Productivity Gain[b]	--	Yes	Yes	Yes
$ Indirect (Downstream) Productivity Gain[c]	--	--	Yes	Yes
$ Value of Environmental Benefits[d]	--	--	Yes	-- [g]
$ Local Income Growth from Business Attraction [e]	--	--	-- [f]	Yes

a Transportation system users are defined as the travelers for passenger travel and the shippers for freight travel
b defined as additional net income produced through cost savings or scale or production economies for shippers
c "downstream" income effects on other businesses that indirectly also realize productivity or cost benefits
d value of air quality, water quality, noise improvements, expressed in terms of "willingness to pay"
e shifts in business activity from outside areas to within the study area (any associated productivity gain would be counted elsewhere)
f Attracting additional business activity from one location to another is only a societal benefit insofar as there is a benefit of redistributing income growth from richer areas to poorer areas.
g Personal time savings and environmental improvement do not directly affect the flow of dollars in the economy (though in theory they could lead to indirect changes in economic patterns if they affect migration rates).

It should be clear that economic impact models are not benefit accounting systems. The separate valuation of traveler, economic and other social impacts, as shown here, is made stressed in the NCHRP *Guidebook for Assessing Social and Economic Impacts of Transportation Projects* (Forkenbrock and Weisbrod, 2001) and the internet guide to transportation benefit/cost analysis (California Dept. of Transportation, 2004).

These distinctions can become confused when a regional economic impact model is used to force non-money (social and environmental) impacts to affect business productivity and economic growth measures. For instance, the REMI-PI model has an input commonly referred to as the "amenity variable." It allows the analyst to determine a dollar value of non-money benefits such as time savings for personal travel and air quality improvements, and then input them as factors affecting the model's population migration equation, paralleling the impact of a reduction in housing costs. The model then predicts a rise of in-migration, causing an increase in supply of workers (greater than the expected growth rate for employment), which leads to a drop in wage rates, which raises apparent output per dollar of wages and hence makes the area appear more competitive for attracting business. Ultimately, that leads the model to forecast a net increase in regional jobs and income.

That string of effects is theoretically plausible, though there does not appear to be any empirical evidence that such a string of changes has ever actually been triggered by a highway improvement or other individual transportation project. In practice, this approach serves to make the economic model appear more complete as a representation of total project benefits, and it also serves to generate larger values for overall economic growth impacts. However, the magnitude of this result depends on assumptions concerning local unemployment, local population migration rates and local wage rates. Ultimately, it is a very indirect way of making the model show apparent impacts on the flow of dollars in the economy, and there is no way to be sure how the predicted impact on regional income will compare to the initial valuations of either personal time or air quality improvement. As a result, the amenity variable has been avoided in many studies that used the REMI model to assess transportation project impacts. Instead, a common practice in recent years has been to report personal time and environmental impacts as elements of social benefit that are distinct from impacts on the flow of dollars in the economy.

The issues raised here illustrate the overlap and interrelationship of economic growth measures with economic benefit measures. They also illustrate the importance of distinguishing social benefits and costs from economic growth impacts. Finally, they reinforce the need for analysts to be mindful of the spatial aspect of economic growth and benefit measures, and avoid assuming that all macro-scale effects are equally applicable for micro-scale projects.

6. Towards a New Framework

6.1 Needs. From this review, it should be clear that there are wide differences among both the definition of regional scale and the spatial granularity at which various classes of predictive models operate. That leads to corresponding differences in the facets of transportation impacts to which they are sensitive. It follows that an analyst wishing to select an economic impact models for the evaluation of transportation project proposals will have to hone in on the most relevant and important aspects to be analyzed for their particular situation. Then the most appropriate modeling and measurement approaches can be selected to address them.

These findings also have important implications for empirical research, for they suggest a need to focus more research on the structure of specific transportation economic impact relationships involving factors previously listed in Table 1. That can also help to improve the validity of future predictive models. Altogether, findings from this review suggest eight guidelines that should be considered by both researchers and policy analysts seeking to select among predictive models and impact measurement methods:

1. Consider economic impact factors beyond just the value of daily average travel time and travel cost savings, including the potential value of highway system connectivity and peak period reliability improvements for both commuting and goods movement.

2. Consider the importance of multimodal implications, such as how a highway project can affect access to jobs, recreation, airports, rail intermodal terminals and border crossings.

3. Consider the potential for changes in transportation conditions to hit certain industries that are particularly dependent on schedule reliability for time-sensitive deliveries.

4. Consider the need for analysis methods that can identify when transportation impacts are magnified or constrained by other local economic growth factors, such as utility infrastructure, financing, labor skills and capacity for growth.

5. Avoid confusion by using analysis methods that can separate economic (flow of dollar) impacts from value of benefits that do not directly affect the flow of dollars.

6. Distinguish areas of impact: (a) local, (b) state, (c) national and (d) global impacts, and show results for the level of study area that is most appropriate for those who will be using the analysis results.

7. Distinguish benefit and cost perspectives: (a) savings for travelers, (b) savings for all users including freight shippers and recipients, (c) generation of income in the economy, and (d) the value of all benefits to society, and report results as appropriate for those who will be using the analysis results.

8. Select modeling approaches that stress the particular types of causal factors and access elements of most relevance to the type of transportation project being considered and its location context, recognizing that various economic responses and market mechanisms can be of differing relevance depending on size of the project and scale of the study area.

6.2 Framework. Given the wide difference in input definitions and output presentation among various models, there can be value in establishing a consistent framework that follows these eight guidelines and provides a basis for viewing the context of individual models and research studies. As the foundation for predictive analysis, such a framework would also: (a) allow for inputs spanning the range of transportation impact factors cited earlier in Table 1, (b) allow for presentation of results in terms of clearly articulated measures as defined earlier in Table 3, and

(c) provide modularity to allow for use of any travel demand model, market access assessment tool and regional economic model that can utilize the relevant inputs.

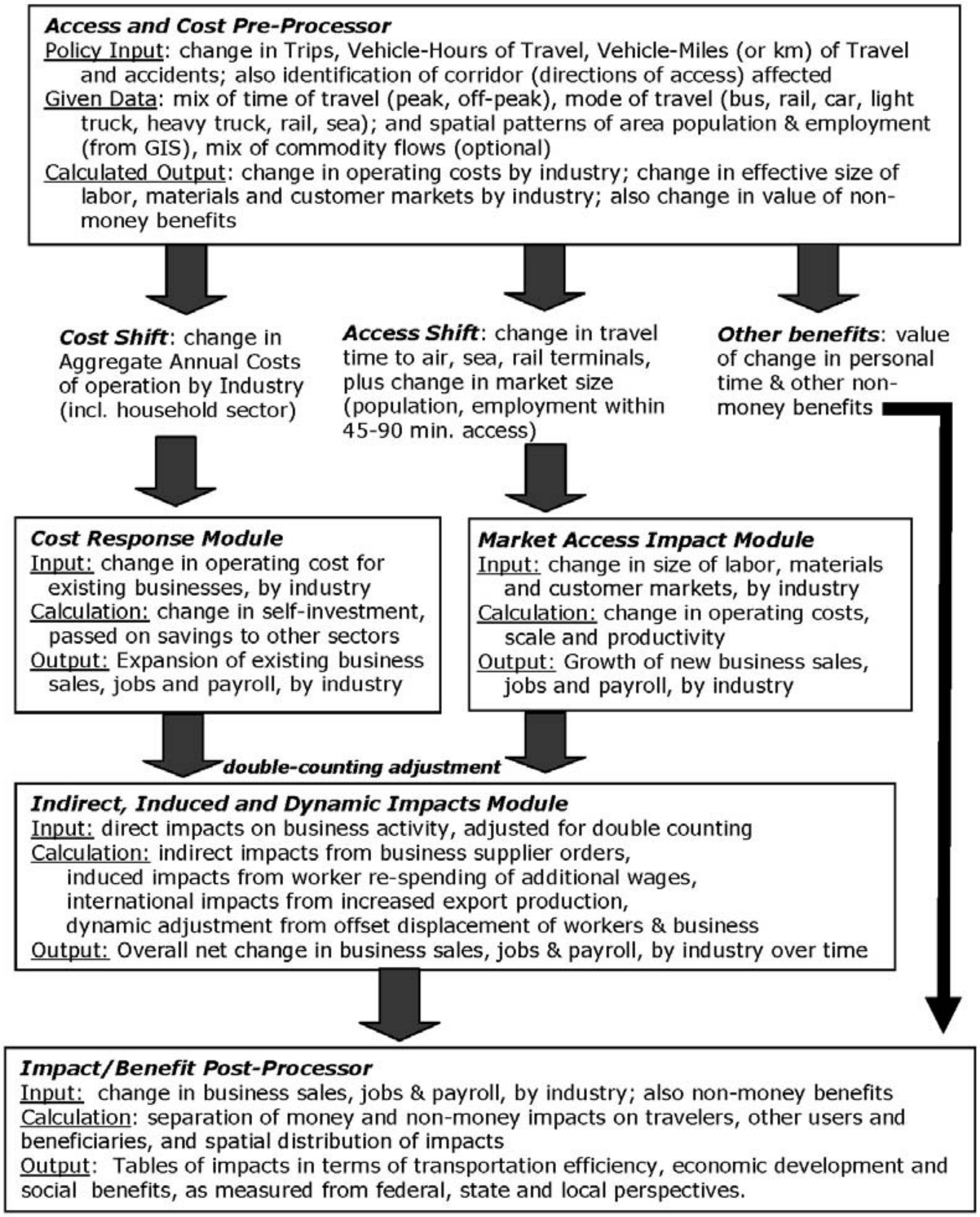
One approach that has been developed to address these considerations is a web-based system called TREDIS (Transportation Economic Development Impact System). Using a modular architecture shown in Figure 1, it is designed to work with different transportation, access and economic models that can accommodate the types of factors identified in the flowchart. This approach incorporates the following design features:

6.3 Inputs – By design, users are confronted with a comprehensive set of input screens covering all of the factors listed in Table 1 including changes in travel times, costs, reliability, productivity and market access for car, truck, air, water and rail modes. Separate inputs are available for passenger and freight travel, and for labor, truck delivery and intermodal access changes. While the list of inputs is large, a user may select to use only those inputs that are judged relevant for any given transportation improvement scenario. The objective of this approach is put the full range of multi-modal inputs in the face of the analyst, to ensure that there is some thought about the range of project effects. The analyst is then free to intentionally ignore some classes of transportation impact (such as impacts of one mode on use of other modes), but that will be an explicit choice rather than an accidental oversight or result of unknowingly choosing a model that does not account for such effects. This approach also facilitates the use of inputs from multiple sources, such as use of peak traffic congestion models, spatial access models and intermodal terminal data in addition to highway models that measure average daily changes in travel times and distances.

6.4 Analysis Calculations – A modular framework is useful for developing multi-modal transportation impact scenarios, applying regional (or multi-regional) economic impact models, and portraying overall impacts and benefits from various alternative perspectives. This involves three key design elements. (1) The framework is designed so that it can use potentially information from any transportation simulation model or "sketch planning" spreadsheet analysis method to estimate changes in use and travel characteristics for road, rail, air, and/or water transportation. (2) The framework allows for linkage to any geographic information system for analysis of changes in highway accessibility to markets and intermodal facilities. (3) The framework allows for information from the first two elements to be fed into any regional economic model and source of commodity flow information. These elements basically follow the Figure 1 flowchart structure. An important use of the modularity and linkages in this framework is that they also provide a capability to track intermediate calculations and impacts, helping to avoid the complaint of a "black box" model system.

6.5 Output – The framework imposes a structure for reporting economic development impacts and benefit/cost findings in a consistent and clear format. It is designed to distinguish impacts as measured differently from local, state and national perspectives. It is also designed to distinguish measures of economic development impacts and benefit-cost analysis, using the form shown earlier in Table 3. Those various measures are options that can be used or ignored as appropriate for different audiences and purposes. The presence of alterative views on one page is intended to help analysts avoid mistaking the interpretation of any single impact measure (such as seeing a measure of local economic impact and drawing conclusions about statewide impact from it).

Figure 1. Modular Structure of the TREDIS Framework



Source: www.tredis.com/flowchart.shtml

6.6 Next Steps. The framework described here has been used as a basis for organizing inputs, models and analysis results for studies of the economic impact of proposed or planned highway, public transport, high speed train and aviation projects. However, even with this basic framework as a starting point, there is a substantial remaining need to improve the structure, dynamics and interaction of factors within transportation economic impact models. For instance, integration of a static travel demand model with a dynamic economic model can lead to clear biases in impact forecasts. This can occur because static travel demand model generally do not forecast time-of-day schedule shifts for commuters and truck deliveries in response to rising congestion, which can lead economic models to over-estimate business and household relocation responses. On the other hand, travel demand models that use only daily average data can under-estimate impacts associated with dramatically more severe peak period conditions. The use of a general analysis framework that distinguishes critical benefit and cost elements is useful, as it can aid in addressing these problems. More importantly, it provides a starting basis for helping to organize modeling and thinking about the nature economic impacts that can result as a consequence of transportation improvement projects.

7. References Cited

ARC (1964). *Appalachia: A Report by the President's Appalachian Regional Commission*, US Government Printing Office, 1964

Bedford, Tim and Roger Cooke (2001). *Uncertainty: A Guide to Dealing with Uncertainty in Quantitative Risk and Policy Analysis,* University of Cambridge Press.

Blakely, Edward J. and Ted K. Bradshaw (2002). "Human Resource Development," Ch.9 in *Planning Local Economic Development: Theory and Practice*, Sage Publications.

Bowersox, D.J. and D.J. Closs (1996). *Logistical Management – The Integrated Supply Chain Process,* McGraw-Hill.
[
Buckley, Patrick (1992). "A transportation-oriented interregional computable general equilibrium model of the United States," *The Annals of Regional Science,* Volume 26, Number 4, December, pp.331-348.

Cambridge Econometrics (2003). *Transport Infrastructure and Policy Macroeconomic Analysis for the EU*, European Commission, 2003.

CATS (1962). *Chicago Area Transportation Study: Transportation Plan)*; Chicago Area Transportation Study, Chicago, IL.

California Dept. of Transportation (1994). *Internet Guide to Benefit-Cost Analysis in Transportation*. http://www.dot.ca.gov/hq/tpp/offices/ote/Benefit_Cost

Christaller, Walter (1933). *Central Places in Southern Germany.* Original German in 1933; translated by Charlisle Baskin, Prentice Hall, 1966.

Combes, Pierre-Philippe and Miren Lafourcade (2005). "Transport costs: measures, determinants, and regional policy implications for France," *Journal of Economic Geography* 2005, (3):319-349.

Conference Board of Canada (1994). *Slave Province Transportation Corridor: Economic Impacts and Taxation Revenue*, Northwest Territories Dept. of Transportation.

Echenique, Marcial H. (1994). "Urban and Regional Studies at the Martine Centre: Its Origin, Its Present, Its Future", *Environment and Planning B*: *Planning and Design*, Volume 21, pp. 157-533.

Economic Development Research Group and Cambridge Systematics (2001). *Handbook for Assessing Economic Opportunities from the Completion of Appalachian Development Highways*, Appalachian Regional Commission, Washington, DC.
http://www.arc.gov/images/reports/highway/Handbook-Econ-Opps.pdf

Economic Development Research Group (2004). *Handbook: Assessing Local Economic Development Opportunities with ARC-LEAP*, Appalachian Regional Commission, Washington, DC.
http://www.arc.gov/images/reports/arcleap/ARC-LEAP_Handbook.pdf

Economic Development Research Group (2005). *The Cost of Congestion to the Portland Region,* Portland Business Alliance, Port of Portland and Metro, Portland, OR.
http://www.portlandalliance.com/pdf/Congestion_Report.pdf

Enright, M.J (1996) "Regional Clusters and Economic Development: A Research Agenda" in U. Staber, N. Schaefer & B. Sharma (Eds) *Business Networks: Prospects for Regional Development,* Walter de Gruyter: New York.

Forkenbrock, D. and G. Weisbrod (2001). *Guidebook for Assessing Social & Economic Effects of Transportation Projects,* NCHRP Report 456, National Academy Press.

FHWA (1970). *Benefits of Interstate Highways*; Federal Highway Administration, Washington, DC.

Fujita, M.; Krugman, P.; Venables, A. (2001), The Spatial Economy, Cambridge, MA.

Highway Research Board (1966). "Will Model Building and the Computer Solve Our Economic Forecasting Problems?," *Highway Research Record #149,* pp.1-28.

Horst, Toni and Anne Moore (2003). "Industrial Diversity, Economic Development and Highway Investment in Louisiana," *Transportation Research Record* #1839, Transportation Research Board.

Hunt J.D. and Abraham J.E. (2005). "Design and implementation of PECAS: A generalized system for the allocation of economic production, exchange and consumption quantities"; Chapter 11in *Foundations of Integrated Land-Use and Transportation Models: Assumptions and New Conceptual Frameworks,* Elsevier, London, UK, pp:217-238.

Isserman, Andrew and Rephan, Terance (1995). " The Economic Effects of the Appalachian Regional Commission : An Empirical Assessment of 26 years of Regional Development Planning." *APA Journal,* Summer pp 345-364.

Ivanova, Olga (2004), "Evaluation of infrastructure welfare benefits in the Spatial Computable General Equilibrium (SCGE) Framework," Department of Economics, University of Oslo
http://www.oekonomi.uio.no/seminar/torsdag-v03/ivanova.doc

Juri, Natalia R. and K. Kockelman (2006). "Evaluation of the Trans-Texas Corridor Proposal: Application and Enhancements of the Random Utility Based Multiregional Input-Output Model, *Journal of Transportation Engineering*, Volume 132, Issue 7, July, pp. 531-539.

Kaliski, J., S. Smith and G. Weisbrod (1999). "Indiana's Major Corridor Investment-Benefit Analysis System," *Proceedings of the Seventh TRB Conference on Application of Transportation Planning Methods*.

Krugman, Paul (1991) "Increasing Returns and Economic Geography," *Journal of Political Economy*, Vol.99, 1991, pp.483-499.

Krugman, Paul (1995). *Development, Geography, and Economic Theory,* MIT Press, Cambridge, MA.

Leontief, Wassily (1951). "Input-Output Economics," *Scientific American*, October: pp.15-21.

Lindall, Scott, Doug Olson and Greg Alward (2005). "Multi-Regional Models: The IMPLAN National Trade Flows Model" *Proceedings of the 2005 MCRSA/SRSA Meetings*, Arlington VA April.

Lopes, Luís Peres (2003). "Border Effect and Effective Transport Cost," Faculty of Economics, University of Coimbra Portugal.

Luskin, David et al. (1999). *Facts and Furphies in Benefit-Cost Analysis: Transport*, Bureau of Transport Economics, Australia Dept. of Transport of Regional Services, Report 100.

Marshall, Alfred (1919). *Industry and Trade,* Macmillan & Co, New York. http://socserv2.socsci.mcmaster.ca/econ/ugcm/3ll3/marshall/Industry&Trade.pdf

Martino, A. et al (2005). *Macro-Economic Impact of the White Paper Policies,* Annex XII of ASSESS Final Report, DG TREN, European Commission, Brussels.

Nadiri, Ishaq and T. P. Mamuneas (1998). *Contribution of Highway Capital to Output and Productivity Growth in the US Economy and Industries*, prepared for Federal Highway Administration, Washington, DC.

Parsons Brinckerhoff, Cambridge Systematics, and Regional Source Research Institute (1989). *Summary Report: CONEG High Speed Rail Regional Benefits Study: A Report on the Benefits to the Region of Improved Passenger Rail Service Between Boston and New York,* Council of Northeastern Governors High Speed Rail Task Force.

Pignataro, Louis J et al (1998). "Transportation Economic and Land Use System", *Transportation Research Record,* #1617, Transportation Research Board.

Politano, Arturo and Carol Roadifer (1989). "Regional Economic Impact Model for Highway Systems," *Transportation Research Record 1229*, Transportation Research Board.

Shen, G. (1960). "An input-output table with regional weights." *Papers of the Regional Science Association*. 6: 113-19.

Schaffer, William (1972). "Estimating regional input-output coefficients," *Review of Regional Studies*, v. 2, n.3, pp.57-71.

Stokes, R.W., N. Pinnoi and E.J. Washington (1991). *Economic Development Impacts of Expenditures for State Highway Improvements in Texas*, Texas Transportation Institute for Texas DOT.

Targa, Felipe, K. Clifton and H. Mahmassani (2005). "Economic Activity and Transportation Access: An Econometric Analysis of Business Spatial Patterns," *Transportation Research Record* #1932, Transportation Research Board.

Weber, Alfred. (1929). *Theory of the Location of Industries*, translated by C.J. Friedrich, University of Chicago Press.

Weisbrod, Glen and F. Treyz (1998). "Productivity & Accessibility: Bridging Project- Specific and Macro-economic Analyses of Transportation Investments," *Journal of Transportation and Statistics*, v.1, n.3, pp.65-79.

Weisbrod, G., D. Vary and G. Treyz (2003). "Measuring the Economic Costs of Urban Traffic Congestion to Business", *Transportation Research Record* #1839, pp.98-106, Transportation Research Board.

Weisbrod, G. and J. Beckwith (1992). "Measuring Economic Development Benefits for Highway Decision-making: The Wisconsin Case," *Transportation Quarterly*, Vol. 46, No. 1, pp. 57-79, January.

Weiss, Martin (2002). "A Brief History of Economic Development and Highways." Paper presented at the TRB Conference on Transportation and Economic Development (TED2002), also published by the Federal Highway Administration web site at http://www.fhwa.dot.gov/planning/econdev/edhist.htm

Wornum, Christopher et al (2005). *Montana Highway Reconfiguration Study*, Cambridge Systematics Economic Development Research Group, ICF and SEH for the Montana Dept. of Transportation. http://www.mdt.mt.gov/research/docs/reconfig/final_report.pdf